Techniques and Plants for the Tropical Subsistence Farm

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Vegetables for the Hot, Humid Tropics.
- Part 1. The Winged Bean.
- Part 2. Okra.
- Part 3. Chaya.
- Part 4. Sponge and Bottle Gourds.
- Part 5. Eggplant.
- Part 6. Amaranth and Celosia.
- Part 7. The Peppers.

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ABSTRACT

For the subsistence farm to be a success it must feed the farm family nutritious food year round. To accomplish this requires careful planning. The land must be used carefully and deliberately to get the maximum benefits from the limited amount available. This publication is designed to help teach the subsistence farmer how to best meet his family's nutritional needs. Tips on overall planning are given and the necessary tools and equipment are listed. Background information is given on soils and soil fertility. Techniques to maintain soil fertility are discussed, as are other techniques to help make the farm more productive (techniques of planting, postplanting care, insect and disease control, harvest, and storage).

General information about human nutritional needs forms the background for detailed discussion of various plant groups and the roles they fulfill in the human diet. Individual species of leaves, legumes, roots and tubers, fruit vegetables, and cereals that are especially appropriate for the Tropics are recommended. The use of trees on the subsistence farm is discussed and various trees are recommended either for their edible products or for other special products, values, or uses they might have.

Production of forage crops in the Tropics is treated (site selection and treatment, planting, management, grazing, and storage) and, again, specific recommendations are made of forage species. References are provided throughout, to lead the reader to other sources of information about techniques, crops, or farm products, and a list of other useful references is given. Index terms: cereals, forages, fruits, horticulture, nutrition, plant cultivation, subsistence farming, trees, tropical agriculture, vegetables. *Address communications to Franklin W. Martin, CATIE, Turrialba, Costa Rica.*

Overall Planning

Two systems of agriculture can be found throughout the Tropics, modern commercial agriculture and traditional subsistence agriculture. Commercial agriculture is often based on large farms and intensive use of resources, a kind of agriculture that has much in common with most agriculture in the Temperate Zones, and the kind served by current social institutions, including agriculture experiment stations. Traditional agriculture, on the other hand, is often based on small, primarily subsistence farms, and often is not served by experiment stations or other social institutions. While modern agriculture is often specialized for production of a few crops to sell, subsistence agriculture is concerned principally with production for the family (even though most small farms produce some crops for sale).

There are about 5 million farm villages in the Tropics. One billion people live on small farms, supported by subsistence agriculture. These farms are often isolated from cities or modern transportation, and the people on such farms must master a wide range of skills to supply their needs. To help alleviate the situation of those who must subsist on small farms, we must design appropriate technology, find the right plants and animals, teach nutrition, foster better eating habits, and reach the farm people with the information and materials they need. This publication describes useful techniques and choice plant materials for the tropical subsistence farm. The information was gleaned from many sources; some was developed experimentally for the Tropics.

Although both small-scale and large-scale agriculture require an intimate knowledge of principles and techniques, small-scale agriculture is probably more complicated because on small farms many different kinds of crops and animals are produced together. And although so many ecological niches occur in the Tropics that one set of instructions cannot cover all circumstances, there are general techniques that are useful on any small farm; information on tools and equipment, site selection and preparation, climate, soils, planting, postplanting care, protection from pests, harvest, storage, nutrition, and crop selection.

No two subsistence farms are [illegible]ly alike. By preference or because of soil [illegible]te limitations, different crops will be grown and different animals will be raised. Nevertheless, the principles that make a subsistence farm a success will be the same. These principles must be inculcated in planning more than just the food production system. Other plans that cannot be neglected if the small farm is to be completely successful are plans for: (1) water and fuel systems, (2) house and farm structures, (3) fencing, (4) dividing the farm into areas for different purposes, (5) facilities for processing and storage, (6) preparing meals, and (7) maintaining soil fertility.

Planning must also include the location of buildings, roads, and water and sanitary facilities. Arrangement must be planned in advance; making changes once farming has begun can be costly (in labor, time, and perhaps in cash). Planning should include safe storage facilities. In some parts of the Tropics plans should include a refuge in case of hurricanes.

One of the best plans for getting the most from a small piece of land was developed by the Samaka Service Center (1962). The plan (fig. 1) is for a small plot, 20 by 30 meters (about one-seventh acre), and allows for a house, pigshed, large-animal shed, chicken coop, toilet, fishpond, and fruits and vegetables of many kinds.

The ideal site for planting crops would: (1) have a flat or gently sloping surface (steep slopes are desirable only if bench terraced); (2) have well-drained, loamy soil, high in organic material and plant nutrients; (3) be protected from winds by buildings, windbreaks, or neighboring hills; (4) not be located where crops will be in the shade of

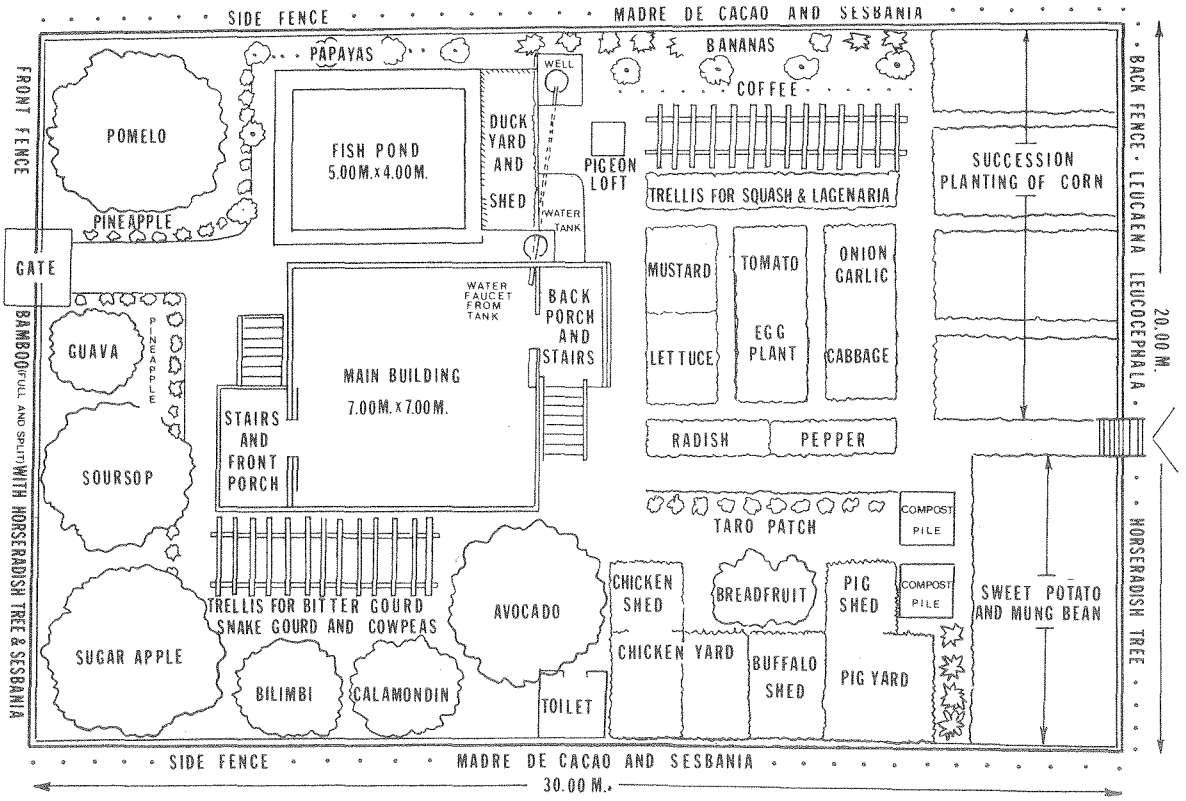

FIGURE 1.—Plan for a subsistence farm in the Philippines (Samaka Service Center 1962).

roofs, trees, or hedges or where crops will have to compete with trees or hedges for water and nutrients; (5) be near the home and not readily accessible to thieves (during very hard times, protection from thievery might be the most important consideration and where feasible, screening plantings with hedges or planting in fields hidden in forest are suggested); (6) be near a source of unpolluted water for irrigation; (7) be near the market (if any products are to be sold); and (8) be protected from animals (Winters and Miskimen 1967).

Planning food production begins with the choice of foods to be produced. This choice should be made on the basis of the nutritional value of the foods, knowledge of what can be grown and then personal preference. Knowledge of how to produce the foods selected should be acquired before large-scale plantings are attempted. If the knowledge is not available from neighbors or farm extension agents, it can be acquired by observing small-scale, experimental plantings. The importance of this knowledge should not be underestimated; it is a far more complex task to produce many crops to feed a family than one crop to sell.

Once the choice of foods is made, the amount to produce must be estimated. This decision is complicated by differences among families in amounts they can use, and because yields vary with season and from year to year. It is usually better to produce much more of each crop than is needed so that the failure of one crop does not lead to a shortage in the family diet. The family should be well fed before the products of the farm are sold for cash, but when surpluses occur, they can be sold, traded, or fed to animals. Some rough suggestions about amounts to plant on the small farm are given in table 1. Of course these amounts will vary widely among individual farms. Only several years of experience can teach the small farmer how much to plant.

The number of animals should be enough to supply all requirements for meat and eggs, and minimum requirements for milk. Again, careful observation and practice will teach the farmer how much is required. (For more information on animals, see "Afterword.")

Table 1.—Appropriate amounts of various crops for the subsistence farm[1]

Crop	Amount of land	Notes
Leafy vegetables	25 m^2	Produce year round.
Vegetable legumes	50 m^2	Produce year round.
Grain legumes	0.5-1.0 ha	Plant several; produce during best season.
Roots and tubers	0.5 ha	Produce during best season.
Fruit vegetables	50 m^2	Produce year round.
Cereals	0.5-1.5 ha	Produce during best season.
Pasture for goats	0.5 ha	Divide in subplots and rotate use.
Pasture for small animals (chickens, ducks).	250 m^2	Maintain animals in movable cages.

[1] The amount of food produced by this scheme should be enough for a family of 6.

The farm should be planned so that a steady stream of produce is available year round and the choice of crops should be made on the basis of their nutritional value. Work should be invested mainly in those crops that best sustain the body. But in order to plan the small tropical farm to produce the maximum amount of nutritious food, the effects of such climatic factors as rainfall, temperature, and day length will have to be taken into account.

In the Tropics, as in many parts of the Temperate Zone, heavy reliance is placed on timely rainfalls. When rain is insufficient, supplemental water must be supplied, and plans for irrigation (water source and means of delivery) should be made before problems arise. In the Tropics, excess water is more often the problem. Frequent rainfalls leach the nutrients from the soil, create conditions that make fieldwork difficult, restrict plant growth (by reducing the supply of oxygen to the roots) and stimulate development of plant diseases. Some crops are rain resistant, and others even prefer rain, but many (such as tomatoes) are very difficult to produce during tropical rainy seasons.

Temperature can limit the growth of some crops. Many Temperate Zone vegetables are cool-season crops and do not thrive in the hot temperatures of the Tropics (except for varieties that have been developed to withstand heat). Some cool-season crops, such as cabbage and its relatives, can be grown in the Tropics during the cooler months, or at elevations where temperatures are lower.

Day length also profoundly influences tropical plant growth; it is the most important factor in determining when some species of plants flower. Tropical sorghums, for example, are planted in the spring and reach great heights before they flower in late fall. If the same varieties are planted in the fall, they will flower while still relatively small. To obtain maximum yields, one must know what effect day length will have on the crops to be planted.

The rainfall, temperature, and day-length preferences of typical tropical crops, as well as suggested planting dates, are given in table 2. (Spring refers to the time when day lengths are increasing rapidly, summer when days are longest, fall when day lengths are decreasing, and winter when days are shortest.) Of course, most species are highly variable, and there are varieties of Temperate Zone species that have been bred and adapted to the Tropics. Table 2 should be considered a preliminary outline. Only by actually trying a crop can a farmer tell how it will do for him.

TOOLS AND EQUIPMENT

A certain minimum number of tools must necessarily be purchased (fig. 2). Good tools, cared for well, can last for a generation, but good quality tools may be difficult to find.

First, a machete is required for clearing land. In the Tropics a machete is more useful than a scythe (which serves best for succulent materials) or an axe (which serves best for wood). To sharpen the machete, a grindstone is desirable and a file essential. A good complement to the machete is a crosscutting saw (the kind whose blade can be sharpened by filing). Axes and hatchets are also useful.

Tools for working the soil, the hoe, the spade, and the turning fork, are necessary even though in many areas the soil should be turned as little as possible to avoid erosion. Of course there are

Table 2.—Optimum growing conditions for tropical crops

Name	Rainfall preference[1]	Temperature preference[2]	Seasonal preference	Length of season (months)	Planting time
Vegetables:					
Amaranth	Moderate	Warm	Long	1-2	Variable.
Beet[3]	Moderate	Cool	Indifferent	2-3	Fall.
Bell pepper	Moderate	Warm	Indifferent	2-4	Year round.
Bitter gourd	Indifferent	Warm	Indifferent	2-4	Spring.
Broad bean[3]	Low	Cool	Short	4	Fall.
Broccoli[3]	Moderate	Cool	Indifferent	2	Fall.
Brussels sprouts[4]	Moderate	Cool	Indifferent	3-4	Fall
Cabbage[4]	Moderate	Cool	Indifferent	2-4	Fall, spring.
Celosia	Moderate	Warm	Long	1-2	Variable.
Chayote	Moderate	Warm	Indifferent	6-12	Year round.
Chinese cabbage	Moderate	Cool	Indifferent	2-3	Fall, spring.
Common bean	Low	Warm	Indifferent	2-3	Spring.
Cowpea	Low	Warm	Indifferent	2-10	Year round.
Eggplant	Moderate	Warm	Indifferent	2½-5	Year round.
Head lettuce	Low	Cool	Indifferent	2-3	Variable.
Hyacinth bean	Moderate	Warm	Short	2-8	Fall.
Kangkong	High	Warm	Long	2-4	Spring.
Kale[4]	Moderate	Cool	Indifferent	2-3	Fall.
Leaf lettuce[4]	Moderate	Cool	Indifferent	2-3	Year round.
Lima bean	Moderate	Warm	Indifferent	2-3	Spring.
Luffa	Indifferent	Warm	Indifferent	3-12	Year round.
Okra	Moderate	Warm	Long	3-4	Spring, summer.
Onion	Moderate	Hot or warm	Indifferent	3-4	Suitable varieties year round.
Pea[3]	Moderate	Cool	Indifferent	2-2½	Fall.
Pumpkin	Moderate	Warm	Indifferent	4-6	Spring.
Roselle	Moderate	Warm	Long	5-6	Spring.
Scarlet runner bean[3]	Moderate	Warm	Indifferent	2-3	Spring.
Soybean	Moderate	Warm	Long	3-4	Spring.
Spinach[3]	Moderate	Cool	Indifferent	1½-2	Fall.
Summer squash	Low	Warm	Indifferent	2-3	Spring.
Sweet corn	Indifferent	Hot or warm	Indifferent	3-4	Suitable varieties year round.
Tomato	Low	Warm	Indifferent	2½-4	Year round.
Tropical squash	Indifferent	Warm	Indifferent	4-12	Year round.
Wax gourd	Moderate	Warm	Indifferent	4-12	Year round.
Winter squash	Moderate	Warm	Indifferent	3-5	Spring.
Xanthosoma spinach	High	Warm	Long	2-12	Spring.
Yardlong bean	Low	Warm	Indifferent	3-10	Year round.
Oil crops and pulses:					
Common bean	Moderate	Warm	Indifferent	2-3	Year round.
Cowpea	Low	Warm	Indifferent	3-6	Year round.
Peanut	Moderate	Warm	Indifferent	3-6	Year round.
Safflower	Low	Warm	Long	4-6	Spring.
Sesame	Low	Warm	Long	3-5	Spring.
Sunflower	Moderate	Warm	Long	3-5	Spring.
Roots and tubers:					
African yam	Moderate	Hot	Long	7-9	Winter.
Arrowroot	High	Hot	Indifferent	8-10	Spring.
Air yam	High	Hot	Long	8-10	Spring.
Canna	High	Hot	Indifferent	8-10	Spring.
Carrot[3]	Moderate	Moderate	Indifferent	2-3	Year round.
Cassava	Low	Hot	Indifferent	10-12	Year round.
Cluster yam	High	Hot	Long	11	Spring.
Dryland taro	High	Hot	Indifferent	10	Year round.

See footnotes at end of table.

Table 2.—Optimum growing conditions for tropical crops—Continued

Name	Rainfall preference[1]	Temperature preference[2]	Seasonal preference	Length of season (months)	Planting time
Roots and tubers—Continued					
Parsnip[3]	Moderate	Low	Short	3-4	Summer.
Potato	Low	Variable	Moderate	3-4	Spring.
Sweetpotato	Moderate	Hot	Long	3-6	Year round.
Tannier	High	Hot	Long	10	Spring.
Turnip[3]	Moderate	Cool	Indifferent	1½-3	Spring.
Water yam	High	Hot	Long	9-10	Spring.
Wetland taro	High	Hot	Indifferent	10	Year round.
Cereals:					
Barley[3]	Low	Warm	Long	3-5	Spring.
Corn[4]	Moderate	Warm	Long	3-4	Year round.
Oats[3]	Low	Warm	Long	3-5	Spring.
Pearlmillet	Low	Warm	Long	3-5	Spring.
Rice	Variable	Variable	Indifferent	3-4	Year round.
Sorghum[4]	Moderate	Warm	Long	3-5	Year round.

[1] Actual rainfall may vary. Farmers can judge if their areas are relatively dry, relatively wet, or average.
[2] Cool, 15°-20°; warm, 20°-25°; hot, 25°-30° C.
[3] Not recommended in the Tropics except at high elevations.
[4] Exceptional warm-season varieties exist.

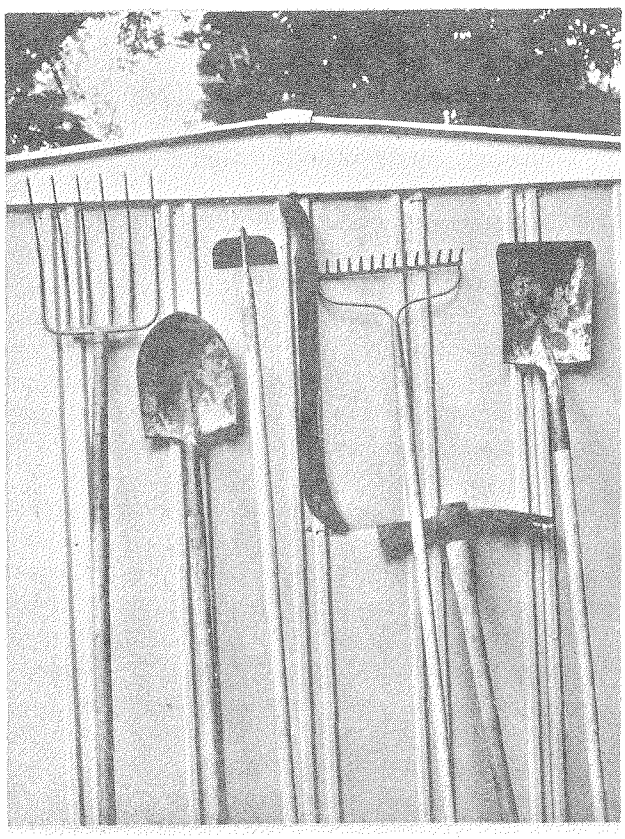

FIGURE 2.—Necessary tools for subsistence farming.

practical reasons to turn the soil: to break up hard soil layers and permit the ready entrance of air and water, to kill some weeds and permanently bury the seeds of others, and to facilitate planting and root development.

There is a new high-efficiency fork designed by the Brace Institute that opens the soil without necessarily turning it.[1] Long-handled tools are more useful than short-handled ones. Extra wooden handles should be kept available unless local woods can be substituted.

Small spray tanks are very handy for spraying commercial pesticides (when available) or homemade alternatives (see "Insect and Disease Control"). Spare parts for all tools and equipment should be kept for repairs. For the harvest, buckets, baskets, or boxes should be kept on hand.

SOILS AND FERTILITY

All agriculture depends on soil (even animal husbandry depends on the soil for feed). But soil is

[1] For more information about this tool, contact Brace Institute, MacDonald College, McGill University, St. Anne de Bellevue, Quebec, Canada.

