A Methodology for Assessing the Appropriateness of New Crops

for

Small-Scale Arid Lands Agriculture: Jojoba and the Tonga of Zimbabwe[1]

by

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Introduction

The arid areas of the world[2] are experiencing increasing population pressure and environmental degradation. In both the industrialized and the so called "developing world," farmers and governments look for ways to get more production from more and more marginal land. If basic problems are to be solved and not aggravated, then ways of growing crops in these environments must be found which maintain and replenish the natural resources instead of destroying them. Sophisticated capital and energy intensive technologies have often failed to do this, as in the U.S. Southwest, just as have traditional, labor intensive methods, as in savanna Africa. The answer to the need for appropriate, resource conserving agriculture is social and environmental, as well as technological.

Much of the development of western style agriculture has centered on improving the plant environment and on breeding new varieties for optimal, highly managed environments (see Boyer 1982). This was the underlying philosophy of the developers of the "green revolution." Because of the need for costly inputs, this approach often exacerbates inequity and promotes concentration of land and other resources in developing countries, just as it helps force smaller farmers out of business in industrialized countries. Because this energy intensive management of plant environments favors what agricultural economists call "economies of scale," it might appear to make sense for farms to get larger and larger. The problem is that this "viewpoint" is very narrow and very short sighted. The energy inefficiency and environmental destruction that often results from its application has not generally been figured into the costs of production.

One way of improving production on arid lands while conserving resources is by growing plants that produce well under hot, dry conditions with little supplementary water, and in suboptimal soil. Using labor intensive methods small scale farmers, with little capital investment, may be able to successfully adopt new crops that fit these criteria.

Many standard cultivated crops are very vulnerable to the risk of drought because arid adaptations have not been selected for during domestication. Even though crops such as sorghum and millet have been selected for drought tolerance for generations by farmers in arid areas, new crops may help extend the area suitable for sustainable crop production, increase diversity (and thus decrease risk), and increase production by better utilizing seasonal labor excesses typical of arid agricultural communities. Therefore, a major element in the development of intensive farming systems for arid lands should be to increase diversity through the introduction of new crop and tree species that have multiple uses and are adapted for arid conditions, intercropping, and relay-planting. Historically, small-scale farmers have been willing to accept new crops introduced from other parts of the world, as long as the introductions can be adapted to their existing farming system and, in the case of food crops, their diet. In the case of new crops for arid lands, agronomic and economic viability usually remains to be proven. In those instances where the domestication process has not yet begun, considerable exploratory and experimental developmental and production research is required before farmers can be asked to assume the major risks of trying most of these new crops. Research on social, cultural and economic aspects of the farming systems is also a necessity and must continue during the period farmers are experimenting with the new crops.

2. Methodology

This paper is based primarily on a review of literature on jojoba, Zimbabwe, and the Tonga. It is intended to delineate, by using a specific example, a general methodology for assessing the appropriateness of new crops for small scale, arid lands farming systems. It is not concerned with the development of a plantation on which Tonga would work as hired larorers. Obviously, substantial field research in the specific farming system including field trials of the new crop and a more extensive survey of existing plantings would be required if a new crop were actually to be introduced.

2.1. General methodology

In a new crops "concept paper," written at the University of Arizona[3] (University of Arizona 1982), we have already outlined the general methodology for new crops research and development, and this section is based on that paper.

Each candidate plant species should pass through three research phases before widespread introduction as a new crop -- assessment, survey, and development. There are hundreds of candidate species which merit investigation in the survey phase and tens of species which are ready for or already subject to either development or assessment. Assessment of the potential for new crops in a given area begins the research, continues at a reduced level during the survey and development phases, and is an important activity before and during introduction of a specific new crop into a given farming system.

The survey phase screens large numbers of locally-adapted plant species of a particular arid/semiarid area for potential as crop species. (It may also include screening plants adaptable to the local conditions from other areas.) The screening process includes ethnobotanical investigations and biological evaluations to select plants with high potential for development.

The development phase includes research on plant physiology and genetics,

selection of cultivars, establishment of production practices and investigation of uses for various plant products.

The assessment phase has two major aspects. The first is an assessment of what type of new crops might fit within existing farming systems to improve the nutritional, economic and social well-being of the farm families and other citizens of the country involved. The second aspect is to monitor the usefulness of specific new crops already in the survey and development stages so that specific locations for their introduction can be identified. Such an approach will help insure that time and money is not spent developing species which have little practical value and that those species developed will be likely to improve the well-being of citizens in developing countries. In this paper we suggest a methodology for the first aspect of the assessment phase using a specific example as an illustration: an assessment of the appropriateness of jojoba for the Tonga farming system.

The following questions refer to both identifying characteristics of ideal new crops and evaluating new crops which are under development for introduction into specific situations. They could serve as a beginning outline for data collection. In the present paper, we are not able to answer all of these questions adequately. We do, however, provide a background, and suggest the information that would be needed.

a) How would the crop fit in existing agronomic systems in terms of intercropping, soil and water management, pests and diseases, cultivation techniques and technology?

b) How would the new crop fit in culturally, socially and demographically with the present agriculture system at all levels? How will it change seasonal and annual labor demands? How will it effect allocation of labor by age or sex? Will women's status be changed? Will land tenure be affected?

c) In the case of food crops consumed by the household, could the new crop replace

other food crops? If so, how do they compare nutritionally? If crops are to be sold, will they replace crops now grown for household consumption? If so, will the income generated be used to buy food that will maintain and improve nutritional status of the household members? The especially vulnerable status of children and pregnant and lactating women should be emphasized.

d) How would the new crop fit into existing systems economically? What are the production costs at various scales of farm operations? What risks are involved in terms of climatic variation, reliance on purchased and/or imported inputs, or hired labor? What are the market potentials in the present infrastructure for local, national or international marketing?

e) What would be the environmental impacts of large-scale adoption of the new crop? Is it likely to be established without long-term degradation of soil, water, or vegetation resources?

f) How would the new crop fit into local industrial development? Could output from processing units be increased by use of the new crop in addition to or in place of a presently used crop? Could local industries, whose products would substitute for presently imported items, be established using the new crop?

2.2. New crops: jojoba

The term "new crop" has come to mean a previously undomesticated or currently under utilized but economically important plant. However, the methodology outlined in this paper should be useful in analyzing the potential of any crop not previously used in a given farming system.

The criteria for evaluating the appropriateness of a new crop for a small scale arid lands agricultural system include environmental, social, economic, time and nutrition factors. Appropriate means that the overall well being of the people producing and the people consuming the product is increased equitably, and that the environment is improved or at least maintained.

Jojoba has been chosen as an example because much research on this plant has been done at the University of Arizona and other places. It has become one of the most frequently mentioned "new crops," and many countries and individuals around the world have shown interest in experimenting with and producing it. Not enough, however, is yet known about this or other "new crops" to allow confident large scale introduction, and several large plantings have failed. This paper summarizes current knowledge about jojoba that would be needed to design a program for its development in small scale arid lands farming systems in the developing countries (Section 3). To our knowledge, this has not been attempted before. These include requirements for seed storage and germination, cultivation (soil, water, temperature, daylight, pest problems, and reproduction requirements. In the next section (4), we use information on experience with domestication and cultivation of jojoba to translate these biological requirements into small-scale farming system requirements for inputs of labor, other energy, capital and other resources, and land area. Our goal is to develop a yearly cycle (for annuals of course there would be only one yearly cycle).

2.3. Farming systems: the Tonga of Zimbabwe

The next step is to analyze selected farming systems to see how appropriate the proposed "new crop" is. This begins with relevant political and economic systems at the national and international levels (section 5). Information is also needed on the environment, on current cropping cycles and labor requirements, potential labor and resources available, social organization, culture pertaining to food and agriculture, and nutrition at the local level (section 6). As can be seen from the questions listed in section 2.1., our definition of "farming system" is much broader than that of many agronomists or agricultural economists who limit it to the farmer's field or to household and national economics.

From the standpoint of farmers in the developing country, this is all

backward. In the real case, the process should be reversed, and the selected farming system analyzed first with a view to the need for calories and other nutrients at different times of the year. Natural, economic and human resources available for increased farm work at various times of the year should also be assessed. One would then review what is known about available crops not currently used in the farming system and select for additional screening those that best suit the needs of the people.

Zimbabwe was chosen because much of it is arid, because interest in new crops has been expressed by the government and the University of Zimbabwe College of Agriculture, and because Zimbabwe is going through a period of major agricultural readjustment following the success of the recent war of liberation. The current severe drought in southern Africa emphasizes the need to live with the arid environment, and not attempt to conquer it. Zimbabwe was not chosen because farming systems there have been well analyzed. In fact, because of the white settler attitude that African agriculture was not worthwhile, it has been largely unstudied.

The Tonga have been selected for three reasons. They live in an arid region of northwest Zimbabwe where jojoba could probably be grown, they have been and continue to be the focus of major development programs, and, because of intensive studies of neighboring Tonga in Zambia, perhaps more is known of their farming systems than any other group in Zimbabwe.

The purpose of our paper, however, is not to provide a definitive case study, but to outline a methodology, so that others may be inspired to apply it to situations they know well. We also hope that the importance of first understanding current farming systems before attempting an alteration might be re-emphasized and lead to further field research by anthropologists, economists, geographers and other social scientists as a part of agricultural development assessment.

3. Biological Cycles and Environmental Requirements for New Crops: Jojoba

Jojoba [Simmondsia chinensis) (Link) Schneider)] is native to the Sonoran Desert regions of Arizona, Sonora, and California we well as to coastal biomes in southern and Baja California. Although data concerning critical environmental parameters is insufficient to allow firm predictions about production of jojoba under cultivated conditions in varying geographical areas, a listing of locations where jojoba is currently being grown is illustrative. Commercial stands or significant test plots of jojoba currently exist in the following locations: southern Arizona, southern California, Sonora (Costa de Hermosillo), Baja California (north and south), Costa Rica (Guanacaste Province), Brazil (Ceara), Israel, India (Rajasthan), Australia (Western Australia, New South Wales), Sudan and Zimbabwe. In Zimbabwe, healthy, young stands of jojoba can be found at Beitbridge and Buffalo Range in the low veldt region of southern Zimbabwe.

In this section, information concerning jojoba establishment, growth and reproduction are reviewed. The first five sections relate to factors affecting vegetative growth and the last three to seed production, storage and germination.

3.1. Temperature

Jojoba is capable of withstanding very high temperatures and regularly survives maxima of 43°-46°C (in the shade) in its native habitat (Gentry 1958). Minimum temperatures are more critical than maximum in determining appropriate site locations for jojoba. Young plants are particularly vulnerable to damage from sub-freezing temperatures. A one year old germ plasm nursery located at Safford, Arizona and made up of accessions from 100 sites in Arizona, California, Israel and Mexico, was utterly destroyed by exposure to -7.2^{o}C for three hours during one night and to -6°C for four hours during another. Plants from the same accessions exposed to -2°C at Mesa, Arizona sustained only minor damage. Although older plants may survive temperatures in the range of

-4 to -6°C, their flower buds sustain damage, growth is slowed and yields lowered. For the above reasons, potential jojoba sites that are subject to temperatures below -4°C should be avoided (Hogan 1979).

Warm soil temperatures have been found to enhance nutrient uptake and growth of greenhouse-grown jojoba seedlings. Soil temperatures of 33°C were most effective in enhancing nutrient uptake and growth when compared to 27 and 21°C (Reyes et al. 1977).

3.2. Water

Jojoba is an extremely drought tolerant shrub which is capable of carrying out net photosynthesis at water potentials as low as -70 bars (Al-Ani, Strain and Mooney 1972). Natural stands exist in areas receiving as little as 125 mm rainfall per year, but jojoba grows and produces best where rainfall reaches 380 - 500 mm annually. Once established, jojoba plants can completely defoliate as a result of severe drought and resume growth after the soil profile is recharged by rains (Gentry 1958). To successfully establish a commercial stand, sufficient moisture is needed to ensure that the young plants are not stressed excessively. In practice, this may mean the application of as much as 60 - 75 cm of irrigation water per year in very dry areas (Wright 1978). In arid regions with strong rainy seasons such as Zimbabwe, considerably less irrigation water may be required for establishment. In Ceara, Brazil, plantations have been established during the rainy season (January-April) without supplemental irrigation, as well as during the dry season, when irrigation was needed (Aragao 1982).

Although jojoba is drought tolerant, optimum soil moisture is required at critical times for good flower and fruit development. What exactly are the critical times is still imperfectly understood and varies with the part of the world in which the crop is to be grown. In Ceara, increased flower bud development resulted from supplemental irrigation during the dry season (the peak flower

development period) (Aragao and Montiero 1982). Values for irrigation water in the range of 38 - 50 cm have been cited for 2 to 3 year old plantations in southern Arizona (Wright 1978). In Israel, increased irrigation of 10 year old plants resulted in increased vegetative growth and seed yield (Benzioni, Mizrahi and Nerd 1982).

Microcatchment water harvesting experiments with wild jojoba near Phoenix, Arizona have shown that plants receiving a four-year average October-July precipitation of 435 mm from rolled catchments showed only moderate seed yield increases over control plants receiving 154 mm during the same period. Plants located in treated catchments that supplied a four-year average of 876 mm of water yielded twice as much seed as did the group receiving 435 mm (Ehler, Fink and Mitchell 1978).

Jojoba has been found to be quite tolerant of salinity both in laboratory experiments (Yermanos, Francois and Tammadoni 1967, Rasoolzadegan 1980) and in the field, e.g., in Israel (Forti 1978).

Excessive soil water content adversely affects jojoba, especially seedlings. Irreversible damage to roots develops before foliar symptoms. Greenhouse jojoba seedlings developed symptoms such as paler than normal leaf color, some drooping and dryness of leaves. Increasing temperature from 23°C to 33°C speeded up the development of symptoms, with 50% of plants affected by the 10th day at 33°C (Catlin, Olsson, and Rost 1982).

3.3. Soils

Gentry (1958) reported that in its native range, jojoba is usually restricted to "well drained, coarse, desert soils as the sandy alluviums and coarse atrital mixtures of gravels and clays derived from such igneous materials as granites and volcanics." In central Arizona, Feldman (1976) found that percent liquid wax in the seed was positively related to percent silt in the B-horizon and negatively

related to percent gravel and total soluble salts in the same horizon. Plants growing on the Graham soil series were found to be highest in wax percentage and were also the largest and most vigorous when compared to plants growing in 13 other soils. The Graham series is classified as a Lithic Argiustoll in the U.S. soil classification (Soil Survey Staff 1975) and is in a clayey, montmorillonitic, thermic family. The Graham is a shallow soil (50 cm or less) usually developed from granites, schists or volcanics. The rock below is frequently fractured and the profile usually contains some large cobbles or rock fragments. The B-horizon of these soils has very well developed structure, allowing excellent drainage and aeration despite its high clay content. The surface horizon of this series is a grassland-type soil (mollic epipedon) which allows good infiltration of water into the soil and also affords good nutrient holding capacity due to its high organic matter content.

Published studies on soil preferences of cultivated jojoba are lacking. At the present time, jojoba is being cultivated on a wide range of soil types with varying degrees of success.