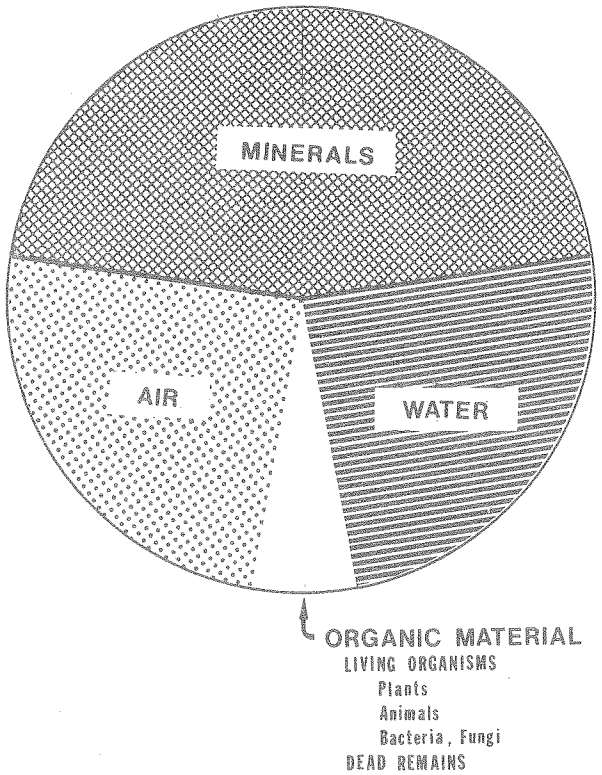

FIGURE 3.—Composition of a typical soil.

not a single, easily defined entity. It is a complex mixture of mineral and organic material, gases, water, and living organisms (fig. 3). Because the soil is so complex, it occurs as thousands of variations with different physical and chemical properties, each different in its suitability for plant growth.

Some of the fundamental differences that occur among soils are mineral content, amount of organic material, water-holding capacity, acidity (hydrogen ion content or pH), texture (relative amounts of different size particles), structure (the grouping of particles), porosity (space for air and water), and base exchange capacity (the ability of the soil to hold mineral nutrients for plant use).

The kind of soil found in any region depends on the geological history of the region. The composition of the original rock, climate (especially rainfall), and the kind of plants that inhabit the area determine soil type. In wet tropical cimates, soil weathering usually follows this sequence: water progressively removes the bases (alkaline salts of sodium, potassium, and calcium), then silica, and finally the sesquioxides (complex iron and aluminum compounds). The end state of tropical soils is often red laterite, an acid soil of low fertility that consists mainly of sesquioxides.

As a rule, tropical soils benefit from the addition of lime (calcium), which can be added as ground limestone or in several other forms (ground bones, shells, and corals). Lime aids clay soils by sticking the individual particles together, improving drainage and aeration. It also reduces soil acidity, which makes it easier for most plants to obtain nutrients. Tropical soils might also benefit from burning off excess woody materials and crop residues, which sterilizes the soil surface, kills weed seeds, and leaves mineral elements on the surface of the soil. Adding mineral fertilizers also helps, but these are often unavailable or too costly.

The best way to maintain soil fertility on tropical subsistence farms is to add organic material (humus) to the soil. Cultivation diminishes soil organic matter; when cropping is continual, maintaining organic matter is difficult and restoring it to levels found in virgin soils is not economically feasible. Adding humus increases the soil's capacity to hold plant nutrients and furnishes the soil with mineral nutrients over long periods. Since organic material is used up rapidly in the Tropics, it should usually be added at least once a year.

There are many sources of organic material; plant waste materials (leaves, small stems, and processing waste) are all usually good, and animal manure is even richer. In the Orient, human manure is also used. All organic materials should be partially rotted first, which is usually done by composting.

Composting converts unwanted plant and animal materials to useful fertilizer. It is accomplished by building a pile of waste materials (plant wastes, manure, bones, dead animals, weeds) with alternate layers of soil. Fermentation of the waste material heats the pile to temperatures that kill seeds and disease organisms, and reduce the organic material to usable forms.

The pile must be aerated in order to complete fermentation. This can be achieved by turning the pile often, but this is a laborious, time-consuming task. Aeration can also be effected by placing several poles in the pile as it is being built up, and removing them when the pile is completed, leaving air passages into the center of the pile.

Even when this technique is used, the pile will have to be turned at least once. (The material on the outside, which would otherwise not ferment, should be placed on the inside of the new pile, and vice versa.) When the heat subsides, compost is ready for use. Composted soil or manure should be generously incorporated into the soil or placed around the roots of the plants.

In a small garden where there is no room for a compost pile, post-hole composting can be substituted. Individual holes are dug large enough for a week's supply of household garbage and filled with garbage and soil for 1 week, then topped with soil. After 2 to 3 months, plantings can be made directly over the hole.

All leguminous plants are rich in nitrogen and are especially useful in compost. They can also be buried in the soil where their minerals will be released by decomposition. Use of these "green manures" will become increasingly attractive as the cost of mineral fertilizers increases.

Plants require mineral nutrients. To be most effective, the small farmer should know something about plant mineral requirements and how they are met.

The most important plant nutrient is nitrogen, which is necessary for the formation of plant proteins. To be available to plants, nitrogen must occur in a soluble, chemically combined form that can be taken up by plant roots. (The most useful form is the nitrate ion). But there is little nitrogen available in tropical soils. The plants that are already growing on the soil contain the bulk of the nitrogen; if the plant cover is destroyed, subsequent crops are not likely to do well unless nitrogen is added. The primary symptoms of nitrogen deficiency are poor plant growth, lack of vigor, and yellowing of foliage (beginning first on older, lower leaves). Applying nitrogen usually stimulates rapid, succulent growth, and intensifies the plants' green color.

Plants get a small amount of nitrogen from rain, which is very important for plants that do not have roots in the soil, but is of little consequence in farming. For subsistence agriculture, the primary source of nitrogen is decaying plant and animal remains (compost or manure). (It is difficult to get enough organic material for this purpose in large-scale farming.) Compost releases nitrogen slowly, without burning plants (as can occur with commercial fertilizers). The bacteria (*Rhizobium* spp.) in the root nodules of legumes also provide nitrogen; they fix free nitrogen in forms that can be used by other plants. Legumes may fertilize nonleguminous plants when the two are planted together. By plowing a leguminous crop into the soil, the amount of nitrogen provided is increased.

Phosphorus is an essential, limiting element in tropical soils as often as nitrogen. It is important in stimulating root development (especially of young seedlings) and is necessary for fruit and seed development. And although it is common enough in the soil (in various chemical compounds), most of it occurs as insoluble compounds, unavailable for plant use. Manure, compost, and cover crops do not add enough phosphorus to the soil to establish and maintain fertility. Furthermore, when soluble phosphorus compounds are added to the soil, they tend to change to insoluble forms, and loss of phosphorus through combining with other elements is speeded up by the heavy rains common to much of the Tropics.

Phosphorus deficiency is common, but its symptoms vary with species, including leaves darker green than normal, small plants, purple-tinged stems or foliage, and retarded flowering and fruiting. Symptoms of both nitrogen and phosphorus deficiency are not ordinarily found together. Phosphorus is only available from a few sources. Commercial phosphorus fertilizers contain large amounts of soluble phosphate, which in granular fertilizers, is released gradually into the soil. Rock phosphates occur in a few areas, which when pulverized, make a good long-term fertilizer. Bonemeal is also a useful additive, even though much of its phosphorus is in an insoluble form. Marine organic materials (seaweeds, fish) are other good sources. There does not seem to be an easy solution to the problem of providing phosphorus to the soil on a subsistence scheme, but a soil with adequate humus and good aeration slowly releases soluble phosphates from the insoluble forms.

The potassium content of tropical soils varies considerably; it is constantly being leached from the soil, but at the same time it is being released to the soil from insoluble reserves. Nonetheless, potassium is seldom abundant, and laterite soils are always deficient. Symptoms of potassium deficiency include browning of leaf tips, crinkling of leaf margins, and premature leaf drop. Wood ashes are a good potassium source that can be applied directly to the soil.

There are several other minerals, the lack of which will seriously limit plant growth, including magnesium, sulfur, iron, manganese, zinc, copper, boron, and molybdenum, but on the subsistence farm, it would be impossible to tell which of these minerals are lacking.

Another important part of soil management is providing drainage or some other means for excess water to run off without risking soil loss from erosion. Some of the techniques used for these purposes are nontillage agriculture, plowing along the contour of the land, constructing drainage ditches, planting in strips and leaving the soil between strips untouched, planting windbreaks, and digging small holes to catch and hold runoff water. Planting on steep hillsides without erosion control is a common mistake often seen in the Tropics. There are large areas in Africa and South and Central America where obvious, irreparable damage has already been done by thoughtless agricultural practices.

In almost all parts of the Tropics there is considerable information already available about local soils, their characteristics, which crops they support, and the preferred methods of retaining soil fertility. One of the best ways to insure the success of small-scale farming is to learn as much as possible of what is already known about farming in one's area, from farmers and literature.

PLANTING AND POSTPLANTING CARE

Plants may be started in containers of soil or may be planted directly in the ground. When containers are used, the soil should be sterilized (heating in an oven will do). The plants that have tender seedlings that are slow to get out of the tender stage (tomato, eggplant, pepper, onion, cabbage and its relatives, lettuce, and most fruit trees) should be started in containers and transplanted.

Seeds may be planted directly in the soil when conditions are appropriate; when the seedbed soil is loose and finely pulverized, water is available, the soil is able to accept water without excessive runoff or subsequent cracking, and temperatures are appropriate (in general, the seeds of cool-season crops require cool temperatures to germinate and vice versa).

In places where excessive flooding is likely to be a problem, the soil should first be formed into beds. Conversely, it is not unusual to plant in holes in desert areas. As soon as seeds are put in the soil or seedlings are transplanted, they should be watered.

Seeds are planted at a depth 2 to 3 times their diameter. With fine seeds it is easiest to plant thickly and remove unwanted plants later. There are specified planting distances for each crop, but these will probably be modified once local experience is gained. Plants should have enough room to reach their mature size, and no more. Since plant sizes will vary with the season, planting distances should vary according to when the crop is planted.

Everywhere, but especially in the Tropics, small plantings need constant care. Even in areas where rains occur regularly, plantings may need to be watered. Weeds, insects, and diseases are continual problems, and at a low level of technology, with mixed plantings, failures of one crop or another are very common. Ideally, one should keep a log to remember dates and treatments and avoid repeating errors.

As soon as the crop seeds germinate, weeds follow. Weeds must be controlled; if they are not, their competitive effects will be so great that the crop plants will produce little. Within the row, weeds can be removed by hand when plants are thinned, and between rows the first weeds can be removed by hoeing. There are also practices that may substitute for turning the soil. Mulching, for example, can control weeds and maintain conditions of soil moisture and penetrability suitable for seed germination and plant growth. Enough mulch is placed on the soil to cover the ground completely and impede weed growth. Mulch can consist of decaying plant materials, leaves, grass clippings, shredded newspaper, sawdust, wood shavings, or any available materials that let water through and impede weed growth and moisture loss. Dark plastic cloth placed on the soil will kill weeds and encourage their decomposition. It must be kept in mind, however, that heavy mulching increases the plant's need for nitrogen. Keeping geese may merit a trial as a control for weedy grasses; they require little special care, and will remove grasses from a planting of broad-leaved crops, converting something of no value to meat. Of course, broad-leaved weeds would have to be controlled some other way.

INSECT AND DISEASE CONTROL

Inevitably, insects and diseases will attack the crops. Success in food production often depends on how early, how frequent, and how severe insect or disease attacks are. But commercial pesticides are unsatisfactory for the subsistence farm for a number of reasons. They are often expensive, they may kill beneficial insects and contaminate other plants, they must be stored carefully to avoid accidental poisoning, and once applied, may contribute to short- or long-term poisoning of people or animals.

Although there is no easy solution to pest and disease problems, there are steps that can be taken to reduce pest and disease problems.

Removing old living and dead material from the planting site and removing weeds and trash from the surrounding area eliminate places that insects and other pests can hide. Plant materials that seem to be free of insects and disease can be composted, but infected plant materials should be burned.

Soil cultivation is also helpful in controlling pests. When soil is turned, insect eggs and pupae are often destroyed, as are nematodes that are exposed to the sun and air. Whenever possible, preplanting cultivation should be repeated just before planting.

Seeds to be planted should be fresh and free of visible insects or disease. Loss of large seeds to rats (which dig and eat them) can be reduced by soaking the seeds in water overnight and planting them the next morning. Newly emerged seedlings can be protected at night by placing cans or bottles over the plants. If birds are a problem during the day, plants can be covered with an open-ended can or perhaps a screen. When seedlings are established in containers before planting, the soil in the containers should be sterilized in an oven.

Mulches placed on the soil may provide hiding places for insect pests. Mulches should be inspected occasionally, especially if damage from cutting insects is observed. Mulches that reflect light (aluminum foil and some plastics) confuse aphids and reduce their attacks. Orange plastic mulch discourages insects in general.

Rotation of plantings also helps control insects. Planting the same crop time after time on the same site affords pests and disease organisms an opportunity to multiply; rotation reduces the probability of such buildups. Crops should never be planted more than once on the same site without an intervening crop. Also, on any one site, avoid planting crops from the same family as the preceding crop.

Perhaps the most effective solution to insect and disease problems is to plant resistant varieties. Insect- and disease-resistant varieties are listed in seed catalogs, and others can often be discovered by observing what other people grow successfully on their farms. There are many local, resistant varieties that remain to be tested and introduced.

Insects and other pests can be confused by disrupting the transmission or reception of the stimuli (visual or olfactory) that enable them to find their way to host plants. If they are confused, they will often not become a problem. The placement of plants themselves can afford some protection by confusing the pests. When two plants of different types are placed side by side the odor and appearance of one will tend to distract from the odor and appearance of another. Conversely, when large numbers of plants of the same type are planted together, their combined odor and appearance readily attract pests of that crop. Therefore, dispersing plantings of crops, or mixing them with other crops will help reduce insect infestation.

In addition to this passive protection, some plants (usually because they have a strong odor) actively repel many kinds of insects (table 3). The French marigold (*Tagetes* spp.) is one of the most useful insect-repelling species, and garlic and onions are also effective. In the garden, rows of bunching onions or individual plants can be interspersed with insect-sensitive vegetables, and many kitchen herbs can be planted around or within the garden with the same effect (basil, mints, and *Lippia* spp., the tropical "oreganos"). Peppermint is said to also repel rats. Harmless or beneficial organisms can be used to control harmful insects and pests, a process called biological control. Biological controls employ natural processes in the service of the farmer. They are often inexpensive and are certainly preferable to chemical controls. One of the simplest biological controls in the tropical garden is the presence of lizards and toads. The lizards are active during the day, and the toads at night. They can be encouraged by providing them with places to hide (cracks and crevices for the lizards and damp places under stones or boards where

Table 3.—Some pests known to be repelled by plants

Pest	Species or group	Plant
Ants	Family Formicidae	Mint.
Aphids	Family Aphididae	Garlic, mint, nasturtium.
Cabbage butterfly	Family Pieridae	Strong herbs, mint.
Colorado potato beetle	*Leptinotarsa decemlineata* (Say)	Bean, eggplant.
Corn earworm	*Heliothis zea* (Boddie)	Marigold.
Cucumber beetle	Family Chrysomelidae	Radish.
Flea beetles	Family Chrysomelidae	Mint, tomatoes, strong herbs.
Leaf miners	Principally family Agromizidae, also family Nepticulidae.	Strong herbs.
Mexican bean beetle	*Epilachna varivestis* Mulsant	Nasturtium.
Nematodes	Many families	Marigold.
Squash bug	*Anasta tristis* (De Geer)	Nasturtium.
Squash vine borer	*Melittia satyriniformis* (Hübner)	Strong herbs.
Weevils	Family Curculionidae	Garlic.
Whiteflies	Family Aleyrodidae	Nasturtium.

toads can hide during the day). A few concrete blocks laid on their side in the center of the garden can provide shelter, and if lizards and toads are available, they can be caught and released in the garden. Care must be taken so that those lizards that eat seedlings and vegetable flowers are not introduced.

The bacterium *Bacillus thuringiensis* is effective against the larvae of many kinds of moths and butterflies, and is available commercially as a powder to be used as a dust or spray. Where caterpillars are a particular problem, living and dead ones can be ground with water and sprayed on affected plants. (Apparently bacteria or fungi always present in the caterpillars multiply enough to kill previously healthy caterpillars.) Insects ground in water, filtered, and used as a spray will often repel insects of the same species.

Lady beetles are useful in controlling aphids and other soft-bodied insects and may even be bought. Many other insects commonly found in the garden help control pests biologically and should not be destroyed, such as dragonflies, damsel flies, aphis lions, doodlebugs, mantids, and walkingsticks. Spiders are also useful (most are not harmful) as are several types of wasps.

Although removing individual insects by hand is seldom feasible, they may be dislodged from the plants by simply spraying the plants with water. A strong spray will wash away aphids and small worms, which once on the ground, may have a difficult time finding their way back to the plant and may succumb to exposure or predators.

Pests can also be removed by trapping. Slugs and snails can be trapped under planks left on the ground; the slugs and snails hide under them and can easily be collected by lifting the boards and scraping the pests off (after which they can be fed to the chickens or otherwise destroyed.) Squash bugs also hide under such boards, and can be smashed each morning. Insects can be lured to a light and drowned in kerosene or water with detergent. The light (preferably blue) is suspended over a container, and the insects that are attracted to it fall into the liquid below. Cans or jars with funnel-like entrances that are easy for insects to enter but difficult to leave, may be baited with a number of different compounds: rotted fruits for flies, stale beer for cockroaches, linseed oil for melon flies, and sugary water for some fruit flies.

There are also several good sprays that are inexpensive, efficient, and that do not leave poisonous residues. Flour dusted on the surface of wet leaves by shaking a cloth bag of flour over them becomes a sticky mess that is effective against many kinds of caterpillars. As the flour dries the insects are impeded or killed. Fine sifted clay suspended in water and sprayed to the underside of leaves also traps or hinders insects.

Some emulsions made from materials available on the farm are very effective. The foliage of strong-smelling plants (hot pepper, onions, marigolds, tobacco, garlic, aromatic herbs, and foul-smelling plants in general) can be ground with water, filtered, and sprayed on crops. Any insect-free weeds could be tested as homemade sprays.

Table 4.—Human nutritional needs

Nutrient	Source
Protein	Plant, animal.
Carbohydrate	Plant, animal.
Saturated fats	Plant, animal.
Unsaturated fats	Plant.
Fat-soluble vitamins:	
Vitamin A	Plant, animal.
Vitamin D	Nonliving
Vitamin E	Plant.
Vitamin K	Plant.
Water-soluble vitamins:	
Vitamin B_1	Plant, animal.
Vitamin B_2	Plant, animal.
Vitamin B_3	Plant, animal.
Vitamin B_6	Plant, animal.
Vitamin B_{12}	Animal.
Other B vitamins	Plant, animal.
Major minerals:	
Calcium	Plant, animal.
Phosphorus	Plant, animal.
Magnesium	Plant, animal.
Sodium	Plant, animal.
Potassium	Plant, animal.
Iron	Plant, animal.
Sulfur	Plant, animal.
Minor minerals:	
Zinc	Plant, animal.
Iodine	Nonliving.
Fluorine	Nonliving.
Copper	Plant, animal.
Chromium	Plant, animal.
Cobalt	Animal.
Manganese	Plant.
Molybdenum	Plant.

HARVEST

Exposure to sun damages many fruits and vegetables. As soon after harvest as possible, produce should be removed from the sun and chilled (if feasible or necessary). If the crop is seeds, on the other hand, they may need several days of drying in a hot, sheltered place before being stored. During harvest, care should be taken to avoid damage. Scrapes, scratches, and bruises allow entrance of bacteria and fungi, which reduces storage life. Since some harvest damage always occues, it is a good rule after harvest to eat damaged produce first, or process it into a long-lasting form.

Of course, what is considered the "normal" edible crop is not necessarily all that can be harvested. Most vegetables have parts that can be eaten that are not usually considered (such as the tender leaves and growing tips). Pods that are not harvested for use green can be harvested dry later. Individual leaves and flowers may still be harvested from lettuce and other greens, even after the plant has begun to flower.

Harvest can also be extended by beginning earlier. In the case of some vegetables, immature forms can be used while waiting for the bulk of the crop to mature. Harvesting itself makes it possible for some plants to produce a second crop (when beans and okra, for example, are allowed to ripen on the plant, new growth usually ceases). Subsistence farmers should avoid planting varieties that are purposely bred to produce only one crop. Older varieties in the Tropics often seem to grow indefinitely unless pests or diseases intervene. Because of the energy it takes to replant, it will often be best to let a planting grow a little longer than usual before discarding it.