3.4. Nutrition

Serious investigation of jojoba nutrition is just getting underway and is hampered by the wide range of genetic variability found in the heterogenous seedling stands which presently comprise the majority of jojoba plantations. In Israel, the application of both high and low rates of N-P-K resulted in ca. 65% higher seed yields than did control plants (Benzioni, Mizrahi & Nerd 1982). At Riverside, California where early Fall frosts are somewhat common, fertilized plants yielded less than controls, because of greater loss of flower buds due to frost (Yermanos 1978). Vegetative growth of jojoba cuttings has been found to be well related to leaf concentrations of N and K and to a lesser degree, P (Feldman 1982). In greenhouse studies, warm soil temperatures (33°C) and high soil

oxygen status (21% Ø) were found to enhance nutrient uptake (Reyes et al. 1977).

Mycorrhizal fungi enhance the productivity of many plants of economic importance by increasing uptake of water and nutrients by fine roots. Glomus fasciculatus has been isolated from field soil containing jojoba roots (Bloss 1979).

3.5. Pest and diseases

Seedling mortality results primarily from freezing, drought and rodents (Sherbrooke 1977). Exposure to excessive salinity during establishment can also cause failure (Reddy 1983). Seedlings require protection from rodents, rabbits and other mammals (Nord and Kadish 1974, Sherbrooke 1977). Leaf cutting ants can also cause losses in newly established stands.

In a study of insects and mites on wild stands of jojoba in Arizona and California, 1Ø6 species were identified (Pinto and Frommer 198Ø). Of these, 5Ø were phytophageous, 29 parasitic and 18 predaceous. Most of the phytophageous arthropods also fed on other species and some were notorious generalists. None caused extensive damage. The numerous parasites and predators probably effect a natural control.

Root rots caused by the two very common associated fungi Phytophthora parasitica Pythium aphanidermatum, have caused losses of potted seedlings as have Rhizoctonia solani and Fusarium spp.(Stanghellini 1977).

Innoculation of growing medium and seedling tissue has shown that jojoba seedlings are highly susceptible to infection with the Verticillium dahliae, a fungus with world-wide distribution (Orum, et al 1981). Jojoba is also susceptible to the fungus Phymatotrichum omnivorum but it is believed that this organism is presently limited in distribution to the Southwest U.S. and portions of Mexico (Alcorn and Young 1979). Known aerial pathogens include Coniothyrium sp. which cause leaf blight (Young and Alcorn 1981).

3.6. Reproduction

Jojoba is dioecious with about 50% each of male and female plants. Multiple male flowers are usually found on alternate nodes and produce bright yellow pollen which is distributed by the wind to female flowers. Female buds are usually single and on alternate nodes. Each contains 3 ovules, but usually only one matures. Flower buds develop during the period when fruit of the preceeding year's growth is maturing (Hogan, Palzkill and Dennis 1981).

While there is a great deal of variation in times of anthesis (pollen shed) and female flower receptivity, it tends to occur just after a period of stress has ended. Thus, in the Sonoran desert the major flowering season is in the spring, after the cold weather ends and while there is still ample soil moisture from winter rains.

In northeast Brazil with a single summer rainy season similar to that of northern Zimbabwe, flowering occurs soon after the start of rains in January and seed are ready for harvest during the months of April and May (Aragao 1982).

3.7. Seed storage requirements

Temperature. No differences in germination appear to result from storage temperatures between 2 and 49°C when seeds are kept "air dry" (Burden 1970).

Time. Experimental results on the effect of storage time on jojoba germination vary. One study found that percent germination after 20 days increased rapidly with storage time and increased from 5% at 2 weeks to 55% at 4 weeks and 95% at 6 weeks (Burden 1970). Another study found that with storage times of 1 week, 4 months and 11 months, there were no differences in germination (McCleary 1974).

Storage at 1.7°C in sealed containers for 10 - 12 years gave almost 100% germination, but when stored at room temperature for two years, germination was

only 40% (Nord and Kadish 1974).

Green fruit should be dried in the shade with ample aeration. Poor aeration leads to mold growth on seed or premature germination, and exposure to full sun causes seed shrinkage (Nord and Kadish 1974).

3.8. Germination and establishment.

Temperature. For good germination, the temperature range is quite narrow, with 28°C (82.4°F) being optimum (McCleary 1974):

Temperature (°C)	Time (Days)	Germination	Comments
13		0	
14		poor	
21	17	100%	
28	9	100%	
34		poor	some fungus - no ill effect on germination

Burden (1970) also found greatest germination at 26 - 30°C. At 18°C in day and 2°C at night (in dark), there was only 40% germination after 70 days.

Other researchers (Nord and Kadish 1974) found optimum temperatures to be lower, 16 - 24°C.

Light. There appears to be no difference in effect on germination between darkness and dim lighting (McCleary 1974).

However, other work has shown that that temperature may interact with light levels in affecting germination (Burden 1970). Dark conditions promoted germination at all temperatures, low intensity light (20f.c.) stimulated germination at higher temperatures, and high intensity light (600f.c. or more)

inhibited germination at all temperatures.

Moisture. Experimental variation in soil moisture has completely suppressed germination, implying that steady soil moisture is an essential requirement (Burden 1970).

In Australia, techniques of direct seeding jojoba for dryland rainfed farming have been developed that produce a high rate of establishment and are now "widely accepted" (Dunstone and Begg 1982). Clean fallowing soil during the winter, soaking seeds to the point of emergence, and planting 3.5 cm deep in moistened beds during spring rains resulted in emergence rates of almost 40%.

In northeast Brazil, planting has been successful at the beginning of the rainy season. Three to 4 seeds per hole are planted at 2 cm depth. With a spacing of 3 x 1.5 m this yields a density of about 2200/h before thinning out 80% of the males (Aragao 1982).

Males are more precocious and can be identified earlier than females, making early rogueing of unwanted males possible.

3.9. Conclusion

From the preceeding review of current knowledge about jojoba, we can see that enough is known to be able to begin field trials, but not enough to begin promoting extensive adoption of this new crop by small scale farmers with little margin for high risk experimentation.

4. Farming System Implications for New Crops: Jojoba

Knowledge about productivity of the new crop under natural conditions, from lab, greenhouse and field experiments, and from its behavior in various farming systems must be extrapolated to obtain requirements for various levels of production. It is not possible to say what optimal production is until the relative costs of the various inputs and the probable levels of return under a specific farming system are known.

Thus, while several guides for commercial production of jojoba have been published (Aragao and Montiero 1982; Hogan, Palzkill and Dennis 1981; Ramonet et al. 1981), much of the information is oriented toward large scale, fairly high energy farming systems, and is not appropriate for the small scale, low energy systems we are concerned with here.

The purpose of this section is to suggest what small-scale farmers in labor intensive, as opposed to capital and energy intensive systems, would have to do to raise jojoba successfully. Because its commercial production began so recently, not enough is known about jojoba to adequately estimate the implications for small scale arid land farming systems. What we will do is to suggest the topics that need to be covered in any adequate assessment of the potential of jojoba.

4.1. Site selection and land preparation

Because of jojoba's intolerance of water logging, the site should be well drained. No sub soiling is necessary unless there is a hard pan. However, any loosening of deeper soil should help because of jojoba's extensive root system. Jojoba roots may reach depths of 7.5 to 9 m when no restrictive soil layers are present (Hogan, Palzskill and Dennis 1981).

Jojoba's intolerance of temperatures below -4°C must be remembered when choosing a site. For fast, successful germination, soil temperatures must be approximately 26°C. This is important because at colder temperatures seeds may

be destroyed by soil microorganisms before they emerge (Hogan 1979).

4.2. Stand establishment

The three planting materials are seed, seedlings or rooted cuttings. The great genetic variability in plants grown from seed has led to the recommendation that commercial plantings be established with asexually propagated material. While it appears that stem cuttings can be rooted in commercial quantities (Hogan 1979), no clones have yet been proven in actual production. A disadvantage of growing many genetically identical plants in one area is the increased risk of major losses due to presence of pests or pathogens.

Compared to direct seeding, transplants are more resistant to weed competition and need less water for establishment. Transplant root systems may be inferior (at least during the first year) and the initial cost is much greater (Hogan, Plazkill & Dennis 1981).

Most plantings in Arizona to date have been by direct seeding (Hogan, Palzkill & Dennis 1981) and in Australia techniques for direct seeding have become established practice (Dunstone & Begg 1982).

4.3. Cultivation

4.3.1. Thinning & pruning

In plantation production, plant spacing is determined in part by the equipment used in cultivation and harvesting. In Arizona, most growers have thinned plants to 1.5 m apart within rows on rows 3.5 to 5 m apart, resulting in 1345 to 1793 plants per hectare. The usual practice is to rogue out unproductive females and all but about 1 male per 5 females. (Hogan, Palzkill & Dennis 1981).

The effects of pruning are not yet known, but it may encourage development of new growth that will produce fruit the following year (Hogan, Palzkill & Dennis

1981). Pruned leaves could be used for fodder (see section 4.7). If machinery were to be used in harvesting, some sort of pruning of lower branches would probably be required.

4.3.2. Water

To assure that plants do not become stressed during early development, 600-750 mm of water are required. After the second year tnis can be reduced to 380-500 mm per year (Hogan 1979). Because most of the roots are deep, shallow watering or light rain probably won't be very beneficial for established plants.

4.3.3 Fertilizaton

Very little is known about fertilizer response of jojoba under field conditions, although it does appear to respond to N-P-K under certain conditions. The experiments of Ben-Zioni et al in Israel have been mentioned above (Section 3.4.)

4.3.4.

Weeding is critical, especially if plants are direct seeded, as they can quickly be outcompeted. Because of jojoba's deep root system, soil close to the young plants can be cultivated without damage to the plant (Hogan, Palzkill and Dennis 1981).

4.3.5. Plant protection

Young jojoba plants profit by protection from dessicating winds and wind-blown particles which can scour the leaves. Intercropping with annuals in early years may therefore be beneficial (see section 4.3.6).

While jojoba appears to be relatively free from serious disease or arthropod damage in the wild, increasing damage can be expected under cultivation, especially

in large monocultures. Small scale growers may have fewer problems if their plants are established at fairly wide intervals and intercropped, or if grown in small, separated fields.

4.3.6. Interplanting

Because it takes several years for jojoba to mature, it may be useful to interplant annuals when establishing plantations. In Brazil, beans, millet, sorghum and manioc have been successfully intercropped, but with some depression of jojoba yields (Aragao 1982:68).

4.4. Harvesting and storage

The fruit should not be harvested until it has fully matured, because the quality of the liquid wax reaches its maximum at this time. Plants from seed or seedlings will show the same range in seed-holding characteristics as those in wild stands in Arizona. Some of these plants produce seed that dehisce when mature, and will drop to the ground as the picker attempts to harvest them, whereas others have fruit that is difficult to remove (Hogan 1979). Therefore hand harvesting of jojoba established from seed should include picking fallen fruit from the ground.

In good wild stands of jojoba in Arizona, pickers pick 2-3 kg. of seed per hour (Hogan 1979).

Seeds should be dried in an open shady area. They will not spoil for up to three years of storage.

4.5. Yields

Production of jojoba under cultivation is expected to increase regularly with increasing plant size. One author has estimated an increase in clean seed harvested per acre from 132 kg per hectare four years after planting to 1580 kg per hectare 12 years after planting (Wright 1978). This was based on plants propagated

by seed.

Yield data for the germplasm nursery located at the University of Arizona Experiment Station is available for plants from ages 2.5 years to 6.5 years. The average yield was 14 grams per plant at 2.5 years, 207 gm/plant at 4.5 years and 691 gm/plant at 6.5 years. At a density of 1148 females per hectare, a yield of 600 grams per plant yields 689 kg per hectare at age 6.5 years (Palzkill and Hogan, 1983).

4.6. Animal and human nutrition

Jojoba is one of the most important browse plants in its native range and the leaves are excellent fodder. Swank (1958) reports a protein content of 8.3 to 21.1%, with a mean of 13.5%.

Where javelina (wild boar) live in areas where jojoba grows, jojoba fruit can provide a significant part of its diet (Eddy 1959). Bailey's pocket mouse can live for weeks on only jojoba seed (Sherbrooke 1976).

The meal that is left after extraction of the seed oil contains about 30% protein and has great potential as a livestock feed if the toxicity present can be removed. The major toxin may be simmondsin, with as many as three other structurally related cyanomethylenecyclohexyl glycosides. It is possible to remove the toxins using solvents (Verbiscar et al. 1980).

It is reported that both Native Americans and Mexicans ate the nuts, either raw or cooked. A drink was made by the Coahuila Indians of Mexico by grinding, boiling and straining off the liquid. And in more recent times, people in Mexico prepared the seed by first roasting, then grinding and boiling with other ingredients (Balls 1962).

4.7. Liquid wax processing and marketing

Jojoba's notoriety as a potential new crop stems from the unique nature of

its seed oil, which is a liquid wax very similar to sperm whale oil. It can be used in the manufacture of cosmetics, high quality lubricants and waxes and as a base for the manufacture of numerous other chemical compounds (Hogan 1979).

The present production of jojoba oil, mostly from hand harvested natural stands, is sold to the luxury cosmetic and novelty markets. Some is sold to researchers. The present, relatively high prices will not persist if jojoba oil production increases and begins to compete with other oils and waxes (Walters, Macfarlane and Spensley 1979).

One of the major potentials for jojoba oil is as a replacement of diminishing supplies of sperm whale oil, which is now used primarily in extreme high pressure lubricants, in industrial cutting lubricants, and in fat liquors for tanning leather. With decreasing supplies of sperm oil and pressure to limit consumption because of fears of extinction of the sperm whale, jojoba oil could find a market in replacing sperm whale oil. Much research, however, remains to be done, and synthetic substitutes for sperm whale oil are also being developed. At the time jojoba oil becomes available in large quantities, much of the sperm whale oil market could already be satisfied by synthetic substitutes now being developed. Another major area in which jojoba oil may be expected to compete is the animal and vegetable wax market. This is a small market with most end uses satisfied by a particular wax, so that there may not be a great potential for jojoba competition (Walters, Macfarlane & Spensley 1979).

As supplies of jojoba oil increase, however, new markets may open up as a result of new research findings.

It is generally assumed that for jojoba to be economically viable, large plantations where operations are mechanized will have to be established using genetically uniform plant material selected for superior productivity. The present cost of hand harvesting is considered to be a major obstacle and machine harvesters are being developed. Breakeven costs after 12 years for Indian reservations in

Arizona and California have been estimated by Stubblefield and Wright (1977) at between $7.15/kg for hand harvesting and production of 2,000 kg/hectare to $1.25/kg for machine harvesting and 5,000 kg/hectare. For small scale farmers in arid lands developing countries, the price of labor is not usually an obstacle, however, whereas the price of machinery is.

4.8. Conclusion

Small trial plantings under conditions similar to the farming systems to which jojoba will later be introduced are essential for assessing its potential for success. It will then be possible to quantify the time, management skills, energy, capital and other inputs needed at various times of the year, and to compare these data with the existing farming system. Farmers' opinions of the new crop and how it might best be adapted are essential. Involving farmers and their communities in the field trials will facilitate the gathering of this information.

It will also be vital to assess the potential usefulness of jojoba once it is produced. Markets for jojoba are small but may have great potential for efficient producers. Efficiency is a relative term, but the market price must give a return to the producers and the developing country processing organizations to make it worth their while. In the case of jojoba, it is especially important to take a long hard look at the market potential and the alternatives for improving the well-being of the farmers and their country with less market risk, less capital investment and with a more flexible innovation. The fact that jojoba appears to be largely inedible by humans means that if markets or other crops fail, people cannot resort to eating the new crop in which they have invested so much in.

5. Arid Lands Farming Systems at the National Level: Zimbabwe

It may sometimes seem expedient to attempt the introduction of agricultural innovations into a local farming system without considering the historical, political, social or economic context of that farming system at the national and international level. The degree to which local systems around the world have become integrated into a global system, however, makes such an approach unwise. This is especially true in the case of a cash crop like jojoba which would be difficult if not impossible for local small scale growers to process and market themselves. They therefore depend upon the government or other agency to provide for the bulk collection, processing and marketing. An understanding of international markets and their likely future is necessary before encouraging farmers to commit resources to growing jojoba because jojoba products are not likely to be consumed primarily within Zimbabwe (See section 4.7.).

There are more basic reasons for considering the larger context of local development. Farmers make choices based on their assessment of alternative options. Economic as well as noneconomic criteria are important. For example, it may be that farmers would rather migrate to obtain wage labor in another area during the slack season rather than implement a new technique or crop at home because returns for migrant labor are greater. Seasonal and long-term migration has become an established tradition among the valley Tonga. Historical interactions between farmers and government agents may greatly influence the probability of success of proposed changes. The long, bitter history of forced resettlement of Africans by white settlers in Zimbabwe necessitates a very careful approach to resettlement of any kind.

Land redistribution was a major tool used by Europeans to obtain the best land in Zimbabwe for their exclusive use and to force Africans into dependency on the whites, providing them with cheap labor. Land redistribution is also one of the most important tools being used by the current government of Zimbabwe to implement

agricultural development. The Tonga have been and will continue to be affected by government resettlement and land redistribution programs, and an understanding of the national context is critical to an understanding of the development potential among the Tonga. Our emphasis in section 5 is therefore on land distribution and agriculture.

5.1. Physical Environment

Zimbabwe is located in the savanna of south central Africa and is characterized by gently undulating plateaux (see Figure 1.). The country is divided into two major water-sheds along a line running from the northeast to the southwest (Speece 1982). Rainfall occurs in one summer rainy season of no more than five months, and the average is about 675 mm per year. Coupled with high average temperatures (about 20 - 30°C), potential evaporation exceeds rainfall for most of the year (Department of Meteorological Services 1981).

Zimbabwe has been divided into five Natural Regions on the basis of "effective rainfall, or the rainfall available for plant growth (Vincent and Thomas 1960). These Natural Regions and their subdivisions have been, and still are, used as the basis for agricultural planning in Zimbabwe. Under the white government, the "inherent intensity of utilization" of the different Regions referred exclusively to imported European agriculture as practiced by white settlers (see section 6).

5.2. Social Environment

The population of Zimbabwe at the time of independence in mid-1980 was estimated to be approximately 7,429,000 people (Speece 1982:10), with a growth rate between 3.6 and 4% (USAID 1982:73). Twenty percent of this population live in urban areas which are believed to be growing almost twice as fast as the rest of the population.

About 96% of Zimbabwe's population is African, 70.8% of this total are Shona

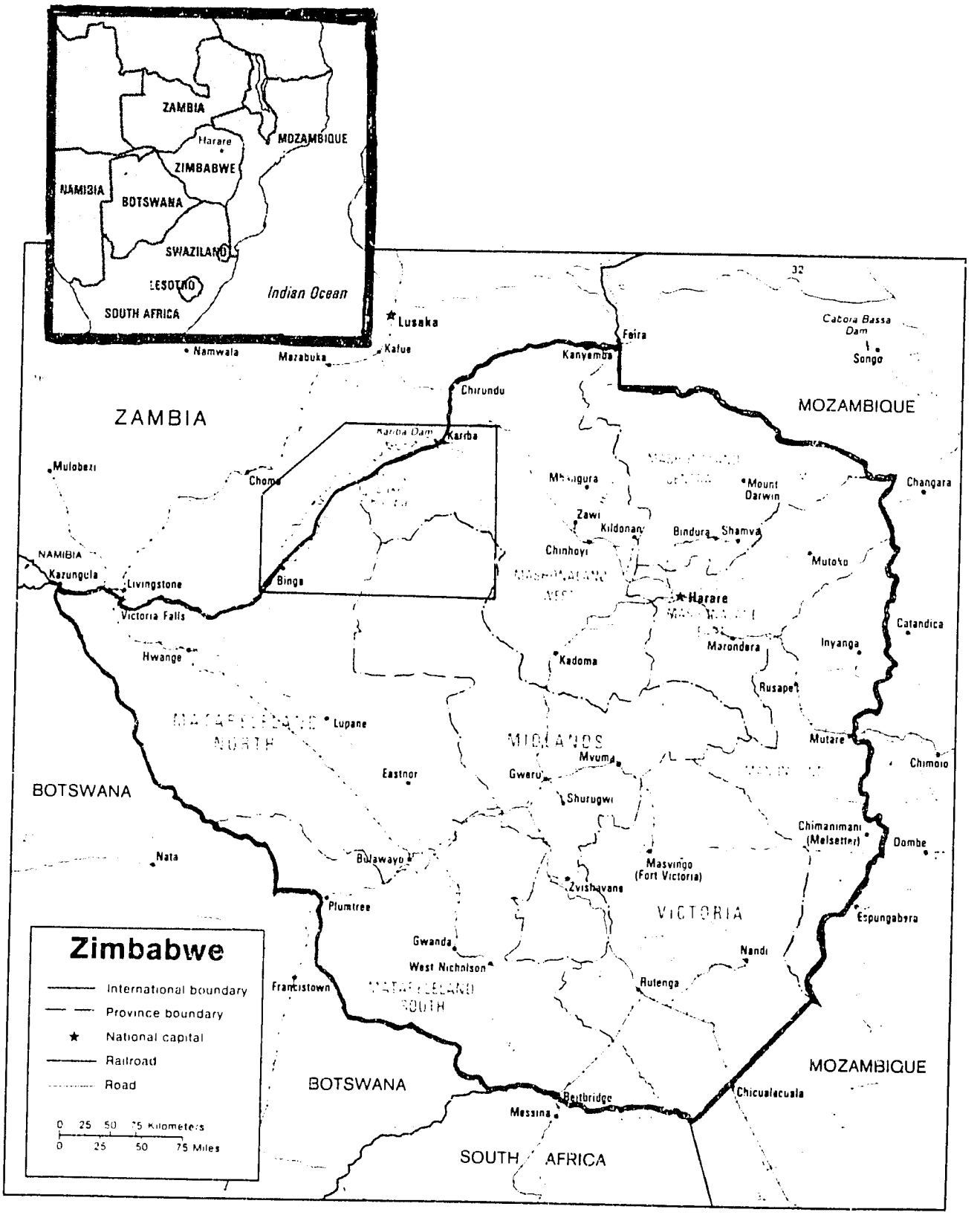

FIGURE 1. Zimbabwe - Area shaded indicates enlarged map Figures 3 and 4.

speakers, 15.8% Ndebele or Nguni speakers. In addition to these two major African ethnic groups, the remaining 12.4% of the African population of Zimbabwe is composed of numerous small groups living primarily in border areas (Speece 1982:12, 16). Among these, 1.2% are Tongas living along the northern border south of Lake Kariba (Nelson et al. 1975:75).

5.3. Land Distribution and Agriculture

As the leading food exporter in Black Africa, Zimbabwe earned $655 million from agricultural exports in 1982 (Novicki 1983:13). Comprising 13% of the country's GDP, these agricultural products are produced by two very different sectors, the commercial and the communal, formerly known as the European Areas and the Tribal Trust Lands (TTLs), respectively. These sectors are the products of a system of land distribution developed over the last 50 years. The final result of this distribution is that by 1969 Black Africans, then comprising approximately 95% of the country's total population, were allocated 47% of the country's land (See Figure 2). The White population, less than 4% of the total population, were also given 47% of the land, the remainder being designated as "national lands." Within these allocations, the arability of the land varied greatly. "Of the limited area suitable for crop production, Africans were restricted by law to only 37%, whereas 63% was occupied by Whites" (Nelson et al 1975:270, 277). The role of these sectors in Rhodesian agriculture was decidedly different.

As a consequence of the diversification needed following the "Unilateral Declaration of Independence" (UDI) proclaimed in 1965, the commercial sector produces a wide varriety of agricultural products including tobacco, beef, cotton, sugar, maize, dairy products, soybeans and wheat (USAID 1982:8). Among the some 6300-6500 farmers in this sector, there is a great variety in farm sizes, with a few very large holdings and many substantially smaller ones. The commercial farms produce 93-94% of all marketed agricultural output (Novicki 1983:13; Blackie

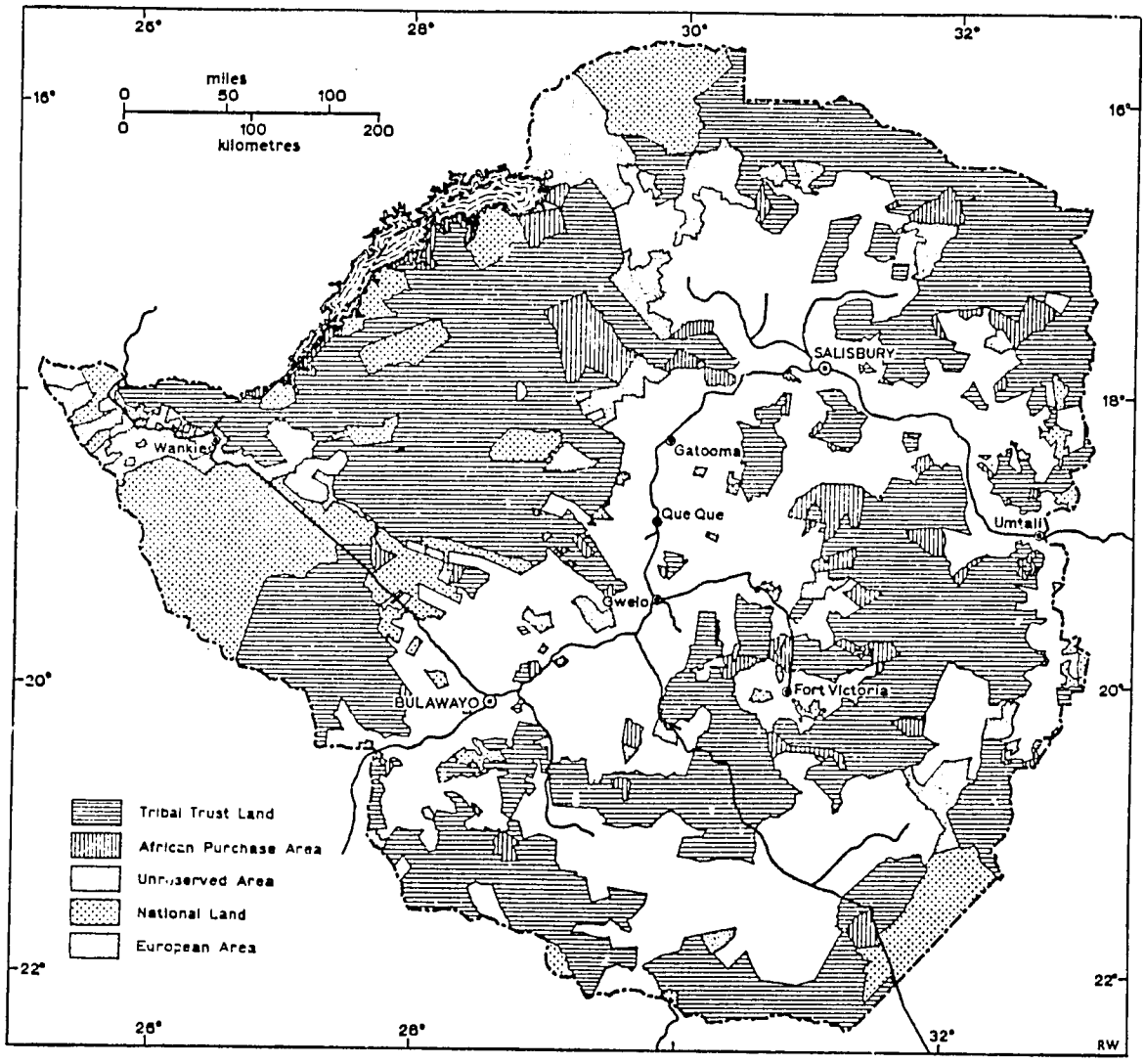

Figure 2. Land apportionment in Zimbabwe, 1968. (From Kay 1970:52)

1982:151), and recent studies show that in these areas the productivity of the land is six times that in the communal areas and the productivity per unit of labor is eight times that of the communal areas (USAID 1982:58-59).

The commercial farm sector accounts for one-third of all of the formal wage employment in Zimbabwe, 327,000 farm laborers being reported in 1980. If you include family members living with the laborers, this results in a total farm worker population of 1.7 million people directly supported by commercial agriculture (Kinsey 1982:95).

The communal areas where the average holding size is 1% of that in the commercial areas, (Kinsey 1982:95) are home to about 750,000 families, or 80% of the rural population (USAID 1982:58; Simson 1979:29). Holding size varies significantly with 29.5% of the population occupying 61% of the land (Simson 1979:30). Only one-fourth of the total communal output enters the cash economy (Kinsey 1982:95). But while accounting for only 15% of the country's agricultural output, earning $40 million in 1980, the communal sector also provided subsistence for 4.5 million people (USAID 1982:41; Blackie 1982:151).

Though only 10-20% as productive as the commercial farms (USAID 1982:42), it has been noted that in the bumper maize crop of 1982, "much of the increase in production is coming from the small farmer in the communal lands responding to price. In 1983 some 50% of the cotton marketed in Zimbabwe will reportedly come from the communal areas" (Novicki 1983:13).

5.3.1. History to 1980

The birth of Zimbabwe as an independent Black African nation marked the end of the Rhodesian Government whose racist policies were most evident in its land distribution. Although the new government emphasizes major policy changes, implementation of these while at the same time maintaining the existing economy in the interim, necessitates a cautious approach. Because of this, much of the

structure of pre-independence land distribution remains.

The first African reserves were designated in 1894, shortly after British colonial presence was established in the area that is present day Zimbabwe. As mining and agricultural enterprises developed, large amounts of unskilled labor were needed. The Land Apportionment Act of 1930 helped meet this need through the assignment of fixed areas of land to Blacks and Whites. Because the African areas were inadequate both in quantity and quality, the subsequent population pressure experienced there sought release through wage labor. The fixed boundaries and poor quality of the areas rendered the traditional system of shifting agriculture with individual usufruct and communal land tenure ineffective and detrimental. In 1951, the Native Land Husbandry Act responded to these problems of environmental degradation through a series of government imposed regulations. Forced destocking, conservation measures and a new system of land tenure involving private plots allocated by the government instead of tribal authorities were all measures included in this act.