NUTRITION

In subsistence-farm planning one goal should dominate: meeting the nutritional needs of the family. It is impossible to achieve other goals if nutrition is inadequate. It is not enough that some people in the family or community know what good nutrition is. This knowledge is at least as important as reading and writing. Families, schools, and churches ought to teach the facts of nutrition so that each person knows his needs. For people to realize their fullest potential, they must know about and be able to control their own nutritional resources.

Substances considered essential to the human diet are listed in table 4. Forty or more substances may be necessary. Furthermore, all of the nutrients are necessary every day, although some few can be stored in varying quantities. The amounts of nutrients needed vary from a few micrograms (vitamin B_{12}) to hundreds of grams (energy foods). The nutritional problem is getting all of these nutrients in sufficient quantities each day. Some nutritionists believe that for best health people should eat needed nutrients in the appropriate porportions at each meal; but this is difficult to accomplish.

Fats and carbohydrates supply energy (calories) to the diet. Fats are made up of fatty acids, which can be saturated or unsaturated (which refers to the capacity of the molecules' carbon atoms to combine with other elements).

Table 5.—Amount of food needed daily from four basic food groups

Food group	Representative foods	Amount per serving	Servings per day
Meats and legumes	All meats, poultry, fish, all leguminous seeds.	50-75 g meat, 100-125 g legumes	2-3
High vitamin vegetables and fruits.	Yellow fruits and vegetables, green leaves	125 g	4-5
Milk group	Milk, yogurt, cheese, ice cream, soymilk, tofu.	200 g milk or equivalent	2-4
Bread and cereal group	Whole grain breads and cereals, rice, and paste products.	30 g cereal, 1 slice of bread	4-5

Saturated fatty acids are often classified with carbohydrates, since both are energy sources; unsaturated fatty acids are listed separately, since they act as building materials in the body and have a variety of roles in the body's synthesis of other compounds.

Proteins also act as body-building materials but getting an adequate supply of proteins means more than just getting enough. Proteins are not equal in nutritional value, since they contain varying amounts of amino acids (the building blocks of protein). Of the amino acids, eight are essential to the diet and each must be obtained for the protein ingested to be used by the body. If a protein does not contain enough of some amino acids, parts of the protein will be used for fuel rather than to synthesize new protein. Cereal grain proteins are short of the amino acid lysine. Proteins from legumes and most other plants are short of methionine and cystine. When cereal grains are eaten with grain legumes the proten of the mixture is closer to what the body needs than the protein of either alone. Combining different proteins in the diet (protein complementation) is very important, especially when the amount of protein in the diet is low.

Nutritional elements needed on a smaller scale are vitamins and minerals. Vitamins are compounds needed in small amounts for widely varying but important physiological processes. Some are soluble in water and others in fat.

Minerals are categorized as major or minor, depending on the relative amounts needed by the body. Their function, like that of vitamins, varies widely. Calcium, for example, is needed to build bones, and iron for blood. Minor minerals, often have positions in enzyme systems, and while the amounts needed are small, the need itself is important and cannot be avoided.

The nutritional needs of all individuals are remarkably alike. What differences are found are mainly associated with the age and physical status of the person. Some groups, for example, are more vulnerable to nutritional deficiency than others (babies and small children, pregnant women, the aged). Also, individuals differ somewhat in their ability to use nutrients, even when they are available in the diet. Despite these minor differences, the basic nutritional needs are common to all, and good nutrition begins with planning for these basic needs.

There are systems to aid in planning an adequate diet. For instance, since certain kinds of nutrients tend to occur together, and certain classes of foods tend to supply the same nutrients, one way to balance the diet is to use foods from four basic food groups daily (table 5). Although this system is a simplification of complex facts, it is useful in diet planning. Many common foods are not found in table 5. Coffee and tea, for example, might be agreeable in the diet, but are not essential. And although many foods that supply chiefly carbohydrates (energy) are not included (because carbohydrate requirements usually will be filled when the diet is otherwise balanced), a person who works hard physically will need large amounts of such high-caloric food.

Some nutrients do not necessarily occur in foods, and may require special effort to be included in the diet. Vitamin D, for example, occurs only in some seafoods. But healthy persons who do not bathe too frequently and who are exposed to the sun obtain enough vitamin D from secreted substances that are converted to vitamin D and reabsorbed through the skin.

A lack of certain minerals, such as iodine, in some soils is a difficult problem to solve on the small-scale farm (except in the primitive areas where sea salt containing trace elements is carried to the interior for trading purposes). When

available, iodized salt can be purchased to fill the need for iodine.

Foods produced on the subsistence farm are, of course, the critical elements in balancing the diet of small-farm families. But the knowledge and attitudes of the cook are also vitally important. The cook must not only know enough to select the right foods, but must be able to stimulate the family to eat them. Eating preferences are established at a very early age, and it is often difficult to get people to eat better, even when more nutritious foods are available. Those who seek to motivate the subsistence farm family to eat the right foods will have to deal with the knotty problem of food preferences and prejudices.

The biggest nutritional problems in the Tropics are lack of sufficient protein, carbohydrates, vitamin A, vitamin C, calcium, and iron. Deficiencies are compounded by poor dietary habits and ignorance of the principles of good nutrition. The very poorest people do not even get enough carbohydrates. For those who are slightly better off, starchy foods that are easy to produce tend to dominate and compete with other foods that could balance the diet. Edible leaves, almost always present in abundance in the Tropics, could alleviate the vitamin and mineral shortage, but their dietary importance often goes unrecognized. Protein shortage may be the result of either poverty or poor dietary habits, and is corrected by addition of animal foods (meat, milk, eggs) or by combining cereal grain and grain legumes as dietary staples.

Vegetables and Cereals

The vegetable garden should be part of every subsistence farm. The principal nutrients needed to sustain life can be obtained from vegetables. Only one important nutrient, vitamin B_{12}, is not available in vegetables and must be obtained from animal sources. A diet based only on vegetables might be boring to many persons, but the value of vegetables in the diet cannot be denied. They are especially important as sources of vitamin A and C.

But in some places in the Tropics vegetables are little used, or are even disparaged. Since nutrition is the focus of the subsistence farm, small farmers will have to be taught the value of vegetables. They need not take up a large part of the subsistence farm. Even a small plot can produce large amounts of vegetables when they are carefully grown. The plots must be very fertile, and the plants need careful, almost daily attention, but with attention, the vegetable garden can produce all year round.

Vegetables must be grown on a site where it is sunny for most of the day. The best site may be the dooryard, and the best caretaker the housewife. Proximity to the house makes it easier to spend a few minutes several times a day taking care of the most pressing needs in the vegetable garden and helps with the planning (the frequent visits to the garden reveal to the housewife what is running short, what is extra and can be traded or sold, and what problems and obstacles remain to be solved). Furthermore, vegetables can be harvested immediately before use, when they will be at their best.

The best vegetables for the subsistence farm are not necessarily the same varieties or species that are desirable for the commercial farm. Rather they are those that supply needed nutrients, require a minimum of purchases (fertilizer, pesticides, or other soil, site, or plant treatments), produce an edible product over a long period of time (as compared to other varieties of the same species), and produce food in a minimum of space. The storage characteristics of the edible part may also be important. Vegetables should be free of toxic materials and should appeal to the eye and palate.

The vegetable group includes two fundamentally different kinds of foods: the dark-green leafy vegetables, yellow vegetables, and fruits that supply vitamin A (and often vitamin C); and the roots, tubers, bananas, and plantains that mainly supply calories. Leaves are often good sources of protein as well. The yellow vegetables and fruits (including some red fruits) add variety and interest to the diet and in some cases they may substitute for green leaves, but usually they are not as good, not as cheap, and not as easy to produce.

LEAVES

Leaves are a very important class of vegetables that are much neglected despite the fact that there are perhaps thousands of edible tropical leaves, some of which are adaptable to almost all tropical situations (Martin and Ruberté 1979). Leaf vegetables ought to be grown on every subsistence farm and should be eaten at least once a day. Some of the best of the edible tropical leaves are listed in table 6.

The protein content of leaves is surprisingly high; it is comparable (on a dry-weight basis) to that of legumes. Leaves are the best plant source of calcium, and are good sources of iron.

Vitamin A deficiency is common in the Tropics and is the principal cause of irreversible blindness among children, and yet all leaves contain provitamin A (carotene), and some leaves are particularly rich in it. (Dark-green leaves are usually the best sources.) Vitamin A requirements can be fulfilled by including a normal portion of green leaves in the daily diet. In fact, since leaves often contain vitamin C also, a person can fulfill all of his vitamin A and C requirements by eating 100 grams of the right leaves daily.

Table 6.—Some of the best edible leaves of the Tropics

Common name	Species	Uses	Advantages	Disadvantages
Amaranth	*Amaranthus* spp.	Cooked	Very rapid growth, good flavor.	Susceptible to insects, short lived, high oxalic acid content.
Celosia, quail-grass.	*Celosia argentea* L.	Cooked	Easy to grow, high nutritional value.	Somewhat weedy.
Ceylon spinach	*Basella alba* L.	Cooked	Perennial, high yields	Poor production during winter, high oxalic acid content.
Chaya	*Cnidoscolus chayamansa* McVaugh.	Cooked	Perennial, easy to grow, drought resistant.	Contains hydrocyanic acid, has stinging hairs.
Chinese mustard, kaichoy.	*Brassica juncea* (L.) Czern. & Coss.	Raw, cooked	Easy to grow, high in protein and vitamin A.	Soon goes to seed, susceptible to insects in some areas.
Horseradish tree	*Moringa oleifera* Lam.	Usually cooked	Perennial, many plant parts edible, high nutritional value.	Poor growth during rainy season, strong taste.
Indian lettuce	*Lactuca indica* L.	Raw	Resists tropical summers, regrows rapidly, heavy yields.	Flowers early.
Indian mulberry	*Morinda citrifolia* L.	Cooked	Perennial, easy to grow, high nutritional value.	Fruit has a disagreeable odor.
Katuk	*Sauropus androgynus* Merr.	Usually cooked	Perennial, easy to grow, high nutritional value.	Long, spindly branches are easily toppled.
Sunset hibiscus	*Abelmoschus manihot* (L.) Medik.	Cooked	Perennial, high yields, good flavor.	Susceptible to several diseases.
Watercress	*Nasturtium officinale* L.	Cooked	Perennial, high yields, high nutritional value.	Needs much water, has strong flavor.

FIGURE 4.—Mature Chinese mustard (kaichoy) plant, ready for harvest of leaves.

Highly productive and highly nutritious, leaf vegetables are either perennial or annual. The perennials are generally easy to grow and probably yield more per unit area than most food plants. And leaves are always available because they are produced continuously. The annual species often grow quite rapidly and produce for a long time. Once a person becomes accustomed to eating leaves, they become a welcome part of the daily diet.

Some leaves contain toxic substances, perhaps the most common of which is oxalic acid. Leaves that have a high oxalic acid content should not be eaten daily. Oxalic acid interferes with the body's uptake of calcium, and if ingested too often, could lead to chronic calcium deficiency. A few leaves contain glycosides of hycrocyanic acid and must be cooked 10 to 15 minutes before use. Because of toxicity, it is best to vary the selection of leaves used as food. In Java and West Africa, where many different leaves are used as food, they are frequently mixed together.

The amaranths (*Amaranthus* spp.) are short-lived annuals from various parts of the Tropics that are widely used as greens in West Africa and Southeast Asia (Martin and Telek 1979). They are often weedy and are thus depreciated. Under highly fertile conditions these succulent plants grow rapidly. Young plants may be uprooted or older plants may be cut every week or two to yield large amounts of edible highly nutritious greens. One drawback is that amaranths are often plagued with insects. Since amaranths contain considerable amounts of oxalic acid, they should be cooked and their use alternated with that of unrelated greens.

Celosia or quailgrass (*Celosia argentea* L.) is similar to the familiar cockscomb of Temperate Zone summer gardens. The vegetable varieties from Africa are distributed around the world but still little known (Martin and Telek 1979). Celosia is very easy to grow and, in fact, tends to be weedy. The plants are sturdy and insect resistant. They grow more slowly than most leafy vegetables, but require less fertile soil. Celosia will eventually flower and often reseeds itself (the seeds are small, like those of amaranth). Tender shoots can be cut repeatedly from the plants and when cooked make excellent greens.

Ceylon spinach or basella (*Basella alba* L.) is a

perennial, succulent vine from South America now widely used throughout the Tropics as cooked greens. Basella has two forms, one light green and the other dark red. It is one of the easiest leaf vegetables to grow, and yields in abundance. It grows well from either cuttings or seeds, and can be maintained in a bush form by pruning. It is excellent for growing in containers as well as in the garden, but requires fertile soil and plenty of water for maximum growth. Shoot tips and younger leaves are harvested. Like amaranth, basella contains too much oxalic acid. Yet, it is tasty and has a mucilaginous texture similar to that of okra.

Chaya (*Cnidoscolus chayamansa* McVaugh) is a perennial shrub that has been neglected but merits much wider use (Martin and Ruberte 1978b). It is from the Yucatan Peninsula of Mexico, and is only sparsely distributed in other areas. Chaya is propagated by planting large woody branches that root readily, except where drainage is poor. It is tolerant of many soils, and can be grown in both the humid and the dry Tropics. Only one chaya plant is needed per household because the plants are large and vigorous. Branch tips up to 3 centimeters in diameter and their tender leaves are the vegetable. Although chaya contains glycosides of hydrocyanic acid and has stinging foliage hairs, it is edible when cooked, and contributes protein and vitamins to the diet.

Chinese mustard or kaichoy (*Brassica juncea* Czern. & Coss.) is one of the few species of *Brassica* adapted to the hot, humid Tropics (fig. 4). A native of Asia, it is seldom seen in the American Tropics. Kaichoy grows rapidly from seed, and benefits from some shade and cool temperatures in the garden, but can withstand summer heat if well watered. Large older leaves are harvested to provide a continuous supply for up to 6 months. Repeated seeding makes it possible to produce this vegetable year round. Kaichoy is very high in provitamin A and vitamin C, and has a high protein content. It is best cooked, but a small amount of raw leaf added to other salad greens gives a delightful flavor.

The horseradish tree (*Moringa oleifera* Lam.) (fig. 5) could fill many roles in the Tropics. It probably originated in India, where practically all its parts are used. Although it has spread throughout the Tropics, it is still not well utilized in many areas. It is a tree of dry areas, but can be grown in the hot, humid Tropics if established during the rainy season. One problem is that its soft wood is very attractive to termites. The tripinnate leaves have a strong, spicy flavor when eaten raw. Their content of provitamin A, vitamin C, and protein is very high, and probably no other leaf used as a vegetable contains more calcium. The flowers and young pods are also eaten, and the roots are soft and suitable as a strong condiment.

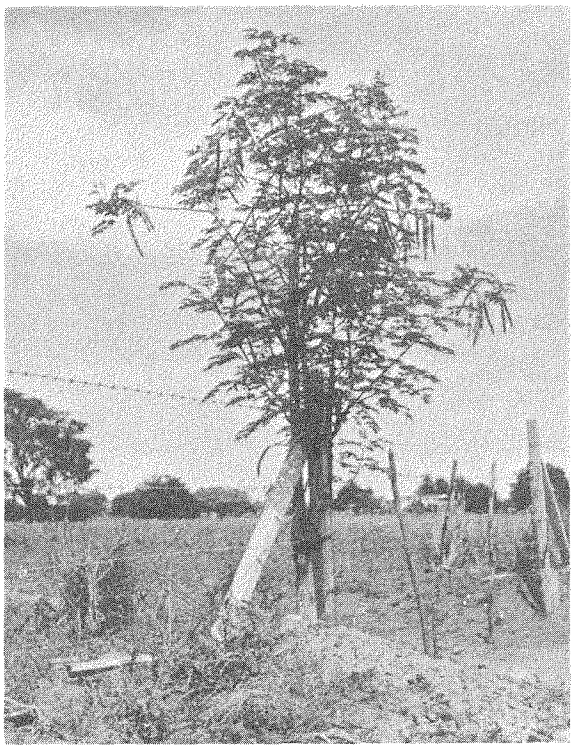

FIGURE 5.—The horseradish tree, an outstanding vegetable with many uses.

Indian lettuce (*Lactuca indica* L.) from Southeast Asia (fig. 6) is considered by some to be the best lettuce for the hot, humid Tropics. Like all lettuces, it requires a fertile soil. Seeds are small, and seedlings require careful attention. The plants grow rapidly and produce large succulent leaves. These may be harvested individually, or the tops may be snapped off of large plants (and will be replaced rapidly by new growth). Once flowering begins, it cannot be suppressed, but leaves may be harvested until they are exhausted. Year-round production is easily achieved by planting every 3 to 4 months. Yields are excellent and the plants can be grown successfully in pots. The lettuce has a somewhat bitter taste, but its flavor and texture are perfect for mixed salads.

The Indian mulberry (*Morinda citrifolia* L.) is

FIGURE 6.—Indian lettuce, an excellent lettuce for the humid Tropics.

a small tree that occurs mostly in dry places (including beaches) that is also resistant to tropical rains. Although this tree is not widely cultivated, it should be easy to grow. Its persistence is illustrated by the fact that after a century or more of neglect, such trees are still found among the ruins of Hawaiian native villages. The easily recognized, large, shiny, ovate leaves are perhaps the richest source of provitamin A in the plant kingdom. The flavor is rather strong but appreciation of it can be learned. The fruit resembles a very large mulberry and is cooked green; it has a disagreeable odor when ripe.

Katuk (*Sauropus androgynus* Merr.) is a

FIGURE 7.—Sunset hibiscus, a productive perennial leafy vegetable.

perennial shrub with long upright stems. It is easily established from cuttings and may be grown as a hedge plant. Frequent pruning is necessary or the plant will produce too many tall branches that are easily toppled, making management difficult. Leaves and flowers are produced on horizontal branches that resemble compound leaves. The highly nutritious, dark-green leaves are stripped from the branches for cooking. The raw shoot tips have a strong but interesting flavor that goes well in salads.

Sunset hibiscus [*Abelmoschus manihot* (L.) Medik.] is little known in the Western Hemisphere but is a very popular leafy vegetable in the islands of the South Pacific. It is a perennial shrub with large palmately lobed leaves on long petioles (fig. 7). It is vigorous, and a few plants will produce more than a family can eat. In some locations it grows for years with a minimum of care, but in other areas it suffers from a stem rot. The leaf blades are succulent, and when cooked, overly mucilaginous, but the flavor is excellent.

Watercress (*Nasturtium officinale* L.), familiar in the Temperate Zone, is easily grown from seeds or cuttings, grows especially well in running water, and can be grown in well-watered pots almost anywhere. The spicy greens are used as a garnish in salads or cooked in a variety of oriental dishes. Nutrient content is high; in fact, the amount of nutrients watercress produces per hectare surpasses that of almost all other vegetables.

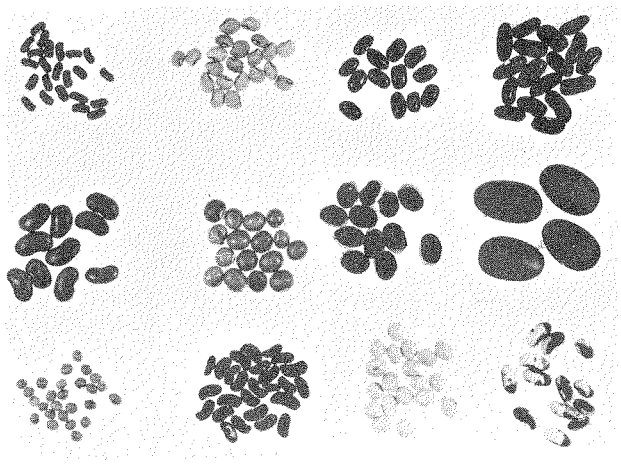

FIGURE 8.—Seeds of several important grain legumes: rice bean, catjang cowpea, small red common bean, black wax bean, red kidney bean, winged bean, hyacinth bean, sword bean, mung bean, black asparagus bean, soybean, bush asparagus bean.

LEGUMES

Legumes are a group of plants whose green pods, immature seeds, or leaves are used as vegetables, or whose dry seeds are used boiled or in the same manner as cereals (when they are called grain legumes or pulses).