The pressure on the rural African population for outside earnings continued and Rhodesia soon found itself with a surplus of labor in the urban areas. In 1965, the Tribal Trust Lands Act returned jurisdiction over land allocation to the tribal authorities. In this way, urban Africans could be returned to the TTL's and the government could divest itself of responsibility for the rural situation as well as the urban African population not needed by industry. The "Unilateral Declaration of Independence" was proclaimed by the Rhodesian Government this same year and Rhodesian Africans were told they must solve their own problems as the country strained to sustain itself under international sanctions. The emphasis on commercial agriculture especially since UDI, and the toll of 7 years of civil war on the rural population left 'communal,' African agriculture seriously deteriorated at the time of Zimbabwe's independence.

5.3.2. Government Policy Since 1980: Resettlement and Redistribution

Redistribution of land and assets was a major issue during the war. Since independence, the new government has given resettlement of rural areas highest priority. "(war) refugees,... the landless...and those with insufficient land to maintain themselves and their families" (Kinsey 1982:97), are those being resettled.

Focusing on the "20-60% of the White controlled land (which) is either unused or underutilized" (Riddell 1980:5; quoted in Kinsey 1982:94), the Government, through the Ministry of Lands, Resettlement and Rural Development, purchases unused commercial areas on a "willing seller/willing buyer basis." Resettlement itself is carried out according to two different programs.

The "intensive resettlement program" was started five months after independence in September 1980. It has "the overall objective of resettling some 18,000 families from the crowded communal areas onto 1.1 million hectares of formerly commercial farming land over a period of 3 years" (Kinsey 1982:96).

Based upon careful planning, this program intends to provide all the necessary infrastructure required by the new settlers and an "acceptable standard of living for the farmer and his immediate dependents" (Government of Zimbabwe 1981:20, as quoted in Kinsey 1982:98).

There are three different models by which the intensive resettlement program is being implemented:

"Model A - intensive village settlement with individual arable allocations and communal grazing areas.

Model B - intensive settlements with communal living and cooperative farming.

Model C - individually allocated arable land with communal grazing in conjunction with a core estate operated on a communal basis." (Zinyama 1982:151).

The projected cost of the program is $Z 60 million and "by mid March the

planning for resettlement of some 1.1 million hectares was well advanced and implementation had been completed for some 30% of this area" (Government of Zimbabwe 1982, quoted in Kinsey 1982:97).

The second type of program known as "accelerated resettlement" is an emergency, stop-gap measure designed to deal with the most serious problems of landlessness and overpopulation. Being an immediate response to the most pressing needs of the overrun rural areas, accelerated resettlement involves no planning and provides no infrastructure or social services to those being settled. This program utilizes smaller and often isolated parcels of land, "in comparison with the intensive program the average accelerated scheme to date is less than one-half as large in physical terms and about 40% smaller in terms of the number of families settled" (Kinsey 1982:101).

The long term plan of the Zimbabwean Resettlement Program is to settle 162,000 families in the 3 years, starting July 1982, which would mean "transferring some 60-70% of commercial land to African farmers" (USAID 1982:59).

There are several problems posed by rural resettlement in Zimbabwe. At this important stage in Zimbabwe's development, the commercial sector provides a critical economic base for the country's growth. Employing and directly supporting a large farm worker population, not to mention those involved in related processing and manufacturing, this sector also provides a significant portion of the country's food and export goods. Continued population growth, estimated to be 3.6-4% (USAID 1982:73), and the 'population surplus' already existing in the communal areas may mean that even if current ambitious resettlement plans are implemented, "those resettled will be more than replaced in the communal areas within 8 years" (Novicki 1983:13; USAID 1982:60).

5.4. Conclusion: Implications for local agricultural development

Several major forces that have developed over the years at the national level

are important for an understanding of the future of Tonga development. They include land alienation by the government, the economic and political primacy of large scale, European dominated agriculture, over crowding and land degradation in tribal areas, labor migration of Africans outside of their home areas, the integration of local African society and economics into the national and world order, and the distrust of government by Africans.

Because the Tonga area was not considered to be good farm land, it was not appropriated by Europeans, but large areas were taken for recreation and wildlife conservation (see section 6) and by the rising water of Lake Kariba (section 6.4).

Loss of land coupled with population growth led to over crowding and land degradation and helped spur migration to seek labor opportunities in the European sector. The Tonga farming system, like other African systems in Zimbabwe, was largely ignored in the government programs that were forced on the people. While Tongas were deeply influenced by events occurring beyond their traditional borders, and became integrated into that world, they developed a distrust of government because they were never a part of decisions and seldom benefitted from them, receiving, for example, no electricity from Kariba dam (Colson 1971). During the war for independence, Zambia provided a base for Zimbabwean freedom fighters and the Tonga area suffered as a consequence of becoming a major war zone.

In order to assist the small scale and/or traditional farmers in the communal areas, more information is needed as to their present techniques, labor requirements, purchased inputs, the incentives to which they respond and their own interests and ambitions. Since farming is still very much a family and community operated activity, an understanding of social organization is critical for working with Zimbabwe's communal farmers. The lack of any current information of this sort is a repeated lament among those writing about this agricultural sector in Zimbabwe (Nelson et al. 1975:292, 300; USAID 1982:3; Braun 1981:46; Kinsey 1982:94,109). Malcolm Blackie, Professor of Agricultural Economics and Chairman of the Department

of Land Management at the University of Zimbabwe recently wrote,

> "The need then, is first to describe and then to understand the systems which underlie the behaviour of rural communities. As agriculture is the predominant activity in most rural communities, it seems sensible to commence a systematic examination of these communities by describing the individual farming systems of which they are composed. At the centre of each farming system is a farmer who must apply the available factors of production--land, labour, capital and management--to crop, livestock or off-farm activities in order to meet some recognized objectives. The enterprises which he can choose and the factors of production to which he has access are defined by the physical, social and economic environment in which he works and by the technologies available to him. From the range of possible alternatives, the farming system that emerges is only a subset selected within the constraints faced by the farmer. The planner must have reliable data on those constraints. He must comprehend where the sensitive adjustment points of a system lie and how the components of the system interact. Policies and programmes can then be targeted at specific groups for defined purposes. For agricultural policies to be both sustainable and effective in the long term, the aspirations and circumstances of the farmer must be taken adequately into account" (Blackie 1982:155-156).

As Blackie has stated, it is necessary to consider the history and background of agriculture, and local farming systems in particular, before attempting to alter or 'develop' these systems. Distribution and availability of land in terms of both quality and quantity, infrastructural support systems, education and economic incentives and disincentives are all affected by social and political conditions. The introduction of a new crop needs to be preceded by an understanding of these conditions, the situation they create and the implications of the cultivation of the new crop on that situation.

6. Small Scale Semi-Arid Lands Farming Systems at the Local Level: The Tonga

The Tonga people live on both sides of the Zambezi Valley, with the majority in Zambia, but about 70-100 thousand in Zimbabwe, mostly in the northern or Zambezi Valley portion of Sebungwe Region (see Figure 3). They are a small, minority ethnic group in Zimbabwe. The Sebungwe Region has been chosen for a major integrated development program within which many possible changes are being considered (Scudder 1982a). In this section, we will present available information on the Tonga farming system.

The Tonga area is classified as part of Natural Region V (see section 5.1.) where "rainfall...is too low...and erratic for the reliable production of even drought-resistant fodder and grain crops...ranching is therefore the only sound system" (Vincent and Thomas 1960:42).

The Zimbabwe Tonga are relatively isolated and were not originally subjected to the wholesale displacement from their farm land as were the Shona and Ndebele. However, over the years, several competing demands on the land have developed, first by the white settlers, and now by the new government. Partly because of its isolation and the concentration of game here, the government sees the Zambezi Valley as an important source of increasing tourist generated income. For example, the 3,882,000 hectares of the Sebungwe Region are divided as follows: "61% (are) Communal Areas, ... 9% National Parks, 6% Kariba Recreational Park, 8% Safari areas, 5% Forest land and 10% land classified as other" (Scudder 1982a:1). With population growth the need for new agricultural land has increased, and the structure of land distribution in the area has been a source of difficulty for the Tonga and the government departments responsible for enforcing these boundaries (Scudder 1982a:6-7). As Scudder explains, without a re-evaluation of these boundaries and support and strengthening of local farmers then both people and the natural resources of the area will suffer.

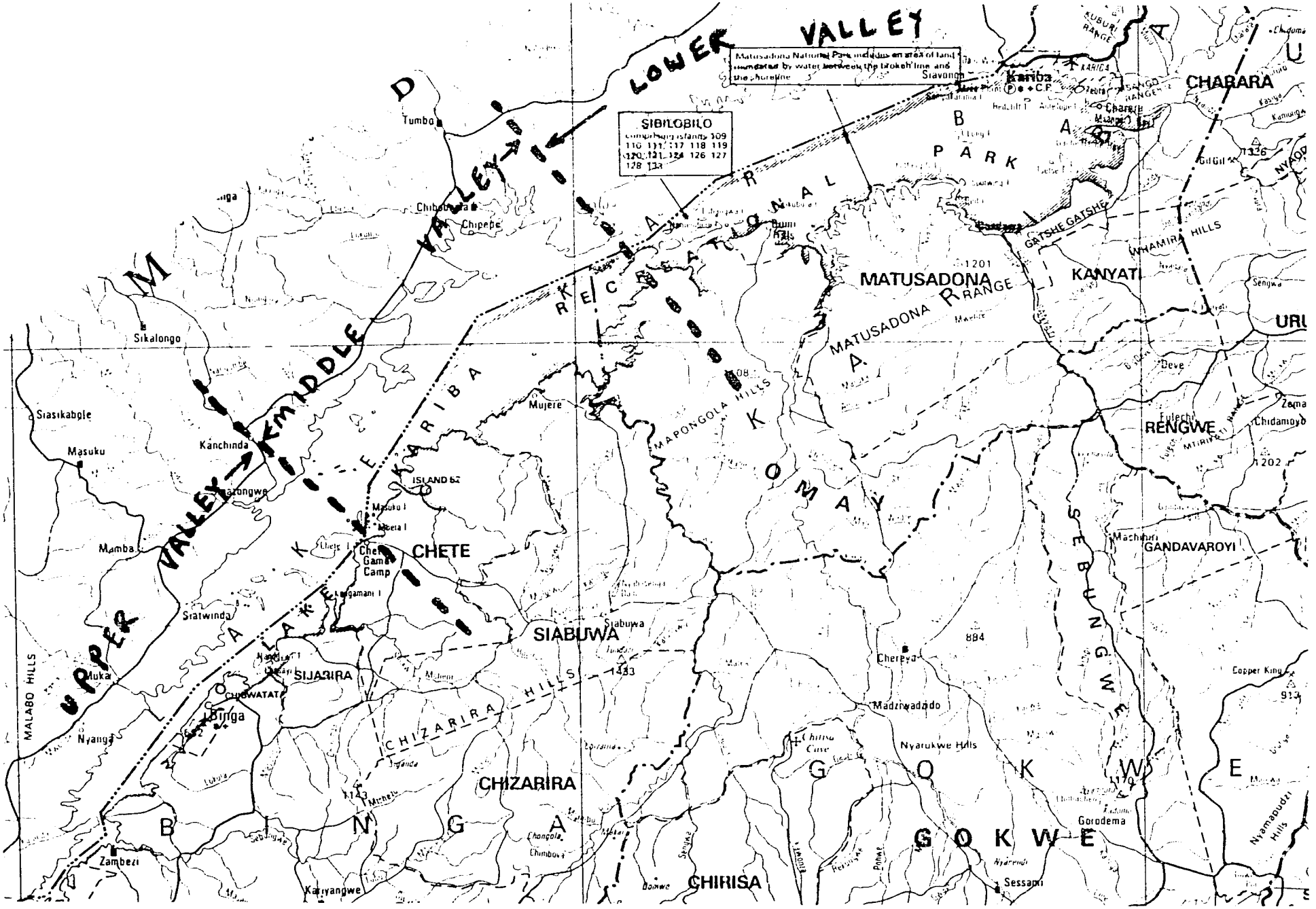

Figure 3. The Tonga area of Zimbabwe.

> "If such support is not available, then pressure on park and wildlife management areas will increase through time as hungry and unemployed people use up the last resources available to them" (Scudder 1982a:6).

In the 1950's thousands of Tonga were compulsorily relocated to make more room for wildlife management, recreation, and tourism (Scudder 1982a:14). The fact that the Tonga have developed a sophisticated cropping system in this area has been almost totally ignored by white settlers and their governments. This is despite the fact that independent observers have recognized their achievements. For example, 45 years ago agricultural ecologists described the Zimbabwean Valley Tonga as having "a relatively advanced system of semi-permanent cultivation of bullrush millet and kaffir corn" (Trapnell and Clothier 1937:54, quoted in Scudder 1982a:8). Even current official thinking reflects this bias. Scudder cites a 1980 Sebungwe Regional study which states that the Tonga are not agriculturalists.

As mentioned in the previous section, there is a great lack of information about communal or traditional farming systems in Zimbabwe. An important reason for choosing the Tonga in the extreme north of the country is that many of them live in adjacent areas of Zambia where they have been studied extensively by anthropologists Thayer Scudder and Elizabeth Colson. They began their work as part of a long term study by the Rhodes Livingston Institute of Northern Rhodesia (now the Institute of African Studies at the University of Zambia). Their "objective was to make a baseline study of the social organization and human ecology of the Bantu speaking Gwembe Valley Tonga prior to their resettlement in connection with the Kariba Dam scheme" (Scudder 1962:xix). We use the term Valley Tonga to refer to the Tonga living in the Zambezi Valley area of both Zambia and Zimbabwe.

As a result of Scudder's initial field work in 1956-57, and later studies by him and his colleagues, he has concluded "that it is possible to discuss the Valley Tonga in both Zambia and Zimbabwe as a single people sharing a basically similar culture" (Scudder 1982a:2). Consequently, the overall results of Scudder's work in

Zambia may be applied to the Valley Tonga of Zimbabwe. He has also made field trips among the Tonga of Sebungwe Region in 1956-57, 1962-63 and 1982.

Unless otherwise cited, the following sections about the Tonga are based upon Scudder's book, "The Ecology of the Gwembe Tonga," published in 1962 and based on field work in 1956-57. Thus it refers to conditions before the filling of Lake Kariba and the resettlement of Tonga. Though not entirely adequate for this type of study, the information available on the Valley Tonga provides an example of useful and relevant data necessary about farming systems for which new crops are being considered. Little is available on current Tonga farming systems, but much of the traditional system described in section 6.3 persists today, or (like draw down agriculture) may in the future regain its former importance. Information on present and future Tonga farming systems is summarized in section 6.4.

6.1. Physical Environment

Soils The most recent official soil map for Zimbabwe (Figure 4) shows that much of the soil in the Tonga area is poorly developed lithosols, less than 25 cm deep, over weathering rock or gravel (Department of the Surveyor General 1979). The second most common soils group is deeper, and composed mostly of sandy loams or loamy sands, being formed mainly on sandstones and quartzites.

Vegetation associations are often used to define underlying soils. Thus, under mixed *Acacia* or deciduous shrub thicket, the soils in the area are "fine to medium grained sandy soils, deep and well drained;" under scrub *Colophospermum mopane* the soils are "medium to coarse grained sands, calcareous, very shallow and eroded;" under "well grown *C. mopane* usually deep, alkaline, usually sodium dominated clays" (Vincent and Thomas 1960:Map 1).

Alluvial and colluvial soils along major water courses supporting *Acacia albida* on lower terraces and *A. tortilis* on upper terraces are the richest but least abundant soils in the Tonga area. They "produce adequate crops year after

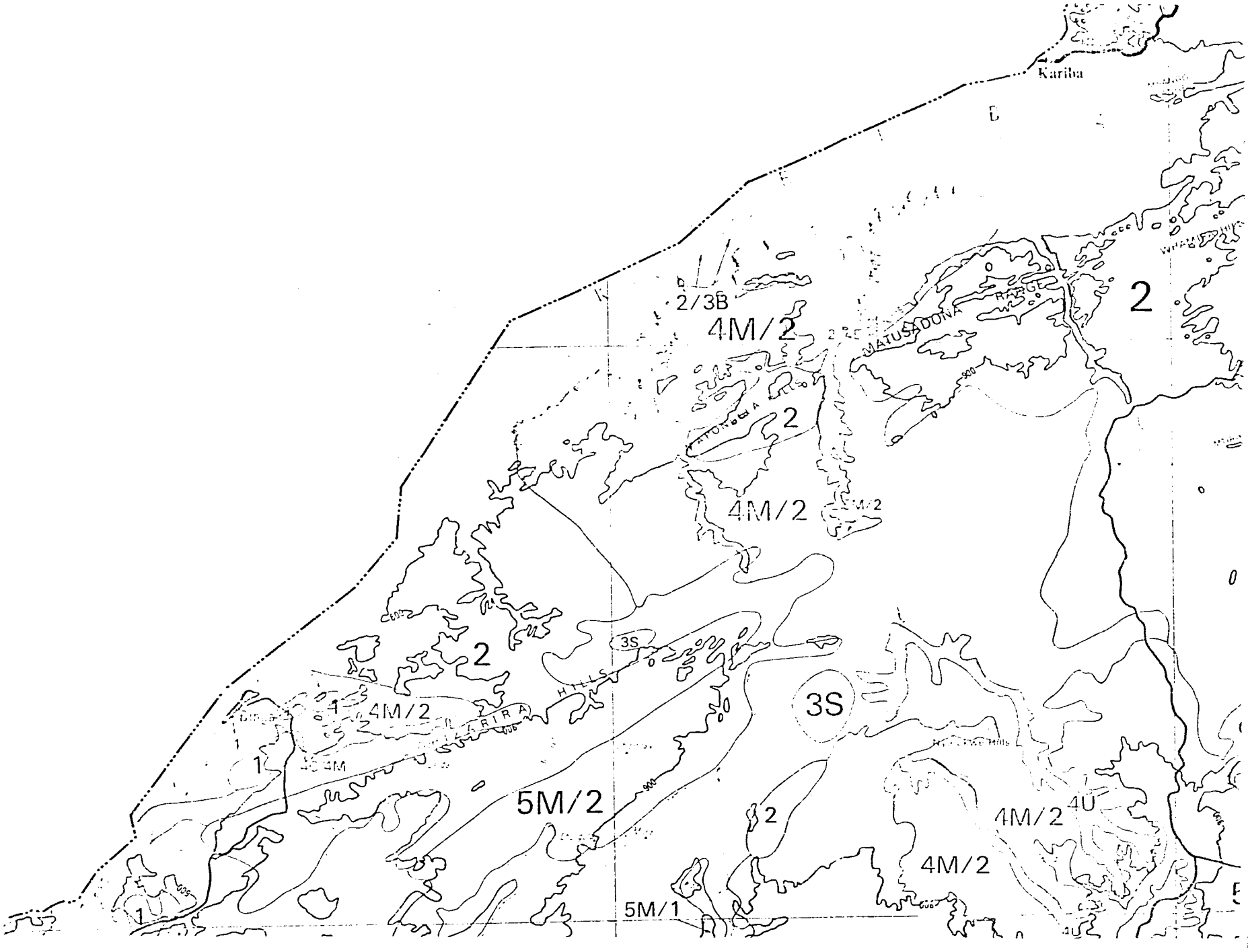

Figure 4. Soils of the Tonga area, Zimbabwe. From Department of the Surveyor General 1979.

CLASSIFICATION

AMORPHIC ORDER

Soils with very feeble development of genetic horizons.

1 Regosol group. Deep sands with less than 10% silt + clay above 2 metres; very little or no reserves of weatherable minerals; extremely low silt/clay ratios (mainly Kalahari sands).

2 Lithosol group. Very shallow soils, less than 25 centimetres deep, over weathering rock or gravel.

CALCIMORPHIC ORDER

Unleached soils, generally with large reserves of weatherable minerals; clay fraction predominantly 2 : 1 lattice.

3 Vertisol group. Moderately deep to deep, dark self-churning clays; clay fractions mainly montmorillonite.

3B, Dark brown to black vertisols, without appreciable water soluble salts or exchangeable Na; formed on basalt (B)

3S Grey to black vertisols, often with appreciable salts and/or exchangeable Na, and often gypseous; formed on Madumabisa shale or other argillaceous sediments.

4 Siallitic group. Soils in which the clay fractions are predominantly illite or illite-montmorillonoid mixed-layer minerals: with or without calcareous accumulation in the lower solum or underlying material.

4E Shallow to moderately shallow, brown or reddish brown clays; formed on mafic rocks.

4M Moderately shallow to moderately deep soils; texturally similar to those of 4P, but usually with smaller reserves of weatherable minerals; formed mainly on sandstones and quartzites of Triassic, Permian, and to a lesser extent, Cretaceous and Umkondo formations

4C Deep, mainly medium to moderately heavy textured soils, usually calcareous below 120 centimetres; formed on colluviums.

4U Soils similar to 4C, but formed on alluviums.

KAOLINITIC ORDER

Moderately to strongly leached soils; clay fractions mainly kaolinite together with appreciable amounts of free sesquioxides of iron and aluminium.

5 Fersiallitic group. Soils with appreciable reserves of weatherable minerals; clay fractions contain some 2 : 1 lattice minerals.

5M Moderately shallow to deep, greyish brown sands or loamy sands over light reddish brown sandy loams; formed mainly on sandstones and quartzites of Triassic, Umkondo, and to a lesser extent, Permian formations.

Figure 4. Continued

year, even during most periods of irregular rainfall" (Scudder 1982a:15). They are generally not shown on maps of the scale of Figure 4. Before field trials of jojoba or other new crops, detailed soil surveys in selected areas would be necessary.

Climate. The Tonga area is quite dry and hot. Section 8.1 shows the monthly rainfall and temperatures for Binga in the Tonga area. January is the only month during which precipitation exceeds potential evaporation, and then by only a few mm (Department of Meteorological Services 1981:179). The total yearly potential evaporation (2,296 mm) is almost 3.5 times greater than yearly precipitation (651 mm). Thus water is the major variable in Tonga agriculture and they have traditionally used the Zambezi River's annual rise and fall to increase production through flood recession agriculture.

The annual flooding was stopped by the building of the Kariba dam and the filling of the reservoir by 1964. After many years of irregular seasonal fluctuation in the level of Lake Kariba, it has now been regularized "with lake levels beginning to fall no later than June-July and continuing to drop with a very low probability of intervening fluctuation, until December-January" (Scudder 1982a:17). This provides a 5-6 month period for cultivation in the higher draw-down areas.

6.2. Social Organization and Land Tenure

The Tonga live in permanent and semi-permanent villages clustered together to form endogamous neighborhood communities or cisi. The villages represent exogamous matrilineal clans which may have members living in other cisi throughout the valley. In each cisi the clan claiming longest habitation of the area is the source of the cisi's ritual leader. The leader's responsibility is to initiate particular agricultural and gathering activities, and maintain the neighborhood's

rain shrine. This position has no unusual privileges or powers other than those of the particular individual who holds it. Because cisi members are related, decision making and dispute solving was traditionally taken care of through rules of kinship. However, with colonial intervention and administrative demands, there developed a village headman position which did not exist previously.

The villages are composed of homesteads which in turn are made up of one or more households. Each married man and married woman has their own granary, a reflection of the system of food production. In a family, the husband will have his own field(s) which are worked by all family members. Each wife will also have her own field(s) for which only she is responsible. In addition, children often have small fields of their own. The wives' first duty is to work their husband's fields. Only when they are cared for may they tend their own plots, most often unassisted.

An individual may acquire the right to cultivate land in a number of ways: from his (her) lineage, from a spouse, from individual affinal or blood relatives, or by clearing a virgin area. These different sources of land bring with them particular restrictions over land use and ultimate control. Both men and women inherit land through their lineage and fields thus acquired may be reclaimed by the lineage. Land given to a wife by her husband is subject to his complete control, should he decide to exercise it, and it may be reclaimed at any time by him or by his lineage after his death. Though less common an occurrence, land given by a wife to her husband is similarly under the control of her and her lineage. Land newly cleared by a farmer is under this farmer's sole control.

6.3 Traditional Farming System Cycles

The farming system of the Valley Tonga is based on several "field types" (see Figure 5. Scudder (1962) refers to them as "garden types") and cultivation techniques. This variety enables them, ideally, to have ongoing food production

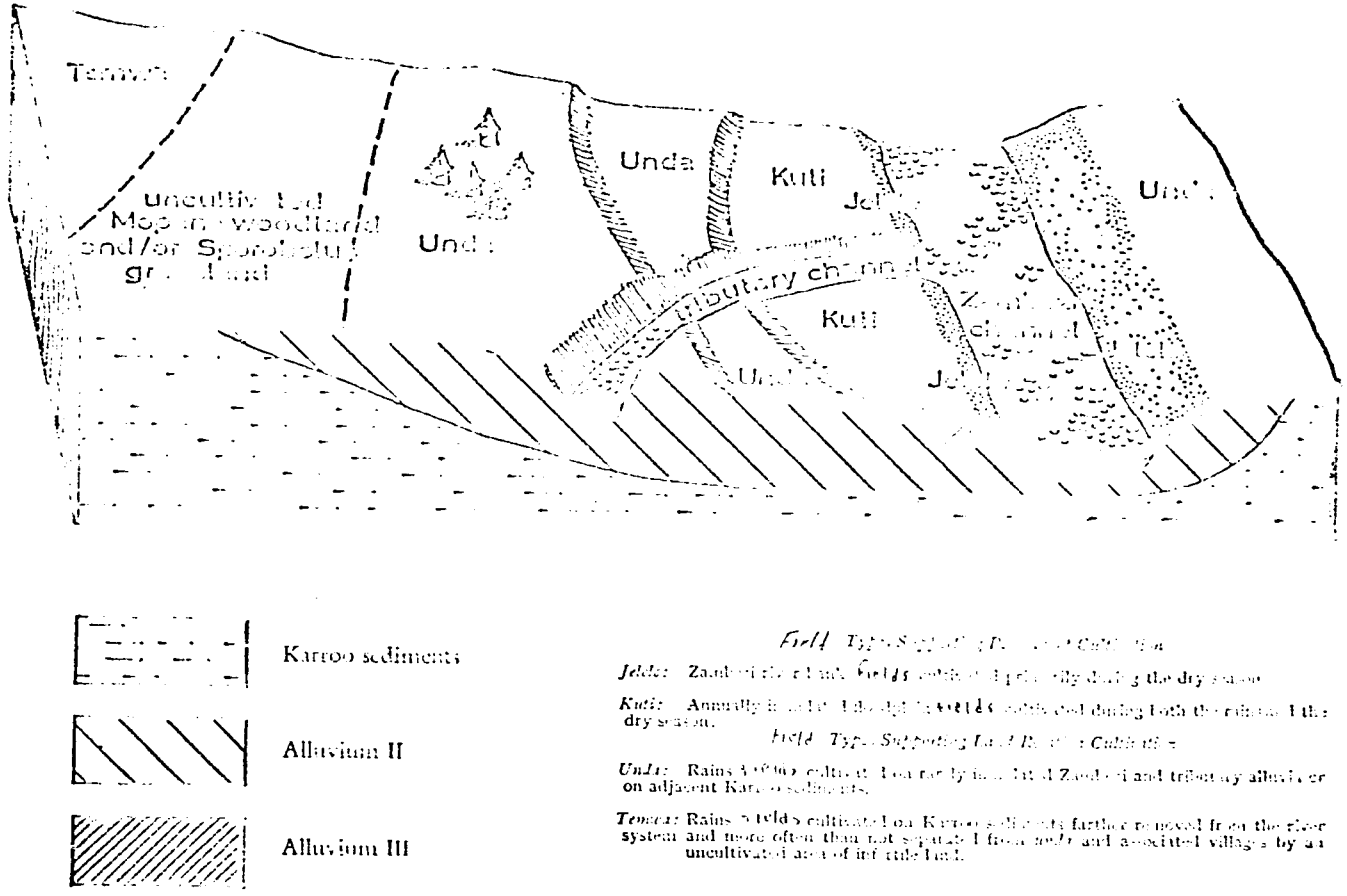

Figure 5. Major Tonga Field Types, middle River Area. (From Scudder 1962:35)

year-round, given favorable climatic conditions, and spreads the risk of crop failure in unfavorable years.

The different "garden types" may be divided into rainy and dry season farming. During the dry season when the Zambezi River receded, maize and vegetables were frequently cultivated on the exposed flood plain. Jelele fields are those along the actual river banks, which are cultivated as the rains cease and the river's water level drops. Kalonga fields utilize small pockets of moist tributary stream-beds as they are exposed by dropping water levels. Tobacco and cucurbits are planted in the kalonga plots. In general, dry season farming requires no weeding and the planting of crops may continue throughout the dry season until rising floodwaters threaten harvests.

Wet season farming is done in two field types. Unda fields lie above the flood plain, surrounding village sites. These fields are planted at the beginning of the rainy season with sorghum and bullrush millet, and must be weeded at least twice during the season. After three to eight years of cultivation, unda plots must be fallowed for four to seven years.

Temwa fields are located at least 1.6 km inland in areas which have been cleared by cutting and burning. Bullrush millet, sorghum, groundnuts and some cucurbits are cultivated in these fields. Once again, weeding is essential and done at least twice per season. The capacity for long term cultivation of temwa plots without fallow periods was, at the time of Scudder's original work, unknown. The system appeared to be relatively new to the area at that time and long term patterns were not yet discernable (Scudder 1962:42-4).

At the time of Scudder's 1956-57 studies, the valley Tonga had, for the most part, a subsistence economy. Cash cropping was only practiced by the few individuals who had more than enough land to provide for their own subsistence. Nowhere was cash cropping replacing food production.

Small quantities of tobacco were grown in kalonga plots along Zambezi

tributaries. Though grown primarily for home consumption, there were indications that improvements in transportation infrastructure would stimulate further cultivation for resale. The advantage enjoyed by tobacco as a cash crop is that it grows during the dry season in areas unsuitable for other crops. Thus it competes for neither labor nor land with food crops.