Legumes are somewhat more difficult to produce than leaves and their production is more closely tied to the seasons. In general, legumes grow best during dry weather. In fact, dry weather is usually necessary to produce high-quality seeds. Nevertheless, almost all can be grown in the hot, humid Tropics during dry seasons. Species and varieties differ markedly in adaptation to particular environments, and especially in susceptibility to local pests and diseases. Since pests and diseases vary during the year and from year to year, it is difficult to specify the best legume for a particular place. A wide variety of legumes should be tested on every small farm during every possible season, so that the best can be chosen for repeated use. Yields of legumes will vary depending on many factors, including choice of species or variety and farming skill.

Grain legumes (fig. 8) have many advantages: the seeds are compact, rich, nutritious, and can be stored for years. (Dry heat in homemade ovens can be used to kill weevils before storage.) After storage, they are prepared by soaking in water overnight (a process that can be speeded up by 2 minutes of boiling before soaking) (Rockland and Metzler 1967). Cooking should be long and slow (for at least one-half hour) to destroy the toxic compounds present in all legumes.

On the small farm grain legumes are suitable for a variety of uses: ground into a meal to be used in breads and other dishes, made into a high-protein vegetable curd, and fermented to produce various products including the cheeselike cake, tempe. Grain legumes can be quite successful if the family can learn the many ways of using them.

Grain legumes are considered good substitutes for meat because of their high protein content, which varies from about 19 percent in pigeonpeas to more than 50 percent in some soybeans. The rest of the seed is chiefly carbohydrates and moisture, but a few cereal legumes (especially peanuts, soybeans, and winged beans) are also good sources of oil. Legume protein varies considerably in nutritive value and like meat, is short on the sulfur-bearing amino acids (methionine and cystine) and sometimes tryptophan. Legumes vary with respect to the amount of other amino acids, and should be complemented in the diet by other foods (especially cereals) that help adjust amino acid deficiencies. Legumes are good sources of most B vitamins, but not riboflavin (vitamin B_2).

Because of differences among legumes in protein content, flavor, and best use, the small farmer should grow as many kinds of legumes as he can. The principal tropical grain legumes and some of their advantages and disadvantages are given in table 7. There are many other minor species that are not listed. For any specific region the suitability of legumes (and what season they can be grown in) must be determined by trial and error. In many cases, breeding is necessary to adapt the legume to local conditions. Nevertheless, some useful generalizations can be made about the major species.

As with leaves, the species of vegetable legumes that are best for the hot, humid Tropics are little known and often neglected. They will require local trials to select the varieties suitable for each region. The species mentioned here (table 8) are attractive, marketable, and suitable for small-scale production.

When legumes are used for their tender green pods or immature seeds, their nutritional value is not the same as that of dry seeds. The B vitamin content is usually high, and some species contain

(*Continued on page 22.*)

Table 7.—Principal tropical grain legumes

Common name	Species	Climatic preference[1]	Altitude preference[2]	Day-length sensitivity	Form	Toxic compounds[3]
Common bean	*Phaseolus vulgaris* L.	Cool to warm, moderate.	Middle	Neutral	Bush or vine	T, H, G.
Cowpea	*Vigna unguiculata* (L.) Verdc.	Hot, moderate	Low	Neutral	Bush or vine	T, H, G.
Hyacinth bean	*Dolichos lablab* L.	Warm, dry	Middle	Winter blooming	Bush or vine	T, H.
Lima bean	*Phaseolus lunatus* L.	Hot, dry	Middle	Neutral	Bush or vine	T, H, HCN.
Mung bean	*Phaseolus aurevs* Roxb.	Hot, dry	Low	Neutral	Bush	T, H.
Peanut	*Arachis hypogaea* L.	Hot, dry	Low	Neutral	Bush	T, H, G.
Pigeonpea	*Cajanus cajan* (L.) Huth.	Hot, dry to wet	Low	Winter blooming	Bush	T.
Soybean	*Glycine max* (L.) Merr.	Hot, moderate	Low	Flowers year round, earlier in winter.	Bush	T, H, G, 4 others.[4]
Winged bean	*Psophocarpus tetragonolobus* (L.) DC.	Hot, humid	Low	Winter blooming	Vine	T, H, amylase.

[1] Temperature preference is listed first, then rainfall preference.
[2] Low altitude is sea level to 500 m, middle altitude is 500 to 1500 m.
[3] T, trypsin inhibitor; H, hemagglutinins; G, goitrogen; HCN, hydrocyanic glucoside.
[4] Soybeans also contain a saponin, an anticoagulant, a diuretic substance, and an histone.

Table 8.—Principal tropical vegetable legumes

Common name	Species	Part used	Preferred environment	Advantages	Disadvantages
Asparagus bean	*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc.	Green pods	Dry Tropics	Excellent flavor	Disease susceptible.
Common bean	*Phaseolus vulgaris* L.	Green pods	Upland Tropics	Good flavor, very adaptable.	Very susceptible to diseases.
Catjang cowpea	*Vigna unguiculata* ssp. *cylindrica* (L.) Verdc.	Green pods or seeds	Widely adaptable	High protein content	Virus susceptible.
Hyacinth bean	*Dolichos lablab* L.	Green pods or seeds	Dry Tropics	Vigorous, drought resistant.	Short-day flowering.
Lima bean	*Phaseolus lunatus* L.	Green pods or seeds	Widely adaptable	Adapted well to intermediate climates	Antimetabolites in seeds.
Peanut	*Arachis hypogaea* L.	Green seeds	Dry Tropics	High protein and oil content.	Needs dry weather to ripen.
Pigeonpea	*Cajanus cajan* (L.) Huth.	Green seeds	Widely adaptable	Bush form, low anti-metabolites.	Small seeds, short-day flowering.
Scarlet runner bean	*Phaseolus coccineus* L.	Green seeds	Upland Tropics	Vigorous perennial	Tuber possibly poisonous.
Soybean	*Glycine max* (L.) Merr.	Green seeds	Dry Tropics	High protein content	Poor adaptability.
Sword bean	*Canavalia gladiata* (Jacq.) DC.	Green pods or seeds	Widely adaptable	Large seed, disease resistant.	Mature seed poisonous.
Winged bean	*Psophocarpus tetragonolobus* (L.) DC.	Green pods or seeds	Hot, humid Tropics	High protein content, adaptable to rainy season.	Will not flower in summer.

FIGURE 9.—Leaves and pods of the bush asparagus bean (a variety of cowpea).

minerals in significant quantities. Their caloric content tends to be a little higher than that of leaves, but legumes as vegetables are not important sources of calories in the diet.

The common bean (*Phaseolus vulgaris* L.) is the best known and most widespread bean of the Tropics and Temperate Zone. In many parts of Central America and in some other areas, it is a staple crop. But it is susceptible to many diseases and insect pests and is suitable for tropical lowlands only during dry seasons. Some cultivars of both bushy and twining forms are used for the tender young pods while others are used for dried seeds. The common bean can be grown everywhere, but it produces best in a fairly dry climate.

Another excellent legume is the cowpea (*Vigna unguiculata* L.). Cowpeas probably originated in the Old World Tropics. They are extremely variable, having several distinct forms and varieties for all kinds of climates (fig. 9). Cowpeas are fairly resistant to insects and diseases of the Western Hemisphere, and will often bear a crop when other legumes fail. Several disease-resistant varieties that will produce in spite of the rainy season have been developed at the Mayagüez Institute of Tropical Agriculture.

The best variety appears to be the catjang cowpea, whose plants are climbing vines that bear abundant seed pods with small seeds over a very long season. Catjang cowpeas can be used as green bean pod; they tend to be stringy but have an excellent flavor. Nutritionally, beans removed from more mature green pods are even better. Dried seeds can be harvested, even in rainy weather, by collecting the pods as they begin to turn yellow and drying them thoroughly before they are stored. Sprouted, they are excellent fresh vegetables.

The hyacinth bean (*Dolichos lablab* L.) is a native of India, and is still used principally in that country, despite the fact that it is now widely distributed throughout the Tropics. Use of the hyacinth bean is often restricted by the species' day-length sensitivity (most varieties do not bloom until days are short). During the flowering season some varieties are small- to medium-sized upright shrubs, and some are large, vigorous vines. During long days, all cultivars grow as large, vigorous, indeterminate vines. Some varieties that flower during long days have been reported. Once established, hyacinth bean is deep rooted and very resistant to drought. The foliage mass dominates most weeds, and may itself be a weedy nuisance. Most plants are short-lived perennials, but a few forms will live for 5 to more years. The winter bush-type cultivars behave more like annuals.

The green pods of the hyacinth bean are cooked whole; when the pods are too tough, the

seeds are removed from them before cooking. The dry seeds are frequently cooked as a dried pulse or sprouted for use as a vegetable. The foliage is relished by cattle.

The lima bean (*Phaseolus lunatus* L.), another widely distributed bean, was probably domesticated in Central and South America. Lima beans prefer a somewhat dry climate, require dry weather to produce dry seeds, and are not adapted to a long rainy season. Bushy forms have been developed, but the wild type and many other cultivars are twining vines whose production is reduced when they are not given trellises. Lima beans may be annual or perennial and may have small or large seeds. Mature seeds may be one of several colors. The ripe (but not dry) seeds of all cultivars are cooked, as are the young pods of some. Dried seeds are used as a pulse. Some contain poisonous cyanogenic glucoside and should be cooked one-half hour or more and the cooking water discarded.

The peanut (*Arachis hypogaea* L.) is an excellent legume for many subsistence farms. It originated in the American Tropics, is widely distributed through warmer parts of the Temperate Zone, and is produced in large quantities in drier parts of the Tropics. It is an annual that produces its pods on stalks (stipes) that penetrate the soil after flowering. Therefore, the soil for peanut culture must be friable (some of the best soils for peanuts are sandy). At harvest the entire plant is uprooted. The plant is then dried by shaking it and leaving it on the surface of the soil, or by hanging it in a sheltered location. It is very important that the weather be dry during the harvest. If peanut seeds are moldy they may have developed poisonous aflatoxins and should be discarded.

Peanuts are used mainly for their dried seeds (and commercially as a source of oil). In the home, the unripe seeds can be used as a vegetable, or the dried seeds can be boiled as a split pulse. The protein level of peanuts is high, and the oil content is very high. Because dried seeds are so easily stored, peanuts can be available year round.

The pigeonpea [*Cajanus cajan* (L.) Huth.] is highly valued in Puerto Rico and some other parts of the Tropics. It is one of the best legumes for subsistence farms because it produces dependably, even in poor soils. It probably originated in India, where many varieties are found, and is widely distributed throughout the Tropics, even though it is seldom appreciated or grown on a large scale. It does best in the dry Tropics but also tolerates the wet Tropics very well.

Pigeonpea grows as a bush, 1 to 3 meters in height. It is a short-lived perennial usually grown as an annual. Most varieties are sensitive to day length; they flower during winter when days are shortest. Pigeonpeas are used as an immature shelled bean, usually cooked with other foods. They are also used as a pulse (soaked in water and boiled, or ground into a meal).

The scarlet runner bean (*Phaseolus coccineus* L.) is superb for the tropical highlands but is not suited to the hot, humid Tropics. It originated in the Tropics of Central America, is widely distributed there, and has become popular in Europe as well. It is a perennial twining vine, capable of regrowing for years from a tuberous root, and it yields best when trellises are provided.

Scarlet runner beans can be established from seeds or planted from sprouts that originate on the tuberous roots. In its native habitat it is often planted with maize, which it uses for support. Scarlet runner bean is also suitable for a backyard or small garden. It can be grown successfully on a fence, where it provides a wealth of pods with large seeds. Crops are produced chiefly during the long days of the tropical summer. Young pods are cooked whole or sliced, mature (but not dry) seeds are shelled for use as a vegetable, and dried seeds can be used as a split pulse. The tuberous root is reportedly edible as well.

The soybean (*Glycine max* Merr.) should be tried on every subsistence farm. It originated in China, has become a very important crop in the United States and Brazil, and is growing in importance in all parts of the Tropics. Modern soybean varieties are small upright bushes that require minimum maintenance once established. They can be closely spaced (10 to 15 cm) to produce a dense crop. Although soybean production in the United States is highly mechanized, they can also be grown successfully on a small scale.

The green but plump pods can be harvested and parboiled, and the seeds removed to be cooked in any way desired. Dried seeds are used as a boiled pulse or can be made into a milk substitute by soaking, grinding, and straining (see "Afterword"). The milk substitute can be used to prepare a highly nutritious vegetable curd. Soybean seeds contain abundant amounts of high-quality oil, and no other legume produces a seed as rich in protein.

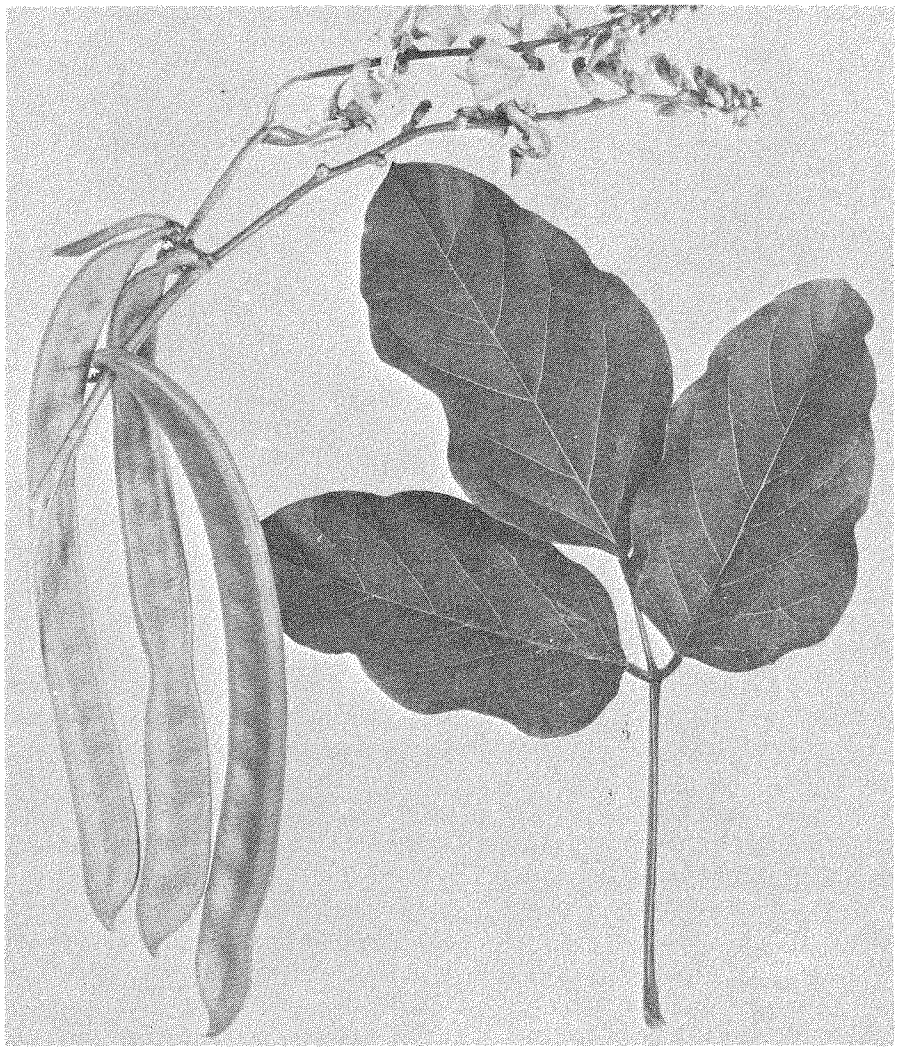

FIGURE 10.—Sword bean pods and leaves.

The sword bean [*Canavalia gladiata* (Jacq.) DC.] (fig. 10), is one of the most controversial legumes of the Tropics. It originated in India and has become widespread: Yet it is seldom utilized, probably because some forms are poisonous, at least when mature. Nevertheless, the sword bean has a number of characteristics that recommend it for the small tropical farm. It is a perennial; with a trellis to grow on, it makes a very large plant that can produce year round. Also, the individual pods are large, as are the seeds, reducing the amount of labor at harvest.

The sword bean is often confused with the jack bean, which is more bushlike and produces longer pods with white, plump seeds. Sword bean seeds are usually larger, rectangular, somewhat flat, and dark pink, rarely white. (Although young jack bean pods are sometimes eaten, all other plant parts, especially dried seeds, are poisonous.) Young, tender sword bean pods are eaten, as are the larger seeds of more mature (but not dry) pods. Pods and seeds should be cooked at least 20 minutes before use.

The winged bean [*Psophocarpus tetragonolobus* (L.) DC.] (fig. 11), is a legume known throughout the Asian tropics that can produce well during rainy seasons. It has been used only sporadically in the New World, but should experience an upsurge in use from introduction of new varieties. It is a perennial bean, slow to start, but vigorous once established. It bears heavily during the season of short days, but some new varieties will flower continuously during long summer days. It will also bear heavily

if the pods are continuously harvested. Although the leaves, flowers, roots, and dry seeds are all edible, the winged bean is best as a tender, stringless bean. For this purpose the young pods are harvested before fiber appears. The thickened pods are themselves good protein sources. For maximum nutritional value the pods are allowed to mature, and the almost ripe seeds are removed for cooking. Both young pods and mature green seeds can be harvested from the same plant. The abundance of food it provides for little effort, especially where other beans are difficult to produce, make the winged bean an excellent vegetable for the subsistence farm (see Martin and Delpin 1978).

FIGURE 11.—Winged bean plant with pods.

ROOTS AND TUBERS

Roots and tubers are very good crops for the subsistence farm. In some cases they can be harvested year round (making the soil itself a storage bank of edible materials). They are belly-filling vegetables that are easy to produce and tend to become dietary staples. Their principal role in the diet is to provide calories, but some have secondary roles. Some contribute useful amounts of protein to the diet, some contain provitamin A, and some vitamin C (although the protein and vitamin content varies among species and among varieties). The best of the roots and tubers are listed in table 9.

Arrowroot (*Maranta arundinacea* L.) is a little-known root crop that is valuable for the small farm because it is easy to grow, is disease and pest resistant, and is usually highly productive. The plant forms thick horizontal rhizomes, pieces of which are used to propagate the species. Rhizomes are available year round in wet climates, but are produced most abundantly near the end of the rainy season. They keep well in the soil and can be harvested as needed. Because the rhizome is fibrous, it is cut into thin cross sections before boiling or frying.

Cassava (*Manihot esculenta* Crantz), while easy to grow and available year round, is the least desirable of the root and tuber crops because of its cyanogenic glycoside content and low protein content. It must be cooked 20 minutes or more to avoid acute or chronic poisoning. The root has only a small amount of protein (and that of poor quality). If cassava is used as a staple food, it should be supplemented with many other vegetables, especially leaves and legumes.

Dasheens or taro (*Colocasia esculenta* Schott), and yautias or tanniers (*Xanthosoma* spp.), are useful crops that produce a starchy corm. Taro is a starch staple in the Pacific, while yautías are used in the Caribbean and in some parts of West Africa. These crops need very wet conditions over a long growing season. They contain a large amount of calcium oxalate, some of which is removed by discarding the cooking water.

Potatoes (*Solanum tuberosum* L.) are useful vegetables (they often contain vitamin C and some protein), but they can only be grown in the Tropics at high altitudes (occasionally at intermediate altitudes). At lower altitudes, particularly in the humid Tropics, they are susceptible to too many pests and diseases to flourish. Current international efforts should result in the development of truly tropical potatoes.

The best root crop for many places in the Tropics is often the sweetpotato [*Ipomoea batatas* (L.) Lam.]. This is a crop that can produce highly

Table 9.—Principal tropical root and tuber crops

Common name	Species	Water requirement	Preferred environment	Season of production	Secondary nutritional value
Arrowroot	*Maranta arundinacea* L.	High	Hot, humid Tropics	Rainy season	None.
Cassava	*Manihot esculenta* Crantz	Low	Dry Tropics	Year round	None.
Dasheen, taro	*Colocasia esculenta* (L.) Schott	Very high	Paddy cultivation	Year round	None.
Potato[1]	*Solanum tuberosum* L.	Moderate	High elevations in the Tropics	Year round	Protein, vitamin C.
Sweetpotato	*Ipomoea batatas* (L.) Lam.	Moderate	Tropics and subtropics	Year round	Protein, vitamin A.
Yams	*Dioscorea* spp.	High	Hot, humid Tropics	Seasonal[2]	Protein, vitamin C.
Yautia, tannier	*Xanthosoma* spp.	Very high	Hot, humid Tropics	Seasonal[2]	None.

[1] Not recommended for the Tropics except as high altitudes.
[2] Depends on species or variety.

nutritious roots in 5 months or less, at any time of the year. Because the leaves can also be eaten, sweetpotato provides a continuously harvestable edible product. The roots contain some protein, significant quantities of provitamin A (in yellow- and orange-fleshed varieties), and vitamin C. Its chief defects are its susceptibility to a common pest, the sweetpotato weevil [*Cylas formicarius* ssp. *elegantulus* (Summers)] and the fact that it is somewhat more difficult to grow than other roots and tubers.

Some excellent sweetpotato varieties are available in the Tropics, but these vary so much from place to place that it is difficult to give recommendations. A search should be made for the nutritious orange- or yellow-fleshed varieties used locally. 'Centennial', 'Gem', and 'Julian' are excellent orange-fleshed sweetpotatoes that are adapted to some parts of the Tropics. In Puerto Rico, the variety 'Taiwan 57' has consistently outyielded all other varieties.

Yams (*Dioscorea* spp.) are also excellent tuber crops, well suited to the hot, humid Tropics (fig. 12). Yams require poles to climb and a long wet season. They are not available all year round, but they can be stored for several months. Thus the best strategy is to plant several species and varieties, and to harvest and store tubers for the off season. The African white yam (*D. rotundata* Poir.) is the earliest to mature, the wing-stemmed yam (*D. alata* L.) follows, and the lesser yam [*D. esculenta* (Lour.) Burk.] matures last. Most edible yams produce useful amounts of protein and vitamin C. For a complete discussion of edible tropical yams, see "Tropical Yams and Their Potential" (Martin 1974-78).

A combination of different roots and tubers might be suitable for the subsistence farm. Fences can be made of closely planted cassava (as a calorie bank for the future), yams can be grown for winter and sweetpotatoes for summer consumption, sweetpotatoes can be grown in carefully prepared beds, and dasheens and yautias can be grown in wet spots.

FRUIT VEGETABLES

The fruit vegetables are varied in form, appearance, taste, and nutritional value (and are, in fact, classified together rather arbitrarily). While they are universally grown and widely appreciated, they do not contribute as much to the diet as other classes of vegetables.

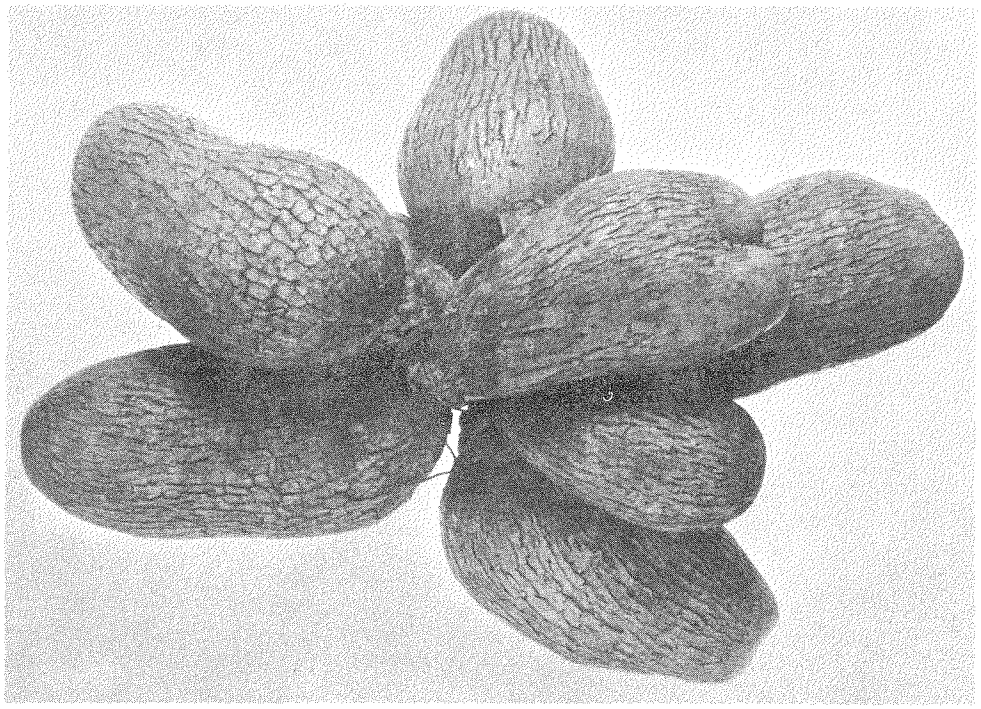

FIGURE 12.—Yam tubers.

All of the vitamins and minerals produced by fruit vegetables can be obtained more easily and reliably from other plant sources (especially leaves). Many fruit vegetables add little more than variety and interest to the diet, and the subsistence farm can be made to work without them. If they are grown, they should be used in their most nutritious form (which is often not the case). Some recommended fruit vegetables and the uses that take advantage of their highest nutritional value are given in table 10. Many common tropical fruit vegetables are not listed in the table because they are of lesser nutritional value. Many of these are still important in the Tropics and may be grown on the subsistence farm for variety and for use in traditional dishes, but they should not take up much of the time or space that could be better used for more nutritious foods.

The bitter gourd (*Momordica charantia* L.) from Southeast Asia (fig. 13) would not appeal to many persons not accustomed at an early age to its strong flavor, but is is easy to grow and (unlike most cucurbits) is a good source of vitamin C. The bitter gourd is a small climbing vine with cucumber- or heart-shaped fruits that have a warty surface. The fruit is used while green. Slices of bitter gourd are soaked in water before cooking and are then cooked in two or more changes of water.

FIGURE 13.—Bitter gourd fruit at the right stage for harvest.

The eggplant (*Solanum melongena* L.) is a minor source of nutrients whose versatility adds

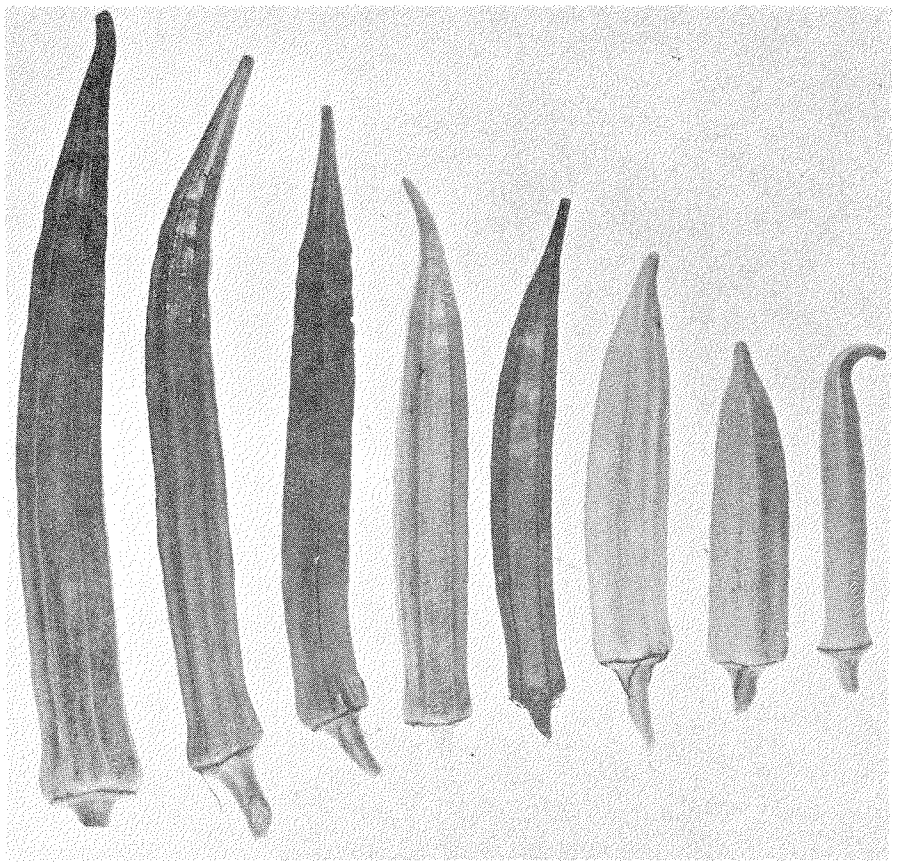

FIGURE 14.—Okra pods.

Table 10.—Some tropical fruit vegetables

Common name	Species	Recommended use	Nutritional contribution
Bitter gourd	*Momordica charantia* L.	Mature fruit	Vitamin C, iron.
Eggplant	*Solanum melongena* L.	Immature fruit	Minor source of most nutrients.
Okra	*Abelmoschus esculenta* (L.) Moench	Almost mature pods, seeds.	Oil, protein.
Pepper	*Capsicum annuum* L.	Ripe and immature fruit	Vitamins A, C.
Pumpkin	*Cucurbita moschata* (Duch.) Duch. ex Poir.	Mature fruit, seeds	Vitamin A.
Squash	*Cucurbita mixta* Pang	Seeds	Vitamin A, protein.
Tomato	*Lycopersicon esculentum* Mill.	Mature fruit	Vitamin C.
Vegetable corn	*Zea mays* L.	Immature ear	Carbohydrates, protein.

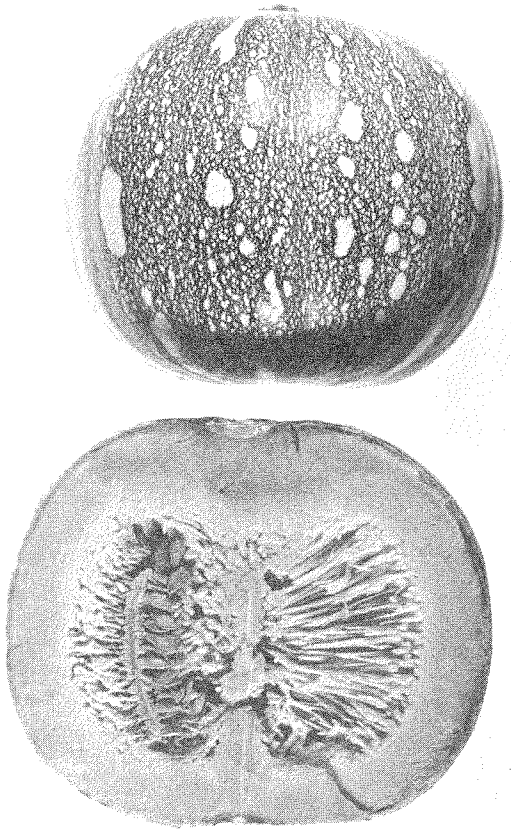

FIGURE 15.—The tropical pumpkin, exterior and interior.

variety to the diet. Immature fruits of many sizes, forms, and colors are stuffed and cooked, sliced and fried, or diced and mixed with other foods. Eggplants must be established carefully from tender seedlings, but once established, are long-lived and very productive. They may be grown almost anywhere in the Tropics except at high altitudes (Martin and Pollack 1979).

Okra (*Abelmoschus esculentus* Moench) originated in Africa and evolved further in India; many modern varieties have been developed in the United States. It is now fairly well distributed throughout the Tropics and warmer parts of the Temperate Zone. It needs warm temperatures and long days for maximum growth, but it can be produced year round in some parts of the Tropics. Okra is characterized by its regular and prolific production (fig. 14). Often a few plants can produce all that a family can use of the fresh vegetable. If when production begins to diminish, fertilizer is added and plants are cut back, they will quickly begin another round of production.

Okra is versatile. Most often, tender pods are boiled as a vegetable. Also, after boiling more mature pods the seeds can be removed and eaten. Young leaves are a good dish of greens. Mature seeds can be ground into a meal rich in protein and oil, that can be used with other flours for baked products. Okra pods do not contain a large amount of any one nutrient, but they do contain fair quantities of a wide variety of nutrients, making a very good vegetable in the diet (Martin and Ruberte 1978a).

Perhaps the best of the fruit vegetables is the pumpkin (*Cucurbita moschata* Duch. ex Poir.) Tropical pumpkins are thick-fleshed, hard squashes with deep yellow-orange flesh and numerous seeds (fig. 15). Pumpkins are produced on long vines that spread rapidly over the soil, rooting at the nodes or climbing into bushes or trees. They may be propagated by seeds or cuttings. Pumpkins grow best where humidity is not excessive, but excellent pumpkins are produced even during the rainy seasons of the hot, humid Tropics, as long as the soil is fertile and well drained.

The pumpkin is used mainly for the hard flesh of its large fruit, which is boiled or baked. In a few places, male flowers and flowerbuds, and even young shoots and leaves are also eaten. The seeds are usually overlooked despite the fact that they are rich sources of edible oil and protein. They can be washed, toasted, and eaten, or dried for grinding into a meal to be combined with many other foods. Toasted seeds store well.

A related species of squash (*Cucurbita mixta* Pang) that has cultivars produced chiefly for the seeds, can be grown in hot, dry areas but is not suited to the wet Tropics. A new variety of squash, 'Lady Godiva', has seeds without seed-coats, and if successful in the Tropics, would help promote use of squash seeds as a food.

The tomato (*Lycopersicon esculentum* Mill.) is surely the world's favorite vegetable for its visual appeal, flavor, and wide variety of uses. It probably originated in the somewhat dry regions of Mexico. It is a tropical species, but is not really adapted to the hot, humid Tropics, despite the fact that it is found everywhere in the Temperate and Tropical Zones.

Varieties of tomatoes bred in North America for high production during a short season are not appropriate for the Tropics. Varieties that continue to grow over a long period of time and produce small quantities of tomatoes regularly (indeterminate varieties) may be best for use on

Table 11.—The best cereal crops for the Tropics

Crop	Species	Advantages	Disadvantages
Corn (normal)	*Zea mays* L.	Easy to produce	Low lysine content.
Corn (Opaque$_2$)	*Zea mays* L.	High nutritional value	Unfamiliar cooking qualities, slightly reduced yields.
Rice	*Oryza sativa* L.	Easy to produce, high yields.	Protein limited in quantity and quality.
Sorghum	*Sorghum bicolor* (L.) Moench.	Easy to produce, supplies building materials, drought resistant.	Protein content somewhat low, brown grains nutritionally inferior.

subsistence farms. Such varieties must be tied to stakes. These conditions (and adequate space) may permit production of some tomatoes even during rains. Poor fruiting in tropical summers may also be caused by hot night temperatures. In such cases, fruit set can be increased by watering plants in the evening to reduce their temperature. Tomatoes are a very good source of vitamin C and a minor source of provitamin A. They are used as a fresh fruit, cut in slices or pieces in salad, and as a source of color and flavor in sauces and condiments. With careful cultivation, they can always be kept in production on the small tropical farm.

There are two principal pepper species (*Capsicum annuum* L. and *Capsicum frutescens* L.). In some cases only an expert can tell the difference, so it is more practical to classify peppers by their use. Large, wide peppers with mild flavors are used for salads or are stuffed; small, more pungent peppers are often pickled; and narrow, very hot peppers (some quite small) are used to flavor foods. All peppers are good sources of provitamin A and vitamin C, and are useful in the diet (Martin et al. 1979).

Peppers originated in the American Tropics. They have been selected and used by man since prehistoric times. Now they have been distributed and are popular throughout the Tropics, and in parts of the Temperate Zone as well. Most are annuals although some can live for 2 years or more. On small farms they are likely to be plagued by viruses and small mites but these problems can be reduced or eliminated by starting young plants in an isolated location and growing successive pepper crops isolated one from another.

Sponge gourds (*Luffa* spp.) and bottle gourds (*Lagenaria siceraria* Standl.) are climbing squashlike vegetables that can be produced in the Tropics during any season (Martin 1979). The young fruits are boiled or sliced and fried. The seeds of mature bottle gourds are rich in oil and protein, and the hard shell is made into utensils or containers. The network of fibers in mature sponge gourds is used to scour dishes or as a bathroom sponge.

CEREALS

Cereals are probably the most important food plants produced on the subsistence farm (table 11). Used in the form of bread or a breadlike substitute, they are important sources of energy, protein, and B vitamins. Some are sources of unsaturated oils and vitamin E (found principally in seeds). Cereal proteins contain adequate quantities of the sulfur-bearing amino acids that are rare in other foods, but they usually contain less lysine and tryptophan than desirable. Therefore, when cereal grains are used as a staple, they should be complemented with other protein foods. Also, in order to maintain their highest nutritional value, cereal grains should not be overly milled or bleached.

The cereals best suited to the tropical subsistence farm are rice and corn. In tropical diets they must often compete with roots and tubers as sources of calories. But although these foods may be similar in caloric content, the amounts of other nutrients they contain differ widely. Thus the foods chosen to balance the diet will depend on the types of staple starch used.

Corn (*Zea mays* L.) is an excellent cereal for the Tropics. It is an excellent energy source. Its calories are derived primarily from stored starch, but also from the oil of the seed. Corn also contains significant amounts of protein (an average of 11 percent), making it a good body-building food as well. But since corn protein is deficient in lysine

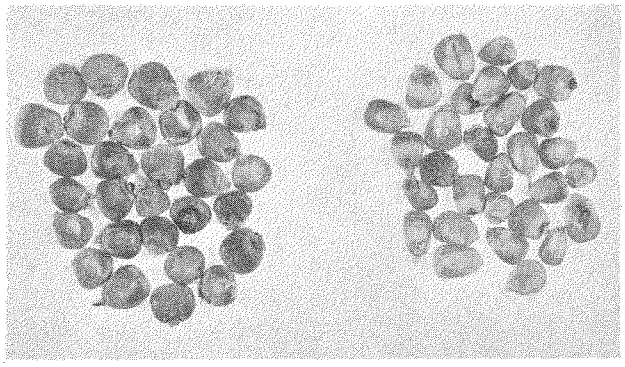

FIGURE 16.—Seeds of Opaque$_2$ corn (left) and normal corn (right).

and tryptophan, in order to utilize the protein fully, corn should be complemented in the diet with a protein source that makes up the deficiency (any protein other than that of cereal grains such as rice and wheat).

Corn's versatility is one reason it is so useful on the small farm. While still immature, it can be boiled or roasted. The dry seed is ground for a meal that can be cooked as a gruel or baked into breadlike products. And every country has its own corn products. Corn is also used as fodder (or is fermented in silage, making its B vitamin content higher).

With the large number of corn varieties and their wide adaptability, it should be possible to grow corn anywhere in the Tropics. Although corn production is usually thought of as large-scale, intensive production, corn can also be produced in small plots with relatively little care. The choice of variety is very important, and in some cases the time of planting is critical, but as long as water is available, corn can be produced in the Tropics throughout the year.

Corn has several forms that are used as vegetables, sweet corn (in which much of the carbohydrate is stored as sugar rather than starch) and several starch-producing corns. These vegetable corns originated in the American Tropics and are still widely used there. With some, the young ears can be used as a vegetable while other ears are allowed to mature for their dried grain. Also, the very small secondary ears that seldom produce a useful product can be removed at the time of silking and eaten raw or used in salads; they are a tender, sweet delicacy.

Opaque$_2$ corns (fig. 16), a group of relatively new varieties, have a much better amino acid balance than normal corn. Their protein quality has been compared to that of skimmed milk. Opaque$_2$ corn used in animal rations helped increase weight gains. In human diets Opaque$_2$ corn prevents the nutritional disease pellagra which is associated with a shortage of niacin (vitamin B_3) and tryptophan. In fact, Opaque$_2$ corn may provide the best plant protein now available.

Nevertheless, Opaque$_2$ corns have not yet been accepted for several reasons: they yield less per unit area than conventional corns; their grains look different; and when ground, their meal has different cooking characteristics from normal corn (Opaque$_2$ flour is not suitable for many traditional corn dishes). Some of these problems are being overcome with newly developed hard-endosperm Opaque$_2$ varieties.

Varieties of Opaque$_2$ are not yet available for all of the ecological situations in which corn is produced. And when Opaque$_2$ corn is grown, it will have to be isolated from other corn varieties (to prevent hybridization) if seed for replanting is to be produced; its character must be preserved. Opaque$_2$ corns and other corns with balanced amino acids will probably become more popular in the next few decades and will probably be a very important resource for the subsistence farm.

Rice (*Oryza sativa* L.) can be produced on a subsistence farm, and where enough water is available, paddy rice is the logical form (see Purseglove 1972). The culture of paddy rice is a labor-intensive enterprise, and is suitable for small-scale applications. When water is a limiting factor, so-called upland rice can be grown. Rice is the cereal produced most widely in the hot, humid Tropics. It is the staple food of millions, especially in Asia. When combined with other foods (as it is normally used) it is an outstanding element in the diet. It does not, however, contain as much protein as other cereal grains.