Maize was sold occasionally, but only those who could afford to have and cultivate additional fields were able to do so. Occasionally sorghum, ground nuts, and bananas were also sold both locally and at larger markets.

6.3.1. Agricultural Labor

The majority of the agricultural work among the Tonga is done by women. While the men are responsible for clearing new or fallowed fields, and building rain and crop protection shelters, all other agricultural work is undertaken by women. The men may participate in this work but it is the women's responsibility. They tend their husband's fields first, and then their own and those of their unmarried children. Because of the priority given the husband's fields, women are rarely able to accumulate enough surplus from their own fields to provide a supplement, in food or wealth, of any consequence. "Women find it almost impossible to crop a surplus even if they own enough land, so that few have sufficient grain to convert into cash, livestock or beer for labor recruitment during the succeeding rains" (Scudder 1962:78-79).

A trend of increasing male out migration in search of wage labor puts an even greater strain on the women farmers. In 1951, 41.5% of the male population was absent from the Gwembe District (Scudder 1962:32). This did however fluctuate seasonally, dropping during the rains when the most agricultural assistance is needed. As land pressure increases and the quality of available land drops correspondingly, more and more men are remaining in wage labor year round and sending money to their families for grain purchases.

Figures 6 and 7 are diagrams of agricultural activities according to crop, and according to garden type. They show the pronounced seasonality of agricultural labor requirements among the Tonga. While only approximations made from available information, the purpose of these diagrams is to demonstrate the usefulness of this information when trying to understand the appropriateness of a new crop within existing agricultural labor requirements.

During the dry season there is no need for weeding, and planting may go on continuously for several months. Because there is relatively no critical timing factor in this type of farming, the farmer is able to cultivate fields gradually, without assistance.

Rainy season agriculture on the other hand must follow a careful timetable for specific tasks. The activities demanding the most labor are planting, weeding, and crop protection. Because of the importance of planting fields at the appropriate time to take advantage of the rains, a labor shortage during this period could greatly limit production of wet season fields. "The rainy season cultivator with small children or other dependants must have access to the labor of others if he is to harvest sufficient grain to satisfy his subsistance requirements" (Scudder 1962:74).

Weeding is necessary only in the rainy season fields. It is a critical task, as neglected weeds will quickly engulf and dominate the cultivated crops. In the temwa fields there are two weedings, the first or kasaba, is started as soon as three days after the field is sown and may continue for a number of weeks depending on the availability of labor. The second weeding or ibbule, occurs later in the rainy season around December. The farmers alternate their work in the temwas with similar tasks in the other rainy season fields.

In these situations the polygamist has the advantage of his wives' labor as they must tend to his fields before their own, often at the expense of theirs. Other family members owing tribute may also assist, although there are no general

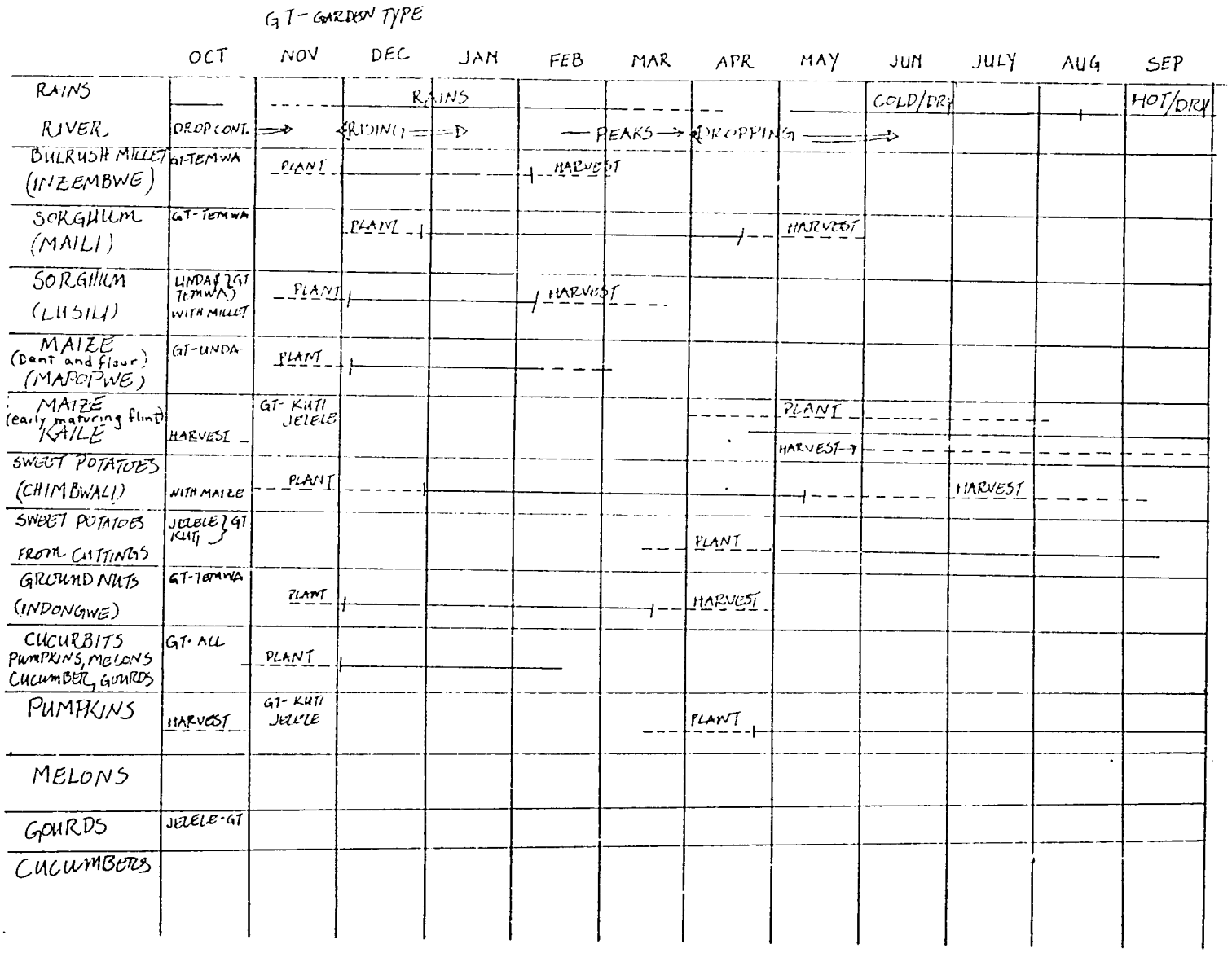

Figure 6. Seasonal cycles of main Tonga crops. Based on Scudder 1962.

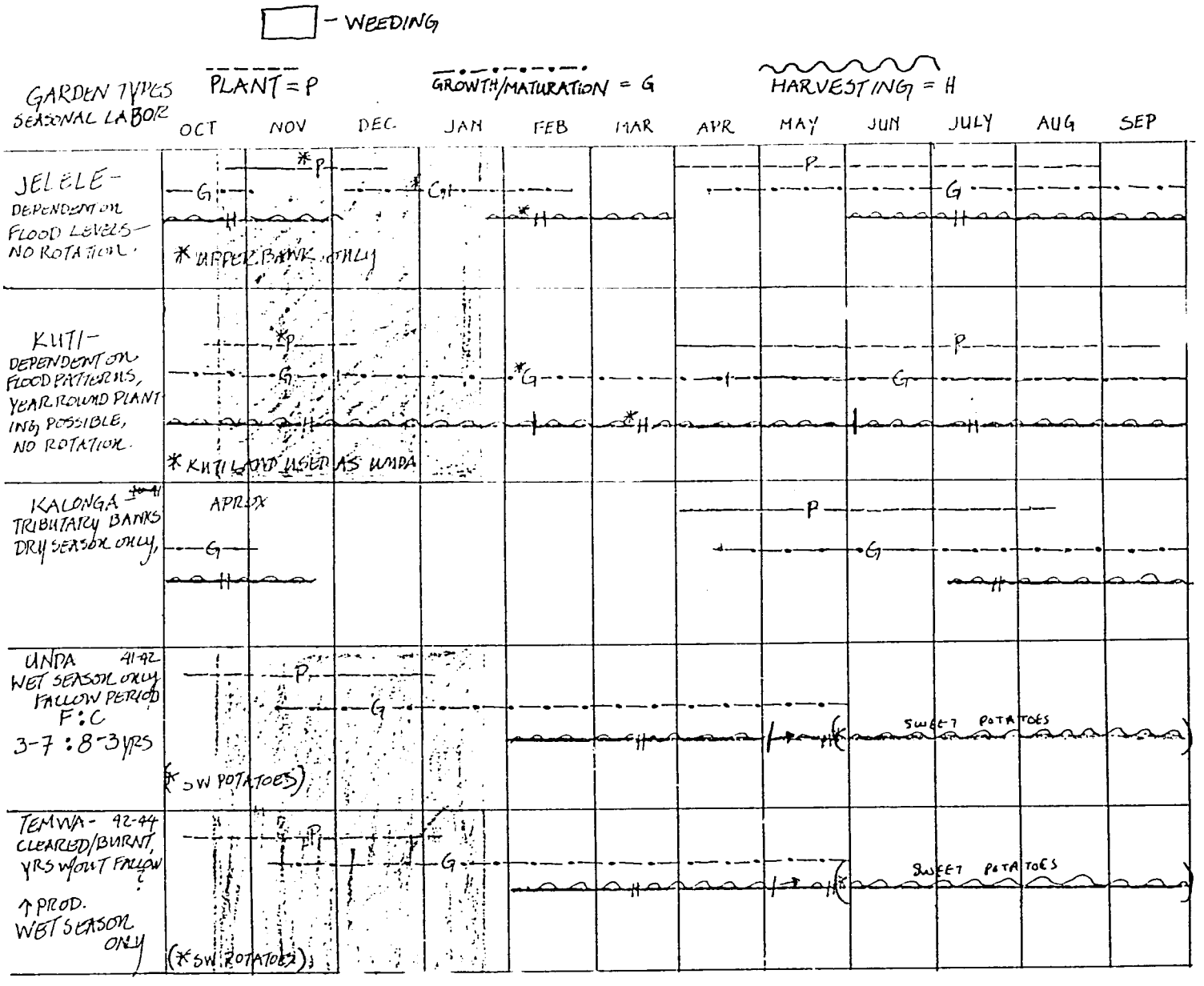

Figure 7. Seasonal labor in different garden types. Based on Scudder 1962.

labor obligations to kin of either side. Work parties of people from the area, though not necessarily the same village, often fulfill seasonal labor requirements. These teams are formed temporarily, dissolving upon completion of the task. Often group labor is reciprocated with locally brewed beer, while individual or small group labor may also be paid with grain, food, meat, a portion of the crop, use of a plow, or labor.

Since the time of his original study, Scudder notes a rise in the use of animal traction for plowing, weeding, and transportation. Starting in the late 1950's, this increase continued until the 1970's, when the trend was reversed due to disease (Scudder, Colson and Scudder 1982:25, 27). Scudder feels the reduction in labor demands and increase in production made possible by ox and plow cultivation are critical to the development and improvement of living standards of the Tonga people (Scudder 1982a:11,23).

Crop protection in the rainy season usually involves a guardian sleeping in the fields to discourage animals from eating and destroying the crops, particularly at dawn and dusk. Using different noise makers, the guardians frighten away such animals as baboons, antelope, hippopotomuses, bush pigs, elephant, and a variety of birds. During the dusty dry season whole families often move down to their riverside fields taking advantage of the cooling water.

It is also necessary to protect crops from livestock damage. Children frequently accompany herds in order to avoid this problem although some fields may be fenced.

6.3.2. Non-Agricultural Labor

The valley Tonga keep cattle, but because of their location in the valley, they do not practice seasonal migration of their herds. The animals, tended by young boys, graze near the villages and water. For the Tonga, animal husbandry requires minimal labor inputs.

Through a wide variety of techniques the valley Tonga fish successfully all year-round. While some of these techniques require large labor forces, the continual availability of this food source alleviates competition between fishing and agricultural work during the latter's critical periods.

Gathering, done by women and children, provides a large selection of leaves, fruits, tubers, and grains. Some of these are collected only during times of hunger, while others are used regularly to enhance the "relishes" which accompany the insime or grain porridge eaten by the Tonga.

The most important feature of the valley Tonga subsistence economy is its diversity. A wide variety of crops, cereals, legumes, and tubers are grown according to a number of different techniques associated with flood recession, dry, and rainy season farming. Food production is supplemented by animal husbandry, food gathering, hunting and fishing. The range of food sources and production techniques provides an important "risk reduction" in an area with unreliable climatic conditions (Scudder 1982a:19).

The increase in wage laborers, especially males, is altering the subsistence economy of the valley Tonga. Poor food production, often due to land degradation, is supplemented by earnings from absent workers. The workers are in turn subsidized in part by the produce of their families at home.

Understanding the existing labor demands of a farming system and the society of which it is a part is critical to determining the feasibility and suitability of a new crop for that system. A new crop whose labor requirements are in conflict with those of already established agricultural or other activities can only be incorporated into the agricultural system if it is of sufficient value to the farmers to warrant a change in labor allocations. On the other hand, a new crop whose labor demands coincide with a period of relatively low agricultural activity such as the dry season in the Gwenbe Valley, could perhaps be incorporated into the farming system with less chance of jeopardiziang the farmers returns.

6.3.3. Nutrition and Famine

When conducting studies regarding the introduction of a new crop, especially a food crop, into a farming system, an understanding of the nutritional conditions and needs of the people is important. The quality and quantity of calories and nutrients, seasonal changes in diet, dietary deficiencies and the cultivation, storage and preparation requirements of the food must all be considered. Such information would be helpful in determining the crops usefulness in responding to the nutritional and dietary needs of the people and hopefully avoid redundant production of foods or nutrients already available in sufficient quantity.

Unfortunately no such information is available for the Valley Tonga. However some information about famine and its causes addresses some of the same questions, seasonality in particular.

Despite the diversity within the valley Tonga's subsistence strategy, food shortages and famine do occur. The field type which is most productive varies according to the location in the valley. While the success of one type may be considered of greatest importance in avoiding famine, it is the combination of the different types and the crops which they produce that provide the cultivators with an adequate diet (Scudder 1962: 44-45).

Historically, famines most often followed poor rainy season harvests. The severity, frequency and extent of these food shortages varies according to the location in the valley. The actual cause of the famine may be at the region, village, or household level. "For the valley as a whole irregular rainfall is the major cause of famine" (Scudder 1962:220). Successive years of inadequate rains or an uneven distribution of the rains during a single season will diminish agricultural production significantly.

In the past, the irregularity of the Zambezi's floods and recessions were a problem for dry season recessional farming which is particularly important

following a poor rainy season harvest. Both early flooding and a lower or higher than usual flood level could damage crops and fields or leave the soil inadequately replenished of water and nutrients. Scudder reports that such irregularity has been alleviated below the Kariba dam, and that dry season agriculture will benefit from this (Scudder 1982a:16-17).