Sorghum [*Sorghum bicolor* (L.) Moench] is a rapidly growing annual or perennial grass that furnishes an edible seed as well as forage for animals. Tropical varieties flower only during the season of short days, but Temperate Zone varieties can be produced year around in the Tropics. Varieties with light-colored seeds are nutritionally better than those with dark seeds (these have a high tannin content, which makes proteins more difficult to digest). Seeds are ground and used as cereal or as a flour. Sorghum can be grown in areas with short rainy seasons, and will mature even after other plants are wilted.

Trees

In many parts of the Tropics people produce their food on land that is best suited for forests. Long-term preservation of the land and its fertility is especially important in such areas because destroying the forest frequently destroys the capacity of the soil to support agriculture. What is needed there are food production systems that combine forest preservation with agriculture.

There are production schemes (called agri-silviculture) that yield wood, foodstuffs and animal products from the same management unit (farms, small communities, or portions of watersheds). In these schemes, good agricultural practices and judicious use of arborescent vegetation are combined. Of course, cooperation among land users is essential; it enhances the potential of the scheme, and helps maintain the productive capacity of the management unit.

Trees offer many benefits. They protect the soil, ameliorate soil microclimate, enhance infiltration of air and water into the soil, improve water quality and regimen, recycle nutrients that would otherwise be lost to percolation, and provide shade, food, forage, fuelwood, and (sometimes) timber. Food production can be added to the forest system without making destructive changes, and degraded agricultural lands can be rehabilitated by interplanting with aborescent vegetation.

Several stable agri-silvicultural systems have been developed in the Tropics that combine production of annual plants, bushes, trees, vines, and livestock to yield a combination of useful seeds, flowers, fruits, vegetables, leaves, medicines, resins, forage, firewood, lumber, and meat. In the simplest systems, trees are used chiefly for wood, fruits, shade, or wind protection. Windbreaks are important, especially where there are strong, dry winds that dessicate the soil. Planted along plot boundaries or among cultigens, windbreaks minimize erosion and regulate water supply. Also, living fenceposts bordering pastures can enclose livestock, yield forage, provide firewood, and eliminate the need to cut small trees to replace fenceposts.

Forest blocks can be scattered among agricultural lands, as they are among rice paddies in the Philippines, to help stabilize the soil and cycle nutrients. When the forest blocks are upper slopes and hilltops (usually in areas of recurrent drought), the trees impede water loss, increase percolation into the soil, and may even increase the productivity of adjacent lower slopes and bottomlands by prolonging the growing season.

Shifting cultivation is a particularly important system for the Tropics, in which trees are used to regenerate the soil over long periods of time. When the forest is cut, trees are burned and crops are planted on the site for 1 to 3 years. When weeds become too competitive, the fields are abandoned, and new (secondary) forests are allowed to develop. During this time (the fallow period) the land is not used.

Land clearing in tropical forests leads to a series of alterations in the soils. Burning adds mineral nutrients to the soil, but these are soon used or leached away. Some soils are hardened when exposed to strong light and soon become infertile. The available minerals (and total fertility) decrease during agricultural use and gradually increase during fallow.

Shifting cultivation works very well where populations are dispersed. In areas of high population density, farmers must resist the temptation to prolong cultivation, clear too large an area, or cultivate steep slopes; soil deterioration and erosion soon follow.

Two modifications and extensions of shifting cultivation, the corridor system in Africa (Coene 1956, Newton 1960) and the Tuangya system from Burma (King 1968), contain specific prescriptions for rotational sequences and choice of crops.

Casual intercropping is a system in which naturally regenerated secondary species (volunteer trees) are allowed to remain in fields used for pasture or other crops, or trees that are rem-

nants of previous forest are deliberately planted. The trees are retained as shade for animals and sources of fruits, edible leaves, firewood, or even timber. But casual intercropping is not a systematic use of trees to contribute to the farm.

Simulation of succession has been suggested as still another alternative to intercropping in the American Tropics. This system consists of cropping sequences that simulate natural succession (such as leafy, stem, and root crops, followed in order by bananas and plantains, palms, and productive forest). In one example (Holdridge 1959), successional phases included subsistence crops, and the terminal stage had capa (*Cordia alliodora* Oken) and pejibaye (*Bactris gasipaes* H.B.K.) as the dominant and codominant vegetation, cacao (*Theobroma cacao* L.) as a suppressed crop, and root and tuber crops scattered on the ground. In fact, polyculture systems with several crops have resulted in greater yields than monoculture rotation systems (Hart 1975).

Several multiple-cropping schemes that consider specific crops can be found in the literature (Holdridge 1951, Hunter and Camacho 1961, Espinosa-Caballero 1976, Peck 1976, and Aguirre 1977).

FRUIT TREES

Among the best trees for the subsistence farm are fruit trees, because they can provide food. They often require little special attention and, if carefully managed and pruned, they can also serve as a source of wood fuel for the farm. The space used by them need not be great; they can be located near buildings, as shade for cages, as part of fencing, in areas that are difficult to farm, or as part of the landscaping of the house and farm. They should not take up space that could be used for intensive production of vegetables, cereals, legumes, or roots and tubers, which merit the bulk of the available land.

The best fruit trees for small tropical farms (table 12) are those that are well known in the area of the farm for their productive ability. Local farmers will know what plantings have worked best for them, but there are often new, highly productive trees that are known only by a few people. Since the people or facilities necessary to produce, graft, and distribute high-quality trees are often lacking, special attention should be given to acquiring trees known to be useful.

There are a large number of fruit trees suitable for the subsistence farm. Many also have edible leaves (including cashew, coffee, papaya, mango, and tamarind). Others have special, little-known edible uses. It is best to select a combination of trees with different nutritional values. For example, vitamins A and C can be obtained from a wide variety of fruits, oils for cooking from coconut or oil palms, and protein from nuts. A few fruits of exceptional value are discussed below.

The canistel or eggfruit [*Pouteria campechiana* (H.B.K.) Baehni] begins to bear when quite small, and is among the most versatile of fruits; it can be used fresh, dried, or cooked to add color and flavor to puddings, ice cream, or baked products (Martin and Malo 1978).

Citrus fruits (*Citrus* spp.) are very popular and usually contain useful amounts of vitamin C. There are varieties available for almost all tropical climates, and the trees usually require little care and take up comparatively little space. The fruits keep well, and the juice, pulp, and rind can all be used. Grafted varieties that have proved suitable in the farmer's locale are worth the initial expense because they are likely to yield heavily.

The guava (*Psidium guajava* L.) is also outstanding; it will bear almost year round in some areas. Its highly nutritious fruits have a wide variety of uses. Its pruned or dead wood is especially good for the cooking fire because the dense wood burns with a high heat and without noxious fumes or sparking.

Mangos (*Mangifera indica* L.) contain useful amounts of vitamins A and C, and are widely appreciated. The trees bear heavily while young but tend to occupy disproportionately large areas when they are older and less fruitful. The wood is good for furniture construction and fuel.

Tall palms that bear edible fruits that can be used as staples are recommended. The best of these are the coconut (*Cocos nucifera* L.) and the pejibaye. These trees furnish food for years, and need little space or attention.

Papaya (*Carica papaya* L.) is an excellent fruit tree even though it is short lived (3 to 4 years). Its leaves, pith, roots, seeds, and flowers can be eaten if they are cooked 10 minutes or more. The fruits are edible when ripe and even (if cooked) when immature.

Tamarind (*Tamarindus indica* L.) is highly nutritious and is more versatile than most people

Table 12.—Fruit trees recommended for tropical subsistence farms

Common name	Species	Climate preference	Nutritional contribution	Notes
Avocado	*Persca americana* Mill.	Somewhat dry Tropics	Oil, vitamins B_2, B_3	Short life span.
Banana	*Musa* spp.	Humid Tropics	Carbohydrates	Readily accepted, widely adapted, heart and inflorescence also used.
Barbados cherry, acerola	*Malpighia glabra* L.	Somewhat dry Tropics	Vitamin C	Widely adapted, small fruit.
Canistel, eggfruit	*Pouteria campechiana* (H.B.K.) Baehni.	Tolerant	Sugars, vitamins	Widely adapted, versatile in use.
Cashew	*Anacardium occidentale* L.	Dry Tropics	Protein, B vitamins	Also has juicy fruit, tolerates drought and poor soils.
Cocoa	*Theobromo cacao* L.	Humid Tropics	Oil, protein	Very wide variety of uses.
Coconut	*Cocos nucifera* L.	Tolerant	Oil, protein	Widely adapted; heart, inflorescence also used, as is sap (for wine).
Coffee	*Coffea arabica* L.	Humid Tropics	None	Used only as a stimulant.
Guava	*Psidium guajava* L.	For all tropical climates there are tolerant varieties.	Vitamin C, calcium	Widely adapted, versatile in use, bears over long season, limited by disease in some areas.
Key lime	*Citrus aurantifolia* Swing	For all tropical climates there are tolerant varieties.	Vitamin C	Widely adapted, versatile in use.
Macadamia	*Macadamia integrifolia* Maiden et Betche.	Dry to moderate Tropics	Oil, protein, minerals, B vitamins.	Underutilized but readily accepted.
Mango	*Mangifera indica* L.	For all tropical climates there are tolerant varieties.	Vitamins A, C.	Productive; widely accepted; leaves, seeds also used; trees tend to get too large for small farm.
Oil palm	*Elaeis guineensis* Jacq.	Humid Tropics	Oil, vitamin A	Extremely productive, easy to manage source of cooking oil.
Orange	*Citrus sinensis* Osbeck	Somewhat dry to humid Tropics.	Vitamin C	Widely adapted.
Papaya	*Carica papaya* L.	Dry Tropics	Vitamins A, C	Fast growing; green fruit, leaves, heart, roots also used.
Soursop	*Annona muricata* L.	Tolerant	Vitamins B_2, B_3	Very popular, useful as fresh fruit or in drinks.
Tamarind	*Tamarindus indica* L.	Dry Tropics	Sugars, vitamins B_1, B_3, minerals.	Widely adapted, seeds and leaves edible as well as fruit pulp.

realize. The pulp around the seeds is used to flavor chutneys, drinks, and other foods, and both seeds and tender leaves can be cooked and eaten.

VEGETABLE TREES

There are a few trees and a number of large woody shrubs that produce vegetables for the small farm (table 13). These are extremely useful because they produce a great deal of food and require only a minimum of attention; they can be used to diversify food production while conferring the same benefits as other trees.

Bananas and plantains (*Musa* spp.), although really large perennial rhizomes, offer the small farm many of the protective features of trees. The fruits of all varieties can be used as vegetables either green or ripe. After fruit production ceases, the remaining flowerbuds can be cooked; the bases of the bracts are delicate vegetables.

The breadfruit (*Artocarpus altilis* Fosb.) is known for its seedless forms, whose fruits are used as starchy vegetables. The seeds of seedy forms (often called breadnuts) are also edible. They are boiled in saltwater, and their flavor resembles that of chestnuts.

The small palms known in Spanish as pacaya (*Chamaedorea* spp.) are grown widely in Central America. Palm flowers, the unopened spathes or inflorescences are considered a delicacy and are boiled or cut into pieces and fried in batter.

The pejibaye is also very versatile (Almeyda and Martin 1980). It will grow well under conditions of low fertility, and its starchy fruits are nutritious and appealing. The palm has multiple trunks; old trunks can be cut, used for timber, edible hearts eaten, and they may be replaced by new shoots.

Several species of vegetable trees are used chiefly for their edible leaves, which are highly nutritious as well as good tasting. These include sunset hibiscus, chaya, Indian mulberry, and katuk (see "Leaves"). The drumstick tree (*Moringa oleifera* Lam.) is perhaps the best, because of the diversity of its edible products (table 13). Cassava, while often grown as an annual, can be left as a shrub or small tree, harvested for its leaves, and its tubers used when needed.

LEGUMINOUS TREES

Leguminous trees (table 14) afford several benefits to subsistence farmers in need of multipurpose crops on limited plots of land. Many are rapid-growing colonizers that produce a low- to intermediate-density wood, and are adapted to several environmental conditions. They are usually fertile at an early age and often produce seed copiously. Many add nitrogen to the soil and produce protein-rich foliage and seeds that serve as excellent forage and, in some instances, as food for man. The terminal branches of some can be cut and used as hay.

Mesquite [*Prosopis juliflora* (Sw.) DC.] is a drought-resistant species that can be planted in dry lowlands through montane habitats. It provides a heavy wood that is resistant to decay and is used in rural carpentry, for fuel, and to produce high-quality charcoal. The bark is used in tanning and the leaves and pods serve as forage. Children sometimes eat the sweet, nutritious pods, which were once a staple of Indians in what is now the southwestern United States. The tree also functions as a honey plant (its flowers attract bees that make honey from its pollen).

Mother of cocoa (*Gliricidia sepium* Steud.) is especially useful as living fenceposts. Stakes up to 2 meters long are capable of sprouting after being "planted" in the ground. The species grows fast, fixes nitrogen; and is good for windbreaks and foliage is plowed into the ground as fertilizer), and serves as an excellent nurse crop in multiple-cropping schemes with cacao, vanilla, and coffee. The wood is hard; it is used in construction and cut branches are used as fuel. The flowers and flowerbuds are edible, and the leaves serve as forage for cattle (but are poisonous to horses). It too is a honey plant.

Sesban (*Sesbania grandiflora* Pers.) is another fast-growing multipurpose legume that serves as a source of fuelwood and pulp. Tender green pods, young leaves, and flower parts are eaten in salads, curries, and soups. The leaves have a high protein content, making them an excellent forage or green manure. The bark yields a useful fiber, and dyes can be extracted from the sap. Other extracts from the plant have been used medicinally.

Tantan (*Leucaena leucocephala* de Wit.) is one of the most promising multipurpose trees; it

Table 13.—Tropical trees and large shrubs that can be grown for vegetables

Common name	Species	Climate preference	Uses	Notes
Breadfruit	*Artocarpus altilis* Fosberg	Tolerant of most tropical climates.	Fruits, seeds of seedy varieties.	Widely adapted; long, prolific bearing season; propagated from shoots, roots, or seeds.
Cassava	*Manihot esculenta* Crantz	Tolerant of most tropical climates.	Tubers, leaves	Widely adapted, propagated from cuttings.
Chaya	*Cnidoscolus chayamansa* McVaugh.	Tolerant of most tropical climates.	Leaves, growing tips	Propagated from cuttings.
Drumstick tree	*Moringa oleifera* Lam.	Dry Tropics	Leaves, young pods, roots	Propagated from seeds or cuttings.
Indian mulberry	*Morinda citrifolia* L.	Tolerant of most tropical climates.	Leaves, unripe fruits	High nutritional value prefers seaside environment, propagated by seeds.
Katuk	*Sauropus androgynus* Merr.	Tolerant of most tropical climates.	Leaves	High nutritional value, used as hedge, propagated from seeds or cuttings.
Millionaires' salad	Palms of many genera especially *Palmus*.	Varies with species	Heart	Palm trunk must be opened to obtain this vegetable.
Palm flowers	*Chamaedorea* spp.	Tolerant of most tropical climates.	Unopened inflorescence	Propagated from seeds.
Pejibaye	*Bactris gasipaes* H.B.K.	Tolerant of most tropical climates.	Fruits, heart	Widely adapted, propagated from seeds or shoots.
Plantain	*Musa* spp.	Humid Tropics	Green or ripe fruits, heart, inflorescence.	Widely adapted, readily accepted.
Sunset hibiscus	*Abelmoschus manihot* (L.) Medik.	Humid Tropics	Leaves, tender shoots	Short lived, propagated from cuttings.

Table 14.—Leguminous trees of special value on the tropical subsistence farm

Common name	Species	Climate preference	Uses
Acacia	*Acacia* spp.	Moderate to dry Tropics	Forage.
Bauhinia, poor-man's orchid.	*Bauhinia* spp.	Moderate to humid Tropics	Forage, fuel.
Blackhead	*Pithecellobium dulce* Benth.	Tolerant	Forage, hedges, pulp of fruits edible.
Cabbage angelin	*Andira inermis* H.B.K.	Moderate to humid Tropics	Shade, hard wood used for furniture.
Cassia	*Cassia* spp.	Tolerant	Forage, green manure.
India padauk	*Pterocarpus indicus* Willd.	Humid Tropics	Timber, shade.
Machette	*Erythrina* spp.	Moderate to humid Tropics	Forage, living fence, fuel edible leaves.
Mesquite	*Prosopsis juliflora* (Sw.) DC.	Dry Tropics	Leaves and pods for forage, fuel.
Mother of cocoa	*Gliricidia sepium* Steud.	Tolerant	Forage, fencing, hedge, flowers edible.
Sesban	*Sesbania grandiflora* Pers.	Dry Tropics	Forage, edible young pods.
Spanish oak	*Inga* spp.	Humid Tropics	Fuel, shade for multiple cropping, edible fruit pulp.
Tantan	*Leucaena leucocephala* de Wit.	Moderate to dry Tropics	Forage, fuel, young leaves and small pods edible.
Tibet tree	*Albizia lebbeck* Benth.	Moderate to dry Tropics	Leaves and pods for forage, fuel, wood for construction.

yields nutritious forage, firewood, and timber; it fixes nitrogen; and is good for windbreaks and shade. Timber production has ranged from 30 to 40 cubic meters per hectare per year. The variety 'Acapulco' has been used to provide overstory for coffee, cocoa, peppers, and vanilla in multiple-cropping schemes, and a Hawaiian variety yields up to 8 tonnes per hectare per year of edible dry forage that contains 25% crude protein. Young leaves and small pods serve as human food, and the pods also yield a dye. Tantan should not become a large part of the diet because it contains a toxic substance, mimosine, but there are cultivated varieties whose mimosine content is low.

Tibet tree (*Albizia lebbeck* Benth.) is a fast-growing species that provides a coarse-grained, strong, long-lasting wood used for furniture, paneling, veneer, turnery, posts for general construction, and fuel. It is tolerant of salt spray and drought, and is widely naturalized throughout the Tropics. The leaves and pods also serve as forage.

TREES FOR WOOD

Trees grown for timber should be tall, fast-growing species with straight stems, and have strong, fine-grained, woods with good machining characteristics. Fuelwoods, should have a high specific gravity (thus a high calorific value), dry fast or have a low greenwood moisture content, be easy to harvest and transport, regenerate easily by coppice or seedling, and exhibit favorable burning characteristics they should not smoke, spark, or release toxic substances when burning). Fence or hedgerow species may be like either of the above, but primarily, they should be easy to establish (preferably by stakes), grow fast, and should not corrode nails or wire. Trees that are good for timber, fuel or fence are listed in table 15.

Australian beefwood (*Casuarina equisetifolia* L.) is adaptable to a wide range of sites, grows fast, and is excellent as a windbreak. It also fixes nitrogen, and its wood is dense enough to make it a good fuelwood.

Capa (*Cordia alliodora* Oken), found between lat. 15° N. and 15° S., is a fast-growing, valuable wood prized for furniture, cabinetwork, millwork, and general construction. It has been used for shade in a multiple-cropping scheme with pejibaye and coffee, and suggested as a timber crop in a scheme with cacao, pejibaye, and tubers (Holdridge 1959).

Rose apple (*Syzigium jambos* Alston) is a hedgerow plant that provides edible fruit, firewood, posts, and charcoal. The trunk sprouts

Table 15.—Tropical trees of special value for forest products

Common name	Species	Site preference	Uses	Notes
Alder	*Alnus* spp.	Cool, moist, montane habitat.	Construction timber	Fixes nitrogen.
Australian beefwood	*Casuarina equisetifolia* L.	Dry to moist lowlands and foothills.	Windbreaks, hedges, fuel	Dense wood, can be propagated from cuttings, fixes nitrogen.
Balsa	*Ochroma* spp.	Moist to wet lowlands or foothills.	Construction of lightweight objects.	Very light wood, grows fast.
Burma toon	*Toona ciliata* Roem.	Moist to wet foothills and mid-altitudes.	Furniture.	
Capa	*Cordia alliodora* Oken	Dry to wet lowlands and foothills.	Timber, furniture, posts.	
Caribbean pine	*Pinus caribaea* Morelet	Lower elevations with high summer rainfall.	Timber.	
Coffee colubrina	*Colubrina arborescens* Sarg.	Dry to wet lowlands and foothills.	Construction timber, shade for other crops.	Water-resistant wood.
Eucalyptus	*Eucalyptus* spp.	Individual species adapted to variety of climates.	Timber, fuel	Grows fast.
False cedar	*Bombacopsis quinatum* Dug.	Dry to wet lowlands	Construction timber.	
Honduras mahogany	*Swietania macrophylla* King	Dry to wet lowlands	Timber, furniture.	
Kadam	*Anthocephalus chinensis* A. Rich. ex Walp.	Moist to wet lowlands and foothills.	Timber, veneer, cabinetwood	Grows fast.
Kapok	*Ceiba pentandra* L.	Dry to wet lowlands and foothills.	Boxwood, fiber, edible leaves.	
Melina	*Gmelina arborea* Roxb.	Moist to wet lowlands and foothills.	Pulp, posts	Grows fast.
Mexican cypress	*Cupressus lusitanica* Mill.	Foothills to montane habitat with high summer rainfall.	Timber, pulp.	
Monterrey pine	*Pinus radiata* Don.	Areas with winter rains and dry summers.	Timber, pulp.	
Ocote pine	*Pinus oocarpa* Schiede	Higher elevations with high summer rainfall.	Timber, pulp.	
Paradise tree	*Simaruba glauca* DC.	Lowlands, monsoon climate to rain forests.	Living fence, fuel, oil for soap.	
Rose-apple	*Syzygium jambos* Alston	Low to medium elevations, humid forests.	Charcoal, hedgewood	Edible fruit, heavy yield.
Spanish cedar	*Cedrela odorata* L.	Dry to wet lowlands	Furniture, fine construction	Fragrant, durable, termite-resistant wood.
Teak	*Tectona grandis* L.f.	Deep soils at low elevations, dry to moist climate.	Furniture.	

after cutting or pruning, and its wood production on poor soils has reached more than 15 square meters per hectare per year basal area.