Large animals such as elephants as well as birds and insects have all caused major crop destruction which led to famine. Plant disease may also claim a high toll.

At the household level, quantity and quality of land and variations in agricultural skill result in differences in production.

Millet (Pennisetum typhoides) and sorghum (Sorghum spp), the cereal crops of primary importance, are grown during the rainy season in temwa and unda plots. Of all crops grown by the Tonga, only millet may be stored over a number of years without perishing (Scudder 1960:81) making surplus production worthwhile.

Kaile, or fast maturing flint maize (Zea mays) is an important crop because of its short maturation period and because it may be cultivated in dry or rainy season fields. Consequently, it was a good emergency crop during times of other cereal shortages.

6.4. Conclusion: The Tonga, Kariba Dam, and the Future

It has been amply documented in recent years that small scale subsistance farmers in Africa adopt new techniques in response to economic incentives (Netting, Cleveland and Stier 1980). Like most farmers, the Tonga have survived by experimenting with new ideas, including new crops. Two of their major crops, maize and groundnuts are New World Crops introduced by Europeans and now important components of the farming system. On the other hand, the forced cultivation of cassava ordered by the government after World War II was a failure partly because the Tonga resented being ordered to grow it (Scudder 1962:84). It was also subject

to heavy termite damage.

The building of Kariba dam forced major changes in the Tonga farming system. What are today Malawi, Zimbabwe and Zambia were joined together in the Federation of Rhodesia and Nyasaland in 1953 in an attempt by the British to preserve their colonial influence there against rising nationalism. The site for a major hydro-electric dam on the Zambezi was partly chosen as a symbol to unite Northern and Southern Rhodesia in the new Federation. The project was financed by the World Bank and other international banks, and its primary customers were to be mining interests in the Northern Rhodesian Copperbelt largely controlled by the United States, Britain and South Africa, and the developing industries of Southern Rhodesia. Little thought was given to the thousands of Tonga who would be forced to leave their land (Colson 1971:4).

With the filling of Lake Kariba, the Tonga field system has become much less diversified. Most jelele and kuti fields no longer exist and draw down agriculture along the lake has not yet been established, and is in fact prohibited by the Zimbabwe government partly to protect wildlife. Tonga rely more than ever on slash and burn cultivation of rain fed temwa fields, and thus on the vagaries of local rainfall.

One of the most important Tonga adaptations to their highly seasonal and variable savanna environment has been the spreading of risk through the cultivation of crops with different requirements, pest susceptibility and harvest times, and the utilization of several different types of fields. Any innovation will be judged for its contribution to total household economic and nutritional risk as well as its potential contribution to the household in optimal years.

The changes occurring with Kariba dam resettlement of Valley Tonga in Zambia have been well documented (Colson 1971). "Quickly adapted innovations such as fishing, had immediate high cash returns or otherwise equally apparent advantages" (162). Cattle keeping, ox plowing and pig raising were some of the others. "New

crops were less easily accepted because their cultivation had to be fitted into the busiest time of the year when the vital subsistence crops had first priority" (164).

Men with sufficient resources of land, capital and labor were sometimes the innovators as was the case with cotton for they had a margin of safety which made the risks of experimentation acceptable. Later spread of cotton was subsidized by government loans. Early varieties of millet introduced by the government spread rapidly. In contrast, a new variety of sorghum spread slowly in the early 1960's when first introduced, but when a market in the manufacturer of beer was found, it was rapidly adopted. There was continual experimentation with new varieties of vegetables and with fruit trees. Small, hand watered dry season gardens spread very rapidly (Colson 1971:164). By the 1970's, Zambian Tonga had become major producers of cotton and sunflower (Scudder, Colson and Scudder 1982:5).

In Zimbabwe, the numbers of Tonga resettled were smaller and documentation of innovation since then appears to be lacking. We do know that Zimbabwean Tonga have rapidly adopted the practice of cultivating small dry season vegetable gardens along streams and in moist depressions (Scudder 1982a:21) and have developed a four-year crop rotation cycle that includes cereals, legumes and cotton (Scudder, Colson and Scudder 1982:25). On the other hand, there are some negative developments. Scudder (1982a:19) reports that in many areas kaile (fast maturing flint maize) is no longer grown; no reason is given. Use of another early maturing crop, red flammida sorghum, chigaligali, is also on the decline (Scudder 1982b:1). Not only is this variety harvestable a month or more before other sorghums and millet, but as a brewing sorghum it provides a good means for a woman to supplement her income through the local markets. There also seems to be a lingering sense of apathy and dependency following the resettlement of the 1950's (Scudder 1982a:10), and an increase in community violence and social disorganization, at least in Zambia (Scudder 1983).

The overall response of the valley Tonga to the challenges of their environment have, however, shown them to be resourceful innovators. If, therefore, jojoba is shown by further research, including field trials, demonstrations and government policies on marketing, to be economically attractive in Tonga terms, and farmers have the opportunity to test it on their own fields, then there should be no cultural barrier to its acceptance.

7. Conclusion: Jojoba for the Tonga of Zimbabwe?

Now that we have reviewed the relevant attributes of the new crop, jojoba, and the farming system the Tonga of Ziambabwe, we can attempt a summary evaluation of the appropriateness of jojoba for the Tonga. Since this paper is meant to develop a methodology and not to reach final conclusions, we will take liberty in speculating where the necessary information is lacking. The points covered here correspond to question categories a - f in section 2.1.

7.1. Agronomy

Based on the data discussed in sections 3 and 4, we have developed an idealized cultivation cycle for jojoba grown in a single-summer-rainy season, mild arid environment in the southern hemisphere (Figure 8). It will serve as the basis for our latter discussion on the appropriateness of jojoba for Tonga farming systems.

There are two main water problems for jojoba establishment in the Tonga environment; too much during the intense rains of December - February, and too little from May through September, when no rain falls. One way this could be solved is by creating small water harvesting catchments around planting holes before the rainy season, and planting seed at 3.5 cm toward the end of the rainy season (which could germinate and become established) on water stored in the soil. Field trials will be needed to determine if some supplemental hand irrigation is necessary for estaablishment. By mounding up around the growing area at planting time, it would insure that seedling roots do not become water logged during the following rainy season. In subsequent seasons, plants could still have the benefit of some extra moisture from water harvested in adjacent areas of the catchment.

Soil temperatures may be high at the end of the rainy season but should be low enough to ensure germination (see section 3.8). While no soil temperature data is available for the Tonga area, we can extrapolate from Sabi Valley at a similar altitude (448 m) in southeast Zimbabwe. The mean air temperature at Sabi Valley in

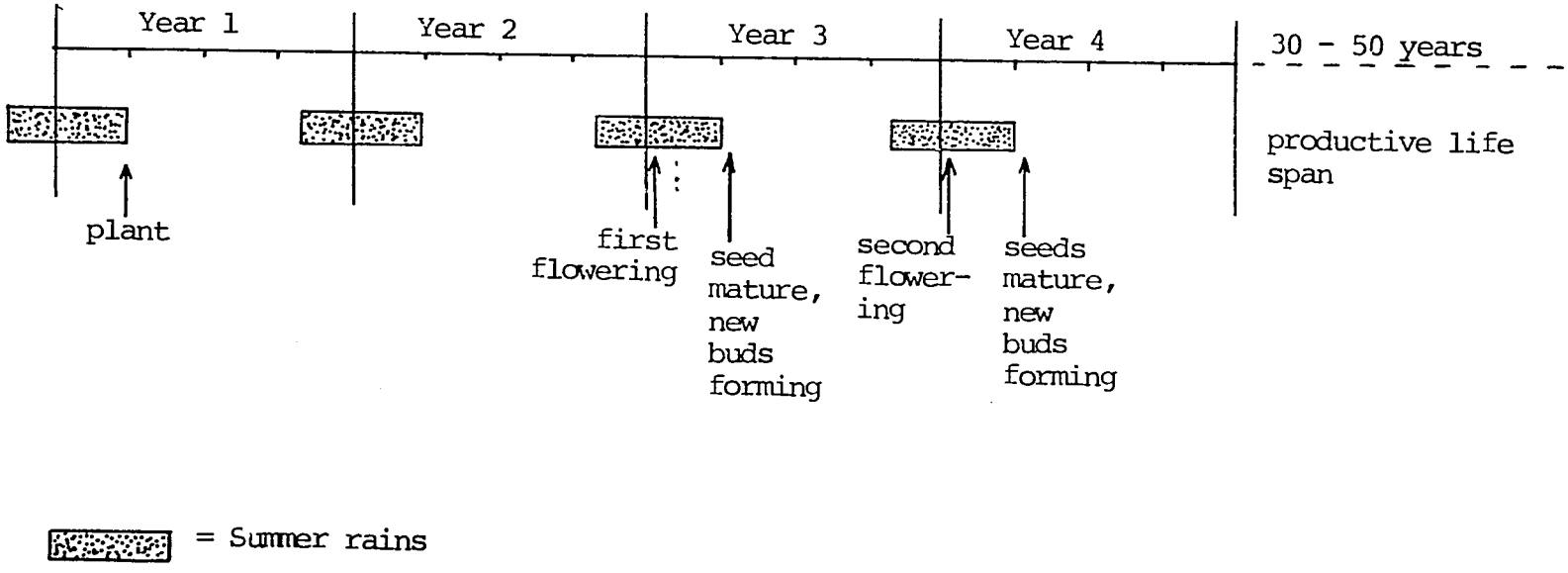

Figure 8. Jojoba cultivation cycle in a single-summer - rainy season, mild, arid environment in the southern hemisphere.

March is 30.8 compared with 26.1 for Binga at the southern end of the Tonga territory, and 31.1 for Kariba at the northern end. Mean soil temperatures at Sabi Valley in March are: at 4.8 cm, 23°C at 0800 and 37°C at 1400 (Department of Meteorological Services 1968). Mulching would help to reduce temperatures if it were a problem.

Jojoba recently established at Beitbridge in southern Zimbabwe (see section 8.2) has been quite successful so far. Soils there are similar to those in the Tonga area, with somewhat cooler temperatures. March mean temperature is, however, only 0.2°C lower than at Binga.

Because jojoba appears to be so palatable to wild animals, it will have to be well protected during its first years of growth. This might be accomplished by protecting growing plants with thorny bush cages, as is common elsewhere in savanna Africa. The Valley Tonga in Zambia have been experimenting recently with mangoes, pawpaw and other fruit trees and their experience should be very useful if the Zimbabwean Tonga decide to try jojoba.

If planted at the end of the rainy season, weed competition won't be a problem for eight months. However, insect problems could be maximized during the first dry season, when there is little other green vegetation.

Not enough experience has been gained with jojoba under cultivation, especially with jojoba in Central Africa to give a good estimate of what pest and pathogen problems are likely to be encountered in the Tonga area. However, if it is grown as a minor crop in mixtures with other crops, or in small patches on marginal land, (See soil type 2, Figure 4), it may achieve the kind of balance it has in its native environment. Large monocultures would be much more susceptible to disease and arthropod problems.

7.2. Cultural, social and demographic fit

Jojoba could be grown in such a way that its competition for land and labor is

minimal. If land preparation for jojoba could be done in advance in the dry season, and harvesting could commence at the end of March or beginning of April when harvesting of the main crops was being completed and before any planting in the lake draw down areas commenced in July, then its impact on the annual cycle would be minimal (see Figure 9). The main area of potential competition would be planting, which would ideally occur at the beginning of the rainy season. This of course is a time when farmers are very busy planting other crops. However, it might be possible to plant jojoba toward the end of rainy season (see section 7.1).

Because of the competition for good farming land, it is unlikely that farmers would be willing to plant jojoba in their better fields. The potential for jojoba to grow in marginal upland soils means that it could be produced without competing for land with food crops or less risky cash crops. Small scale savanna farmers in Upper Volta have successfully established trees in marginal soils using water harvesting techniques similar to those suggested here (Thomson 1980).

While women have traditionally been responsible for subsistence crops, men, as elsewhere in Africa, have put themselves in charge of the cash crops. Zimbabwean women appear very active at the national level in urging reforms in women's status, and it may be appropriate to specifically include women in any development of jojoba for the Tonga. If not, there is always the danger that another new cash crop could not only decrease women's status and increase their work load, but lead to a decline in nutrition.

Because jojoba is not readily perishable or nearly as susceptible to predator damage as sorghum and millet, harvesting could occur over a fairly extended period, say from the beginning of April through the end of June. Because of this, and because seeds are usually easy to reach and pick, it may be that children could play an important role in harvesting. Possible negative effects of emphasizing child labor include undermining formal education and supporting increased population growth. Scudder and Colson observe that in recent years birth intervals

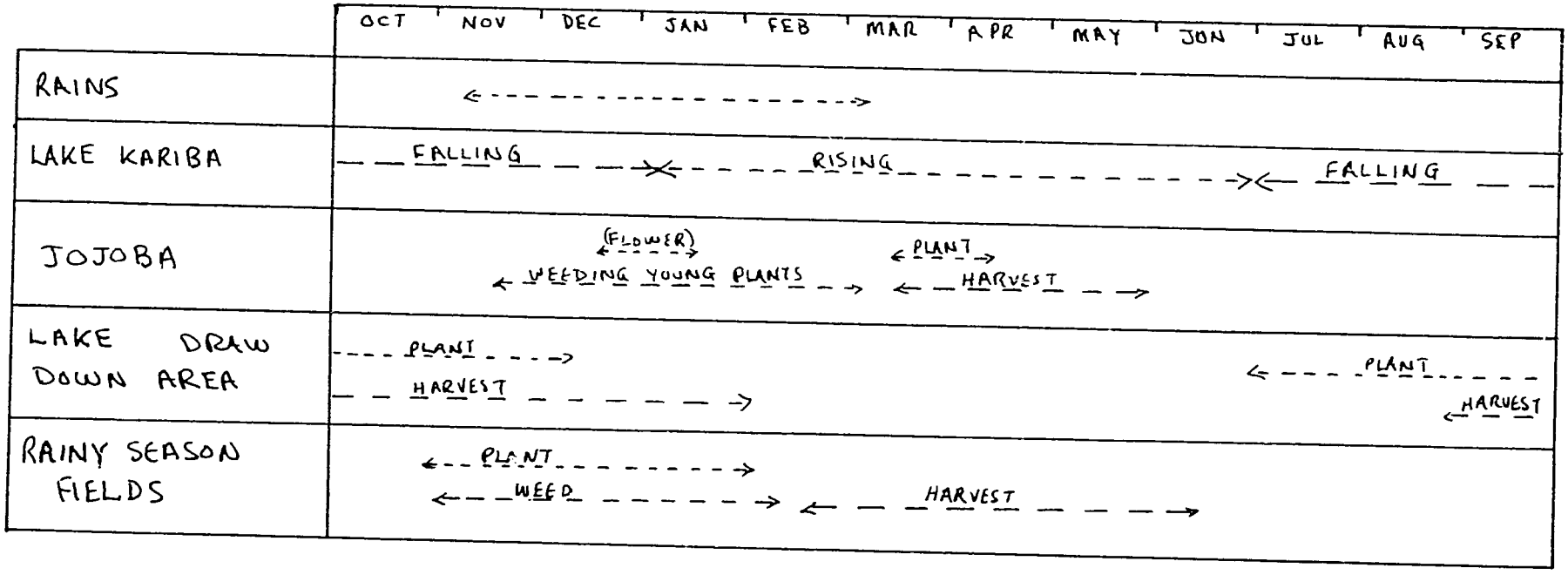

Figure 9. Possibilities for Jojoba in Future Tonga Farming Systems.

have been decreasing thus increasing Tonga fertility. A very similar phenomenon has been reported for other African subsistence farmers where it appears to be at least partly the result of increasing labor intensity of agriculture and the consequent increase in the value of children for their labor (Cleveland 1983).