Species of eucalyptus (*E. globulus, E. grandis, E. robusta* and *E. deglupta*) are quite adaptable, and they have been planted widely. They grow rapidly and are a good source of timber, posts, and fuelwood.

Spanish cedar (*Cedrela* spp.), mahogany (*Swietenia* spp.), oak (*Quercus* spp.), Australian cedar (*Toona* spp.), muskwood (*Guarea* spp.), and species of *Carapa* are good species to grow for timber because they have high-quality woods used in general construction, carpentry, and cabinet and furniture making. Many of these species are resistant to decay and drywood termites. Coniferous trees, such as pine (*Pinus* spp.), cypress (*Cupressus* spp.), and Norfolk pine (*Araucaria* spp.) are valuable sources of saw timber and pulp.

The following species are good sources of shade, fodder, fuel, and construction timber: acacia (*Acacia* spp.), Tibet tree (*Albizia lebbeck* Benth.), poor-man's orchid (*Bauhinia* spp.), shower tree (*Cassia* spp.), mesquite [*Prosopsis juliflora* (Sw.) DC.], powderpuff (*Calliandra* spp.), and immortelle (*Erythrina* spp.). Less common species that are also good sources of timber, fuel, and pulp are Mayan breadnut (*Brosimum* spp.), jacaranda (*Jacaranda* spp.), nutmeg (*Myristica* spp.), pui (*Tabebuia* spp.), almond (*Terminalia* spp.), trema (*Trema* spp.), goldenfruit (*Virola* spp.), and prickly-ash (*Zanthoxylum* spp.), and species of *Apeiba* and *Dalbergia*.

Forage Crops

Forage is herbaceous plants or plant parts fed to domestic animals. Forages are produced either in pastures where animals are allowed to graze, or in protected fields from which forage is cut and carried to the animals. Cut forage can be used fresh, dry as hay, or fermented as silage. Forage usually refers to such material as pasturage, hay, silage, dehy, and green chop (rather than the less digestible material known as roughage), but it can also refer to woody plants that produce succulent growth or browse.

Forage crops are important to the small farm; they can be grown easily, inexpensively, and rapidly, because they can produce continuously, they can utilize lands not easily used for other crops, and by serving as sources of animal feed, are indirect sources of meat, milk, and eggs. Some forage crops also help prevent erosion and some (legumes) can increase the nitrogen available in the soil for other crops.

SITE SELECTION

The small farmer should reserve his most fertile and easily managed lands for food crops and grains and leave lands that are steep, difficult to manage, or have shallow soils for pasture. Forages are ideal crops on some very steep lands, since they require little management and, once established, they can often be harvested by the animals themselves.

Long-term plans for land use must be kept in mind; lands planted to forages for several years can often be planted to trees, but such sites might be so compacted that deep plowing might be required to suit them for growing food crops. Ideally, sites should also provide animals with water, and protection from dogs and thieves. Natural fenceposts can be grown of local trees that can be planted as large cuttings and that root rapidly, such as mother of cocoa or bucar (*Erythrina berteroana* Urban).

SITE PREPARATION

As a general rule, site preparation begins by removing old vegetation. Burning may be the best method because it not only clears the site of unwanted vegetation, but it returns minerals to the soil. Its main disadvantage is that if it is followed by heavy rains, it causes leaching of the soil and possible erosion. Where practical, it is recommended that vegetation be cleared from strips that follow land contours and placed in continuous piles that follow the contour at the lower edge of the strip. As this vegetation rots, its nutrients will be restored to the soil. The piles also serve as barriers to hold such soil additives as lime or fertilizers in place, impeding their loss and allowing them more time to soak into the ground.

Using herbicides to prepare sites is worthwhile if they are available, inexpensive, and effective against the unwanted plants on the site. Herbicides are best applied in the early spring; the dead weeds or brush can be removed several weeks later. Grass-killing herbicides may be worthwhile where undesirable grasses predominate. Since herbicides are dangerous chemicals, they should neither be used nor recommended unless it is certain they will be used according to manufacturers' suggestions on the label and local laws and regulations.

For maximum growth, newly planted forages need a loose and penetrable soil. But plowing is often impossible, and when erosion is expected, undesirable. In such cases, unless the soil is naturally loose, some means of loosening the soil will have to be employed, at least in the immediate area of the individual plants.

Where soils are acidic and lime is available and economical to use, it should be applied to increase forage yields. For best results lime should be mixed into the soil, but it can be applied to the surface if crops are already established.

Table 16.—Propagation of some major tropical forages

Forage	Propagation material	Amount per hectare	Notes
Guineagrass	Seeds, 3%-5% viable	25 kg	Do not cover with soil.
Molassesgrass	Seeds, 80% viable	2 kg	Do not cover with soil.
Napiergrass	Mature stem cuttings	4.5 tonnes	Lay in furrows, cover with 2-5 cm soil.
Pangolagrass	Mature stem cuttings	2-3 tonnes	Lay in furrows, partially cover with 5-8 cm soil.
Paragrass	Mature stem cuttings	2-3 tonnes	Lay in furrows, partially cover with 5-8 cm soil.
Stargrass	Mature stem cuttings	2-3 tonnes	Lay in furrows, partially cover with 5-8 cm soil.
Tropical kudzu	Seeds, 80% viable	7 kg	Soak in water one day before planting; cover lightly with soil that has been inoculated with soil from a kudzu field.

Source: Vicente-Chandler et al. (1974).

PLANTING

Propagation of forages varies depending on the species (table 16). Forages are usually planted in rows for convenience, but seed can be broadcast if the soil is finely broken up. If the field is plowed, ridges or furrows should be 60 to 100 centimeters apart. If planting is done by hand the distances between plants or planting holes should also be 60 to 100 centimeters. Newly planted pasture needs protection from grazing until forages are well established, which may require 4 to 8 months.

The nitrogen fixation of legume forages can be increased by inoculating seeds with species of the bacterium *Rhizobium* before planting. Cultures of *Rhizobium* are commercially available, but seeds can also be inoculated by mixing them with soil from a successful planting.

Fertilizers are almost always helpful, and should be applied if the farmer can afford them. Usually, weeds must be controlled until pastures are well established. Mowing or cutting vigorous grasses with a machete will help eliminate weeds. Vigorous weeds and trees should be removed before they flower.

MANAGEMENT

As forage grows, it rapidly occupies the space available to it. In a mature field the ground will be covered with forage plants, the soil will be filled with the roots, and each plant will occupy a space limited by competition with neighboring plants; a static state is reached in which growth slows or even halts. Forage should be cut or grazed to make room for new growth before this mature state is reached.

When forage is mowed all plants are cut to similar heights, and since some species grow faster than others, the relative amounts of different kinds of forage in the field may change, beneficially or detrimentally. In some combinations of forage species, a species may dominate in one season and others in the opposite season. It is important that the combination of forage species used will not result in a undesirable species dominating the others.

Undercut or undergrazed fields may develop large quantities of old, tough, lignified stems that are not palatable. It may be necessary to cut or burn such fields to obtain palatable new growth. Although burning can eliminate some desirable plants (especially legumes) it can be desirable when fields are extremely weedy or large amounts of woody residues of grasses remain.

Pasturing or cutting removes mineral nutrients (especially nitrogen) from the soil and the more intensive the use, the more rapidly minerals are removed. If adding fertilizers is economically impractical, pastures should not be used so intensively that they suffer loss of plants or do not regrow rapidly enough for regular reuse. Rotational mowing or grazing is the most

desirable management scheme, since it allows unfertilized pastures to regrow after use. The optimum number of plots will vary from one situation to another, but five plots are often recommended.

While nutrients lost can be replaced by applications of mineral fertilizers or manure, purchased inputs should be kept at a minimum. Planting legumes in the forage will provide some nitrogen and will extend the life of the pasture. When pasture plots are used rotationally, enough nitrogen to sustain them is obtained from rain, fixation by legumes (and possibly some grasses), and manure left by grazing animals. Other elements, potassium and phosphorus, are slowly released (from insoluble forms in the soil) by weathering.

Rotation of pastures with other crops is also useful; the soil is broken by the plow, organic materials are incorporated into the soil, and improvements in drainage and erosion control can be made, all of which make the field more advantageous for replanting to forage crops. When pasture is rotated with trees, nutrients that are deep in the soil are brought to the surface and become available for other, more shallow-rooted plants (such as grasses).

GRAZING

Cut forage generally yields more per unit area than grazed forage. Cutting is the best technique for tall grasses even though cutting forage is laborious. But animals' weight gains may be greater with grazed forage than with the same forage presented to them in cut form because grazing animals can select the forage that is richest in protein (Vicente-Chandler et al. 1974).

Pasture plots should be grazed heavily for up to 1 week by animals. Grazing must be adequate. Enough animals should be introduced to a pasture so that all plants are grazed more or less equally. Undergrazing must be avoided because animals will eat the most palatable species first, affording less palatable species more space to grow, changing the composition of the pasture drastically. Within a short time less desirable forages or unusable weeds will predominate. Once plots are sufficiently grazed, animals should be removed from the plot and the untouched, undesirable plant species should be cut with a machete or otherwise removed so they cannot multiply and spread.

Overgrazing, caused by too many animals on the land for too much time or overfrequent use of a pasture, must also be avoided. Overgrazing reduces the regenerative capacity of the pasture.

There are some situations where rotational grazing is not preferred (Semple 1970), as in pastures where production is low and where special management techniques (fertilization, weed control) are not used. In such pastures, which often are found on poor tropical farms, animals receive a more uniform feed from non-rotated pastures. But even in pastures used more or less continuously, it is important to periodically eliminate the species not used as feed so they will not predominate.

STORAGE

Since forage is not produced uniformly throughout the year, the tropical dry season is often a time when supplies of forage are short and animals suffer. This problem can be resolved by cutting forage and storing it for lean periods. Making hay (dried forage) is one way to store it. The forage can be mowed by machine or cut with a scythe or machete. The cut forage should lie for several days until dry, and is then raked and perhaps baled, then carried to storage areas. Once the forage is cut, the weather is particularly important. Rain or any other excess moisture can spoil the hay, and drying it artificially is too costly and impractical on the small farm.

Forage can also be stored in a fermented form, silage. Silage is less nutritious than fresh forage but more nutritious than hay. Freshly cut forage is packed in upright storage bins (silos) or (more practical for small farms) in trenches dug into embankments. Molasses (enough to wet the grasses thoroughly) can be added to the packed fresh grass to encourage fermentation. Silage must be packed tightly and sealed to prevent or reduce entry of air. Successful fermentation of silage depends on the forage species and their water and sugar content. The organisms responsible for fermentation (mainly lactic acid and butyric acid fermentation) add to the nutritive value of the silage.

SELECTING FORAGES

The adaptability of a forage to site (elevation, soil type, temperature, and rainfall amount and

distribution) is perhaps the most important consideration in choosing forages to plant. A good forage grows well and survives with a minimum of care. Even though one should treat pastures and fields of forage crops as carefully as possible, a good forage should be able to resist neglect and abuse. A good forage can also live through the dry season to resume growth when it rains, and perhaps even continue to grow or maintain foliage and nutritive value while it is dry. If the forage is to be cut as hay, it should be uniform, manageable, and should keep well. A good forage is palatable throughout the year, and should regenerate rapidly. Of course, nutritional value and total yields should be as high as possible. Height of forage is an important characteristic. Tall forages may be easy to cut but are often difficult to graze.

Information on the suitability of forages for local sites is often available from agricultural extension or transfer agents; improved varieties or technology might be available. Available regional information should be consulted before establishing a pasture or forage crop.

Ordinarily, for a pasture to produce foliage throughout the year, several classes of forage must be grown together, in complementary combinations or in separate plots. Forage crops in which grasses and legumes are mixed have some advantages over pure stands. Nitrogen fixed by the legumes helps the production of grasses, which fix little or none of their own nitrogen. Combinations of grasses and legumes yield more protein and minerals than grass or legumes grown separately in both the Tropics and the Temperate Zone. A ratio of 25 percent legumes to 75 percent grasses is recommended for pastures.

Forages may be annuals or perennials. Annual legumes and annual grasses, such as sudangrass, sorghum, their hybrids, and corn, need more careful attention than perennial forages, but repay careful attention with very high yields.

The most important forage plants are the grasses. About 75 percent of the forage consumed in the Tropics is grass. Of the 620 genera and 10,000 species of grasses (Graminae) 350 or more species are cultivated, but only the relatively small number of grasses (perhaps 25) that predominate are the principal forage species (table 17).

The second major group of forages, Leguminosae), has 700 genera and 14,000 species. Although legumes are not as prominent in tropical pastures as grasses, (they are difficult to maintain in a mixed pasture), they are extremely important. They improve soil fertility and furnish protein to grazing animals. A few species are suitable for semipermanent stands (like alfalfa in the Temperate Zone), and there are a few leguminous trees that are useful as forage.

There are many other kinds of plants including annual herbs (forbs) and woody shrubs and trees (browse), that are valuable as forages at times. Although they are seldom cultivated, they may occur in unimproved pasture and may be convenient to use.

GRASSES

The hundreds of grasses produced in tropical pastures constitute an enormous and economically important resource. Although it is not possible to reliably classify grass species into groups larger than the tribe (an association of genera), the many genera are quite distinct, in their morphological characters physiology, reproduction, distinct uses, value as forages. It is not necessary that the subsistence farmer know or cultivate a large number of grasses, but he should be able to recognize the 5 to 10 most important species (those species discussed hereafter), and be able to cultivate several different species and take advantage of their distinct attributes (such as an affinity for certain parts of the farm, or special benefits for particular animals).

Tropical grasses often can be planted from seeds but seed production may be poor, and germination erratic because of poor seed viability, or seedlings may die before they are well established (which is usually associated with poor conditions for growth). Tropical grasses can also be propagated by means of normal or modified underground or prostrate aerial stems (rhizomes or stolons). A grass may form stolons or rhizomes or both; sometimes the stolons are no more than upright branches (tillers) from the principal stem that root at their base. Such grasses form clumps (tufts), which can be broken into numerous plants for replanting. Stoloniferous and rhizomatous grasses often fill a soil so thoroughly that they stifle new growth (become sodbound). In fact, thick weedy stands of rhizomatous grass can be difficult to eradicate, once well established.

Tropical grasses are more suitable in areas

(*Continued on page 46.*)

Table 17.—The best grasses for the tropical subsistence farm

Common name	Species	Characteristics	Method of propagation	Disadvantages
Bahiagrass	*Paspalum notatum* Fluegge.	Perennial; creeping; spreading; widely adapted; used as pasture or cut forage.	Seeds, rhizome pieces	Herbage yields not high; nutritional value moderate.
Bermudagrass	*Cynodon dactylon* (L.) Pers.	Perennial; stoloniferous and rhizomatous; prefers moderately dry areas of the subtropics; used principally as pasture.	Cuttings	Weedy; not suitable to hot, humid Tropics.
Buffelgrass	*Cenchrus ciliaris* L.	Perennial; tufted or rhizomatous; prefers dry areas; used principally as pasture; resists overgrazing.	Seeds	Yields inadequate in moist areas.
Colored guineagrass	*Panicum coloratum* L.	Perennial; tufted; a tall grass; adapted to dry areas; used as pasture or cut forage.	Seeds.	
Columbusgrass	*Sorghum almum* Parodi	Perennial; tufted, rhizomatous; adapted to rather dry subtropical areas and many soils; used as pasture, hay, and silage.	Seeds.	
Corn, maize	*Zea mays* L.	Annual; tufted or single stems; vigorous and productive; can be used before or after cob is produced; used as cut forage or silage.	Seeds.	
Dallisgrass	*Paspalum dilatatum* Poir.	Perennial; tufted; spreading; a very leafy, coarse, grass; adapted to hot, sunny areas with high rainfall.	Seeds	Slow to establish.
Elephantgrass, napiergrass.	*Pennisetum purpureum* Schumach.	Perennial; tufted but spreading; adapted to hot, humid Tropics; very vigorous and productive; used as cut forage, sometimes as silage.	Stem cuttings.	
Guineagrass	*Panicum maximum* Jacq.	Perennial; tufted; widely adapted; used as pasture, hay, or cut forage.	Seeds, clump divisions	Weedy; poor seed viability.
Kikuyugrass	*Pennisetum clandestinum* Hochst. ex Chiov.	Perennial; thickened rhizomes and stolons; adapted to middle altitudes of Tropics; used mostly as pasture.	Stolon pieces.	

Merkergrass	*Pennisetum purpureum* Schumach.	Widely adapted; used mostly as cut forage, sometimes grazed.	Stem cuttings	More drought tolerant than elephantgrass.
Molassesgrass	*Melinis minutiflora* Schrad.	Perennial; tufted; viscous; mat forming; adapted to steep areas and poor soils; used as pasture.	Seeds	Pubescence objectionable; needs to be fully established before use.
Pangola	*Digitaria decumbens* Stent.	Perennial; tufted with long stolons rooting at the nodes; persistent; well adapted to lowland Tropics and monsoon climate; used mostly as pasture, sometimes as hay.	Stolon pieces	Aphid and virus susceptible.
Paragrass	*Brachiaria mutica* Stapf.	Perennial; prostrate except for flowering shoots, rooting at nodes; vigorous; used as pasture or cut forage.	Shoot cuttings	Poor as silage.
Pearlmillet	*Pennisetum americanum* (L.) Schum.	Annual; usually tufted; widely adapted; used as pasture, hay, or silage; good seed production on first regrowth.	Seeds	Short lived.
Rhodesgrass	*Chloris gayana* Kunth	Perennial; stoloniferous; widely adapted; used as pasture or hay.	Seeds, rarely cuttings or stolons.	Poor as silage.
Setaria, bristlegrass	*Setaria anceps* Stapf. ex Massey.	Perennial; tufted; adapted to medium rainfall and subtropical conditions; used as pasture, cut forage, or silage.	Seeds, clump divisions.	
Sorghum	*Sorghum bicolor* (L.) Moench.	Annual, some varieties perennial; tufted; widely adapted; drought resistant; used as cut forage or silage.	Seeds.	
Sudangrass	*Sorghum sudanense* Stapf.	Annual; tufted; vigorous; erect; widely adapted; drought resistant; high yields; used as cut forage or silage; improved varieties available.	Seeds	Not good for hot, humid Tropics.
Stargrass	*Cynodon nlemfluensis* Vanderyst.	Perennial; stoloniferous; widely adapted; used mostly as pasture.	Stolon cuttings	Weedy.
Teosinte	*Euchlaena mexicana* Schrad.	Annual; tufted; maizelike; prefers dry areas; used mostly as cut forage, sometimes as hay or silage.	Seeds.	

with semiarid and monsoon climates than in areas where it rains year round. Grasses are pioneering plants on sites where forested areas are disturbed, and are usually succeeded by shrubs or trees, but some may permanently exclude the forest.

Grasses can be adapted to medium temperature (15° to 20° C) and medium light intensities, but for most tropical grasses, growth rate increases with increased temperature and light intensity up to more than 30° C. Most tropical grasses are day neutral (they flower equally well throughout the year) or short-day sensitive (they flower best during short days). They differ remarkably in nutrient requirements and adaptibility to soils and rainfall patterns.