7.3. Nutrition

Jojoba is not a food crop, but it could effect nutritional status in two ways: by decreasing area devoted to food crops and thus worsening nutrition and/or by increasing cash income so that families can purchase food in times of shortage. Cotton for example is labor intensive and nutrient demanding and so competes directly with food production for time and land in Tonga areas where it has recently begun to be cultivated. Jojoba, on the other hand, could be grown in such a way so as not to compete directly with food crops as has been discussed in section 7.2.

7.4. Economics

It is very difficult to gauge the production costs of jojoba grown as a minor cash crop, possibly in marginal soils, using labor intensive methods. All current research we are aware of is based on maximum production using capital intensive methods and large plantings. It is most likely that jojoba's role in the Tonga farming system would be one of providing a small supplement to household income at little expense, i.e., inputs and risk would be minimized while output would be moderate.

At present, there is no good transportation from Tonga to major populations centers. Because jojoba keeps fairly well, this is not critical in terms of loss of the nuts, but transportation costs over poor roads could wipe out any profit.

Again, it must be emphasized that we assume development of jojoba could be done on a small scale, with labor substituting for most capital investment that is

normally assumed essential in industrialized agriculture systems. Costs would otherwise be prohibitive. Estimates for establishing a ten acre jojoba plantation in Central Arizona in 1982, for example, have been estimated at US $2,832 per acre for the first four years (Wright 1982).

Because of the large and imperfectly known risks involved in jojoba production, it would probably be necessary for the Zimbabwe Government to be involved in providing support for establishing production, and for transportation, marketing and processing.

7.5. Environment

Competition for land under conditions of overcrowding leads to poor agricultural practices as individual farmers attempt to maintain household production levels from year to year. Environmental degradation follows, and thus makes the long term situation for the whole community much worse (Cleveland 1983). While the Tonga are traditionally very individualistic, having no chiefs or other central authority, and producing and consuming food in units no larger than the polygymous family, it is not known what indigenous forms of community resource management may have existed.

Land degradation in the Valley Tonga area appears to be related to increasing population and subsequent reduction in fallow periods, cultivation of marginal lands, and over graziang (Scudder 1962:51, 1982a:4-5). Because jojoba is a perenial crop and could be grown on marginal lands, it may help to reduce pressure on land used for more demanding crops. Jojoba, like other newly introduced cash crops, has many attributes that tie it directly to the larger world. Seed and information on growing must come from outside the community, and the product would be transported and sold for processing at a central location.

Such organization could be supportive of increasing community ability to deal with problems of resource management.

7.6. Industrial development

Jojoba oil extraction is not difficult nor does it demand large scale machinery. If jojoba production were to be established in northern Ziambabwe, it would be appropriate to build a processing plant there that could be run by a local cooperative and employ local labor. Tonga in Zambia have proven their organizational and management ability in the fishing industry and in irrigation cooperatives (Scudder 1982a).

7.7. Summary

In summary, we must restate that much more field research would need to be done before decisions could be made on whether to introduce jojoba in the Tonga area.

It would appear that jojoba would be suitable only if investments and therefore risks are kept minimal, and Tonga men and women are directly involved in decisions concerning its development. If such were the case, and if markets for jojoba products could be expected to grow and stabilize at an acceptable level, jojoba could provide valuable supplemental income while further diversifying the Tonga farming system.

It is very important to avoid the pitfall common to many agricultural development schemes in the third world of promoting an innovation without an understanding of the local system and the people who depend on it. It is vitally important that the process of change begin with the men and women who will implement it. Thus, planning for change must begin with an examination of the Zimbabwe Tonga farming system in the field, and jojoba chosen for field trials, and then perhaps introduction, only if Tonga agree with development personnel that in comparison with other possible innovations including other new crops, it offers a high chance of success in Tonga terms.

By examining the feasibility of introducing jojoba as a new crop for the Valley Tonga of Zimbabwe, we have tried to elucidate a general methodological

approach. The primary goal is an adequate understanding of the current farming system and of the likely effects of a proposed new crop on that system. Much more detailed charts of annual cycles than we presented in this paper would be desirable. A great deal of preliminary research that would be very useful in planning work in the field can be done rather inexpensively. It is important to remember that the knowledge and opinions of the farmers themselves, both men and women, are essential ingredients for planning successful agricultural development.

While the simple level of social/ecological analysis in this paper is widely accepted by anthropologists, it is often shockingly alien to many others involved in development. Work by social scientists in the field would elucidate many finer points needed for project success. The value of agricultural and social scientists working together throughout the project cannot be overemphasized.

8. Appendices: Data sheets for jojoba sites

These sheets show minimal information needed to evaluate the physical potential of a site for successful jojoba production with data for Zimbabwe sites (Department of Meteorological Services 1981, Department of the Surveyor General 1979) and Fortaleza, Brazil. Part of the evaluation of the potential for any new crop should involve gathering as much information as possible on sites where it has been tried, and causes for success or failure evaluated. Since details of physiology for a new crop are likely to be lacking, comparing the parameters of a proposed site with those of sites at similar lattitudes is important.

Fortaleza, Brazil was chosen for comparison to Zimbabwe because jojoba has been grown there successfully for a number of years, it is in the southern hemisphere, and has its major rainfall in the winter-spring.

SITE NAME Binga, Zimbabwe CROP GROWN _____

LATITUDE 17° 37' S LONGITUDE 27° 20' E ELEVATION 617 m

CLIMATIC CLASSIFICATION _____ SYSTEM _____

CLIMATE FOR YEAR CROP GROWN: 19____ to 19____

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMPERATURE °C													
$\bar{x}$	25.0	26.1	25.7	26.1	25.4	22.9	20.5	20.5	22.7	26.4	29.3	28.2	26.6
$\bar{x}$ HIGH	30.2	30.4	30.0	30.8	30.4	28.6	26.2	26.3	28.5	32.0	34.6	33.1	31.1
$\bar{x}$ HIGHEST	40.8	38.6	35.5	37.6	37.2	35.3	32.8	31.6	34.9	39.2	40.8	40.5	39.9
$\bar{x}$ LOW	19.9	21.8	21.5	21.4	20.3	17.2	14.8	14.7	16.9	20.8	23.9	23.3	22.2
$\bar{x}$ LOWEST	7.7	18.6	17.8	17.7	14.6	11.6	7.7	8.9	10.7	14.9	16.9	15.5	17.2
RAIN													
RAINY DAYS													
mm	651	178	142	82	18	4	0	0	0	0	14	53	160
WIND VELOCITY													
MEAN (KNOTS)													
MAX (KNOTS)	4.8	4.4	4.2	4.4	4.5	4.2	4.2	4.0	4.9	5.7	6.3	5.6	5.1

What is your perception of the normality of the above climatic conditions compared with any longer term records that may exist? _____

SOIL INFORMATION

Classification: Siallitic - 4M/2 loamy sands over sandy loams System: National

Particle size:

Surface: Sand % _____ Silt % _____ Clay % _____

Subsurface (depth ___): Sand % _____ Silt % _____ Clay % _____

Depth of Soil: moderate shallow to moderate deep

Other pertinent information (hardpans, pH, cec, etc.) Brown to reddish brown, formed on siliceous gneissis

CROP INFORMATION

When planted (season of year) _____

How planted (direct seed, seedlings transplants, cuttings) _____

Water application (irrigation, rain-fed, water harvesting) _____

Flowering (season of year)

first flowers: _____ last flowers: _____

first seed: _____ mature seed: _____

Was it intercropped? _____ With what? _____

Comments: _____

Has crop succeeded or failed so far? _____

Why? _____

SITE NAME Beitbridge, Zimbabwe CROP GROWN Jojoba

LATITUDE 22° 13' S LONGITUDE 30° 00' E ELEVATION 475 m

CLIMATIC CLASSIFICATION _____ SYSTEM _____

CLIMATE FOR YEAR CROP GROWN: 19___ to 19___

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMPERATURE °C													
$\bar{x}$	23.1	27.5	27.0	25.9	23.6	20.0	16.8	16.7	19.1	22.5	25.3	26.4	17.0
$\bar{x}$ HIGH	30.1	33.2	32.7	31.8	30.1	28.0	25.2	25.4	27.6	30.2	32.0	32.4	32.8
$\bar{x}$ HIGHEST	43.4	43.4	42.3	40.1	39.0	36.9	32.6	33.4	38.8	40.7	42.9	42.9	42.0
$\bar{x}$ LOW	16.2	21.7	21.4	20.0	17.0	11.9	8.4	7.9	10.6	15.0	18.7	20.3	31.1
$\bar{x}$ LOWEST	- 0.6	13.6	14.1	11.9	7.1	2.9	- 0.5	- 0.6	0.1	4.3	8.8	11.7	13.0
RAIN													
RAINY DAYS	39	7	5	4	3	1	1	0	0	1	3	6	7
mm	325	70	50	36	24	5	4	1	1	8	21	39	66
WIND VELOCITY													
MEAN (KNOTS)	3.5	4.2	3.9	3.7	3.1	2.4	2.3	2.5	3.1	4.0	4.7	4.4	4.2
MAX (KNOTS)													

What is your perception of the normality of the above climatic conditions compared with any longer term records that may exist? _____

SOIL INFORMATION

Classification: Sialletic Group 2/4 P System: National

Particle size:

Surface: Sand % _____ Silt % _____ Clay % _____

Subsurface (depth ___): Sand % _____ Silt % _____ Clay % _____

Depth of Soil: Shallow to moderate shallow/loamy sands over sandy loams

Other pertinent information (hardpans, pH, cec, etc.) Reddish brown color, formed on siliceous gneiss

CROP INFORMATION

When planted (season of year) 1979?

How planted (direct seed, seedlings transplants, cuttings) _____

Water application (irrigation, rain-fed, water harvesting) irrigated

Flowering (season of year)

first flowers: _____ last flowers: _____

first seed: _____ mature seed: _____

Was it intercropped? _____ With what? _____

Comments: _____

Has crop succeeded or failed so far? Has been quite successful so far - Jojoba

Why? _____

SITE NAME Marandellas, Zimbabwe CROP GROWN Jojoba

LATITUDE 18° 10' S LONGITUDE 31° 30' E ELEVATION 1628 m

CLIMATIC CLASSIFICATION _____ SYSTEM _____

CLIMATE FOR YEAR CROP GROWN: 19___ to 19___

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMPERATURE °C													
$\bar{x}$	17.1	19.4	19.4	18.6	17.4	14.9	12.7	12.3	14.4	17.2	19.7	19.4	19.3
$\bar{x}$ HIGH	23.5	24.6	24.4	24.3	23.7	31.8	19.5	19.5	22.0	25.1	27.1	25.3	24.4
$\bar{x}$ HIGHEST	32.6	30.4	29.9	31.1	28.9	27.2	25.3	26.8	29.8	30.4	32.6	32.4	30.6
$\bar{x}$ LOW	10.7	14.2	14.5	12.9	11.2	8.0	5.9	5.1	6.7	9.4	12.2	13.6	14.2
$\bar{x}$ LOWEST	- 2.3	7.3	9.2	5.5	3.9	- 0.3	- 2.3	- 2.2	- 0.6	1.1	5.0	6.9	7.8
RAIN													
RAINY DAYS	86	15	14	10	6	2	2	1	1	2	5	12	16
mm	873	186	158	99	46	13	7	1	3	10	39	114	197
*WIND VELOCITY													
MEAN (KNOTS)	4.0	3.9	3.8	3.9	3.7	3.5	3.7	3.8	4.1	4.5	4.9	4.2	4.3
MAX (KNOTS)													

What is your perception of the normality of the above climatic conditions compared with any longer term records that may exist? _____

SOIL INFORMATION

Classification: 7G Ferrallitic Sandy loams over clays System: National

Particle size:

Surface: Sand % _____ Silt % _____ Clay % _____

Subsurface (depth ___): Sand % _____ Silt % _____ Clay % _____

Depth of Soil: Moderate deep to deep

Other pertinent information (hardpans, pH, cec, etc.) Surface hor = reddish brown over red or yellowish clays, formed on granite, highly porous, few weatherable minerals

CROP INFORMATION

When planted (season of year) _____

How planted (direct seed, seedlings transplants, cuttings) _____

Water application (irrigation, rain-fed, water harvesting) _____

Flowering (season of year)

first flowers: _____ last flowers: _____

first seed: _____ mature seed: _____

Was it intercropped? _____ With what? _____

Comments: _____

Has crop succeeded or failed so far? Has not been doing well so far ~~Jojoba~~

Why? 1.8 m above ground; cup anemometer Temperatures presumably too low.

SITE NAME Fortaleza, Brazil CROP GROWN Jojoba

LATITUDE 3° 44' 51" S LONGITUDE 38° 33' 47" W ELEVATION 20 m

CLIMATIC CLASSIFICATION _____ SYSTEM _____

CLIMATE FOR YEAR CROP GROWN: 19____ to 19____

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMPERATURE °C													
$\bar{x}$													
$\bar{x}$ HIGH													
$\bar{x}$ HIGHEST													
$\bar{x}$ LOW													
$\bar{x}$ LOWEST													
RAIN													
RAINY DAYS													
mm	1262.6	129.6	209.6	260.8	179.5	147.3	142.3	106.5	17.4	23.3	12.9	5.7	27.7
WIND VELOCITY													
MEAN (KNOTS)													
MAX (KNOTS)													

What is your perception of the normality of the above climatic conditions compared with any longer term records that may exist? _____

SOIL INFORMATION

Classification: _____ System: _____

Particle size:

Surface: Sand % _____ Silt % _____ Clay % _____

Subsurface (depth ___): Sand % _____ Silt % _____ Clay % _____

Depth of Soil: _____

Other pertinent information (hardpans, pH, cec, etc.) _____

CROP INFORMATION

When planted (season of year) _____

How planted (direct seed, seedlings transplants, cuttings) _____

Water application (irrigation, rain-fed, water harvesting) _____

Flowering (season of year)

first flowers: _____ last flowers: _____

first seed: _____ mature seed: _____

Was it intercropped? _____ With what? _____

Comments: _____

Has crop succeeded or failed so far? Jojoba has done quite well - 4 years old

Why? _____

9. Notes

[1]We would like to thank W. Gerald Matlock and LeMoyne Hogan for help in the preparation of this paper.

[2]"Arid" is used in this paper to refer to those areas of the world with little or no rainfall for a significant portion of the year and where inadequate water is a major agricultural problem. Thus it includes most of the savanna areas of the world (see Harris 1980).

[3]This paper was prepared by David Cleveland, Chris Dunford and W. Gerald Matlock with help from LeMoyne Hogan and Richard Felger.

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