Some grasses are best suited for grazing and some are best cut and carried to the animals that will use them. The grasses that are best cut are those that cannot withstand the damage caused by grazing or are tall and could be trampled easily. Table 17 summarizes information about the principal tropical grasses, and the following discussion gives further details about selected species (from Bogdan 1977).

The genus *Brachiaria* includes a large number of species with a wide range of adaptability in the Tropics. Paragrass (B. *mutica* Stapf.), for example, tolerates swampy conditions and also grows well in drier conditions. Paragrass is planted vegetatively; it is a perennial with coarse runners that root at the nodes and produces erect shoots with broad, hairy leaves. It is a very aggressive species and under poor management conditions tends to crowd out all other grasses.

Some of the other perennial brachiarias that produce excellent yields are signalgrass (*B. brizantha* Stapf.), congograss (*B. ruziziensis* Germain & Evrard.), *B. decumbens* Stapf., and *B. dictyonera* Stapf. Brachiarias in general are excellent forages. Some, such as signalgrass, produce viable seed, but most are vegetatively propagated. Congograss produces viable seed in Australia, but when grown in Puerto Rico, it does not produce seed and must be propagated vegetatively. One species, *B. radicans* Tanner, has been found to be toxic to animals.

Of 10 species of the genus *Cynodon* that were evaluated in the central mountains of Puerto Rico over a 2-year period, giant stargrass (*C. plectostachyus* Pilgor) proved the most productive (Vélez et al. 1979). It is a good forage for the somewhat dry Tropics. Stargrass (*C. nlemfuensis* Vanderyst) has been planted extensively, and is an outstanding forage for the humid Tropics, as is bermudagrass [*C. dactylon* (L.) Pers.].

The genus *Digitaria* covers a large number of widely distributed species, the most well known of which is pangola (*D. decumbens* Stent.). Pangola is a perennial grass that produces long stolons, grows up to 50 centimeters in height and spreads quickly, forming dense vegetation in a relatively short time. It flowers abundantly in the Tropics.

A large number of *Digitaria* species were evaluated in Puerto Rico, and one, *D. eriantha* Steud., yielded over 40,000 kilograms of dry forage per hectare per year (Sotomayor 1973). There are many new releases of *Digitaria,* mostly from the University of Florida, which have contributed to the improvement of this genus. Excellent yields (over 35,000 kilograms per hectare per year) were obtained in Puerto Rico with the cultivar 'Slenderstem' (*D. pentzii* Stent.) harvested every 45 days (Sotomayor 1973).

Buffelgrass (*Cenchrus ciliaris* L.) is well known for its resistence to drought. It is propagated by seed and makes an excellent contribution to grassland farming in the dry Tropics.

The guineagrasses (*Panicum* spp.) are very important grasses in the Tropics. They have long been recognized as excellent for grazing, green soilage, hay, and silage. Guineagrass is often propagated asexually because its seed germination is very poor (around 5 percent), a fact that limits its use. If establishment of an economical pasture is desired, the farmer must choose varieties that are able to produce enough viable seed.

Elephantgrass or napiergrass (*Pennisetum purpureum* Schumach.) is grown in most tropical countries because of its high yields. It is a tall forage that grows in clumps and produces abundant tillering. It is propagated by stem cuttings and seldom produces viable seed. Many varieties of this grass have been developed and tested with excellent results. Potential yields are enormous; studies in Puerto Rico show that some varieties are capable of producing nearly 50 tonnes of dry matter per hectare per year (Velez 1979). Kikuyugrass (*P. clandestinum* Hochst. ex Chiov.) is an excellent forage because of its high food value and tolerance to heavy grazing, but at low elevations it is restricted to the subtropics.

Hybrids of sorghum [*Sorghum bicolor* (L.) Moench] and sudangrass (*S. sudanense* Stapf.) are excellent material for pasture and forage. Yields are high and compare very well with those

of other forages. Many hybrids and improved types that are good as feed supplements in slack growing seasons and as reserve feed in drought periods are available from commercial sources.

If properly utilized, forage sorghums and sorgo-sudan hybrids could be of tremendous value as a source of forage for the small farmer. Sorghum can be utilizes for silage and its grain is an excellent energy source.

FORAGE LEGUMES

Only a few of the more than 10,000 species in the family Leguminosae are useful as forage; some are unattractive to animals because they are pubescent, or because of their odor or taste, and many are trees that could be grazed, but whose foliage grows out of animals' reach. But since the family is tropical in origin, most legumes are well adapted to the Tropics. The best tropical legumes for forage are listed in table 18.

Legumes are especially good as forages because, in addition to their ability to enrich the soil with nitrogen, they contain large amounts of protein (near 20 percent dry weight). They contain about the same amount of fat as grasses, and less sugar.

Almost all legumes are planted from seeds, and are often alternated with rows of grass. Irregular germination sometimes occurs when hard seeds do not imbibe water well. To avoid such problems, seeds can be scarified by boiling them in water for a few minutes.

The dry matter yields of legumes per unit area are not as high as those of grasses. Although a few legumes can be grown in pure stands, most grow better in mixed plantings with grass. Forage legumes in pure stands are mostly used as hay because they are prone to be trampled and destroyed when used as pasture. Grass-legume mixtures are used as hay, silage, or as pasture. Mixed plantings are easy to establish but must be managed carefully. Overgrazing will eliminate the legumes and leave only the grass.

A legume's ability to fix nitrogen depends upon the presence of bacteria of the genus *Rhizobium*. But since adding inoculant to the seed may be too expensive or impractical, it may be best to use legumes that are not specific in their *Rhizobium* requirement. Some of these are pigeonpea [*Cajanus cajan* (L.) Huth.], purple bean (*Macroptilium atropurpureum* Urb., and *M. lathyroides* Urb.), finestem stylo [*Stylosanthes guyanensis* (Aubl.) Sw.], and vigna (*Vigna* spp.). There is no perfect solution to the problem of *Rhizobium* inoculation on the subsistence farm (*Rhizobium* strains vary in specificity) but inoculating seed by mixing seed with dampened soil from a successful planting of other legumes is often sufficient.

Centro (*Centrosema pubescens* Benth.), from South America, is a climbing or trailing vine that is an excellent forage. It is vigorous and productive, and grows and survives well when planted with grasses. Although it is native to the hot, humid Tropics, some centro varieties are drought resistant. It is established from seed, but harvest of seeds is difficult because flowering and pod development continue over a long season. The seeds are often hard and they should be scarified before planting. One serious drawback for the subsistence farmer is centro's *Rhizobium* requirements. They are highly specific and good establishment cannot be expected unless seeds are inoculated. Centro regrows readily when grazed or cut and is seldom destroyed in grass pastures. It can even crowd out less desirable foliage. It may not be very palatable to cattle during the wet season, but its nutritional value is high.

The cowpea, a useful, multipurpose legume from tropical Africa, is now widely grown for its vegetable forms (see p. 21) as well as a cover crop, for green manure, or pasture. It is adapted to moderate rainfall, but is also found in the humid Tropics, where it sometimes does very well. Many varieties have been bred, and the best forage cultivars come from Australia. Bushy annual and viny perennial forms both exist, but only the vines are used as forage. Cowpea grows quite rapidly, and can smother other herbage. It is especially useful on the subsistence farm because it can be used first as a source of dried grain and later as forage. The protein content of the herbage is high.

Finestem stylo [*Stylosanthes guyanensis* (Aubl.) Sw.] is a very promising, much-branched, rather erect perennial herb from South America that is highly adaptable and is now widespread. It is particularly recommended by its ability to produce in poor or acid soils. It can survive long droughts but also grows well in hot, humid climates. Stylo is planted from seeds, which are usually hard enough to require some scarification. Inoculation is often unnecessary. Except when it is grown for seed production, stylo is normally

Table 18.—Leguminous forages for the Tropics

Common name	Species	Characteristics	Disadvantages
Acacia	*Acacia albida* Del.	Tree, prefers dry areas, used as cut forage or hay.	Said to damage milk.
Calopo	*Calopogonium mucunoides* Desv.	Annual, used as cut forage.	
Centro	*Centrosema pubescens* Benth.	Perennial climbing vine, widely adapted, used as pasture.	Main growth during short days.
Cluster bean	*Cyamopsis tetragonoloba* (L.) Taub.	Annual herb, widely adapted, used as cut forage.	Main growth during short days.
Coral bean	*Erythrina* spp.	Tree, widely adapted, used as cut forage.	
Cowpea	*Vigna unguivulata* (L.) Walp.	Annual vine, widely adapted, used as pasture or cut forage.	
Finestem stylo	*Stylosanthes guyanensis* (Aubl.) Sw.	Perennial herb, used as pasture.	
Greenleaf desmodium	*Desmodium intortum* (Mill.) Urb.	Perennial upright herb, widely adapted, used as pasture or cut forage.	
Golden gram	*Vigna radiata* (L.) Wilczek.	Annual herb, used as cut forage.	
Horse bean	*Canavalia ensiformis* DC.	Annual vine, widely adapted, used as cut forage.	Dry seeds are poisonous.
Hyacinth bean	*Dolichos lablab* L.	Weakly perennial vine, widely adapted, used as pasture or cut forage.	
Kordofan pea	*Clitoris ternatea* L.	Perennial climbing vine, widely adapted, used as cut forage.	Main growth during short days.
Lototonis	*Lototonis bainesii* Baker	Perennial herb, used as pasture.	
Peanut	*Arachis hypogaea* L.	Annual herb, prefers sandy soil, use as forage can be combined with use for seeds.	
Perennial soybean	*Glycine wightii* Verdcourt	Perennial vine, widely adapted used as cur forage.	
Pigeonpea	*Cajanus cajan* (L.) Huth.	Short-lived perennial, widely adapted, used as cut forage.	
Siratro	*Phaseolus atropurpureus* DC.	Perennial herb, used as pasture or cut forage.	
Spanish clover	*Desmodium uncinatum* (Jacq.) DC.	Perennial herb, widely adapted used as pasture or cut forage.	
Tantan	*Leucaena leucocephala* (Lam.) de Wit.	Tree, widely adapted, used as pasture or cut forage.	Some forms contain poisonous alkaloid.
Tibet tree	*Albizia lebbeck* Benth.	Tree, prefers dry areas, pods and cut foliage used.	
Townsville stylo	*Stylosanthes humilis* H.B.K.	Perennial bush, used as pasture.	
Tropical kudzu	*Pueraria phaseoloides* (Roxb.) Benth.	Perennial trailing or climbing vine, used as pasture.	Pubescence irritates some animals.
Twinflower	*Dolichos uniflorus* Lam.	Weakly perennial low vine, used as pasture, cut forage, or green manure.	
Velvet bean	*Stizolobium deeringianum* Bort.	Annual bushy vine, used as cut forage.	

grown with grasses. Its initial growth is slow, however, and it should not be grazed too early. It is usually grazed because when cut as hay it loses much of its nutritive value.

Greenleaf desmodium [*Desmodium intortum* (Mill.) Urb.] is a large, vigorous perennial herb from South and Central America that has upright stems or is much branched. It prefers a warm, rather wet climate, but is widely adapted. It is especially popular in Australia. Greenleaf desmodium is established from small seeds that need to be inoculated with a specific *Rhizobium* species for satisfactory establishment. Established pastures should not be overgrazed or cut too low, because they will not then regrow rapidly. Desmodium can be grown either in pure stands or with grasses to improve its palatability.

Other *Desmodium* species, such as Spanish clover [*D. uncinatum* (Jacq.) DC.], are also used as forage. Spanish clover is also from South and Central America and is quite similar to Greenleaf desmodium. It is persistent, has high yields, and is easy to establish (but, as with *D. intortum*, inoculation with a specific *Rhizobium* species is necessary).

The hyacinth bean is in widespread use as an edible legume or pulse (see p. 21) as well as a forage crop; it has been reported to be the most drought resistant of the legumes, but it also grows very well in humid areas. It may be annual or perennial, and usually grows vegetatively as a long, vigorous vine during long summer days, and when planted during short days, often grows in bush form. All varieties flower in winter, and a few flower in summer as well. The hyacinth bean is very vigorous, yields heavily, and can be cut frequently. It is usually used in pasture (often with grasses) and is sometimes used as hay or silage.

Lotononis (*Lotononis bainesii* Baker) is a low-growing perennial herb from South Africa that spreads by horizontal stems, rooting at the nodes. It is an important forage in the subtropics because of its high quality herbage and its ability to survive and grow with vigorous pasture grasses. It is short lived (1 to 3 years), however, and needs a moist climate (it does not resist drought). It can be propagated by seed, but it requires inoculation with a specific *Rhizobium* strain. It can also be established from pieces of stem.

The perennial soybean (*Glycine wightii* Verdc.) is a highly variable species from tropical and subtropical Africa. It is fairly long lived (2 to 5 years), grows well with grasses, and is fairly drought resistant. It is a perennial trailing, procumbent, or climbing vine planted from seeds that are sometimes successful without inoculation. It may be difficult to establish in hot, dry weather. When planted with grasses, it should be given sufficient time to grow before grass is seeded. Although the perennial soybean is used principally for grazing, hay and silage have been prepared from it. Its nutrient content is a little less than that of other legumes.

The pigeonpea is a very variable bushy legume that can also be used as human food (see p.). Pigeonpeas are tolerant of many soils, are easy to grow, and the seeds need not be inoculated. They will produce well in semi-arid regions but are also tolerant of tropical rains. Because most varieties grow vegetatively during most of the year and flower as days shorten, pigeonpea is a good forage for the dry season (when forage is usually scarce). Some races are perennial and can produce year round. The foliage is used fresh, as hay, and occasionally as silage. Its nutritional value is high, and its use can result in good animal weight gains.

Tantan is a small to medium-sized, fast-growing tree (see p. 35) from Mexico that is now widespread (and often weedy). Tantan is drought tolerant, but is capable of very rapid growth during rainy seasons. It is a very good source of protein and is highly productive in dry areas where other forages do not grow well. It withstands severe grazing or cutting and, in fact, is difficult to eliminate (except with systemic herbicides). Despite the fact that it requires a specific *Rhizobium* species, it apparently has been established almost everywhere in the dry Tropics. Seeds are long lived and germinate irregularly over several years. The trees must be grazed when very young to keep them small. The foliage, pods, and seeds contain an alkaloid, mimosine, that can cause loss of hair in some animals and metabolic disorders in all that eat it in quantity. The cultivated varieties that have a low mimosine content should be used when tantan is to be grown as a crop.

Tropical kudzu [*Pueraria phaseoloides* (Roxb.) Benth.], which originated in tropical Asia, is now found throughout the hot, humid Tropics. It is a

Table 19.—Miscellaneous pasture and forage plants for the tropical subsistence farm

Common name	Species	Characteristics	Disadvantages
Cactus	*Cereus* spp.	Perennial succulent herbs with spines	Often too spiny to be eaten.
Cadillo	*Urena* spp.	Annual herbs with spiny seedpods, widely adapted, used as pasture.	
Calabash tree	*Crescentia alata* H.B.K.	Fruits are used.	
Commelina	*Commelina* spp.	Annual or perennial succulent herbs, used as pasture or cut forage.	
Euforbs	*Euphorbia* spp.	Wild plants, mostly herbs; used as pasture.	Many species are harmful or poisonous.
Hibiscus	*Hibiscus* spp.	Perennial shrub, used as cut forage.	
Maya breadnut	*Brosimum alicastrum* S.W.	Tree, prefers dry areas, cut foliage and fruit used.	
Morningglory	*Ipomoea* spp.	Perennial climbing or trailing vine, used as pasture or cut foliage.	
Prickly pear	*Opuntia* spp.	Perennial succulent herbs with spines	Often too spiny to be eaten.
Trumpet tree	*Cecropia peltata* L.	Fast-growing tree, used as cut forage.	
Wild fig	*Ficus* spp.	Tree, used as cut forage.	

very vigorous, fast-growing, trailing vine that is often weedy and is difficult to control. It grows rapidly after grazing and is long lived in pastures with grasses. It seems best suited to very poor soils or steep areas where grasses are hard to establish. It may be planted from seeds, crowns, or cuttings of rooting vines. The seeds are hard and need scarification. While kudzu needs inoculation for good growth, its *Rhizobium* needs are not specific. It grows best as days shorten (just before flowering). Like all legumes, kudzu is very nutritious, but its chief advantages are its vigor and high production. Leaf pubescence makes kudzu unattractive to rabbits.

MISCELLANEOUS FORAGES

There are plants other than grasses or legumes that can serve as useful forages on the subsistence farm (table 19). These plants are usually neglected in publications on pastures and forages, but many are used by animals. At times, these plants may be an important part of the animals' diets. Some of them are weedy and are commonly present along fence lines, and some are trees that can be used in fences or maintained as hedges for cutting or grazing. They are more difficult to control than grasses and legumes, but may nevertheless be an important asset on the subsistence farm.

Afterword: Animals and Milk

It is usually not difficult to produce enough protein on the small farm. Despite the myth common in some developed countries (where, in fact, meat intake may be too high) that meat is the essential element in the diet, some meat in the diet is desirable, but it does not have to be a large amount if legumes are eaten in quantity as meat substitutes.

The bulk of the protein needed by the body can be obtained from meat and legumes, which also contribute most of the B vitamins and iron needed in the diet. Meats and legumes do not, however, contain enough of the sulfur-bearing amino acids, so they should be complemented by breads and cereals.

Meat production on small farms is often hampered by lack of refrigeration or curing facilities. In such cases maximum use can be made of resources by raising only small animals. Then the animal can be completely used 1 or 2 days after killing. All parts should be used if possible. Small animals that eat foliage, especially grasses, are recommended. The rabbit is often favored because it is easy to care for, reproduces rapidly, and has a gentle nature (Bennett 1975). Its protein and its sparse fat are both of high quality.

Although the guinea pig is often overlooked as a meat source (U.S. Department of Agriculture 1970) domesticated guinea pigs are marketed as a household meat product in the mountains of South America (Gade 1967). Guinea pigs can live and multiply in a cage on the lawn with no food except the grass, and no water except what they extract from what they eat. The cage is moved daily, and the animals act as a "lawnmower". Small birds, quail, chicken and, where possible, geese and ducks are also good meat sources (Ash 1970, USDA 1972), but their use depends on whether the subsistence farm can produce enough appropriate feed. In large plantings of broad leaved vegetables, geese and ducks are a good means of converting unwanted grass to meat.

The appropriate number of animals to keep on a small farm are listed in table 20.

Milk and milk products are often neglected on small farms because they are the most difficult class of food to obtain there. But studies show that without milk, growth is retarded in man and many species of animals. And milk is needed by all persons, not just children. Long-term calcium deficiencies mean reduced growth, abnormal bone development, irritability, muscle spasms, and reduced health and longevity.

There is no complete substitute for milk. Milk supplies about 100 different nutritive substances. It is an outstanding source of riboflavin and protein, and is the only excellent source of calcium. It is difficult for people to obtain enough calcium without using milk products. Some foods supply calcium in lesser amounts (sardines and

Table 20.—The appropriate number of animals to have on a subsistence farm

Animal	Number	Notes
Hens for eggs	20	Replace 10 each year.
Chickens for meat	50-60	Start 5 each month.
Ducks for meat	2-3 pair	Allow ducks to hatch their young; replace 1 pair each year.
Rabbits	8-10	Keep 2 males, the rest females.
Guinea pigs	30-40	Keep 1 male for every 10 females, eat excess males and young animals.
Milk goat	2	Alternate freshening.
Pigs	2	1 young, 1 older, purchase piglets periodically.

other small fish eaten whole, oysters, other shellfish, ground eggshells, leaves, and some shoot tips) and these should be used as much as possible when milk or milk products are not available. Whether calcium that is ingested is used by the body depends on the quality of the diet itself. Calcium uptake is increased by high protein, high vitamin D, and low to moderate fat consumption and reduced by consumption of oxalic acid, phytic acid (both found in many leaf vegetables) and excess fats. Thus attention should be given to the entire diet as it effects calcium uptake and not just calcium sources.

On the small farm the best solution to the milk problem is to raise milk goats (often considered the poor man's cow). Although the purchase of goats represents an initially large investment to some, it is one that is repaid again and again. Goats are small, and are not difficult to take care of. The techniques for rearing them are well known, and excellent breeds are available almost everywhere in the Tropics.

Goats can consume remnants of food and farm byproducts, and when carefully staked and moved from site to site, can control weeds along roadsides and ditches, under fruit trees, and around buildings. Goats can use as pasture those small areas around the farm that are neglected or otherwise unusable. But goats must never be let free to wander the farm, nor should they be allowed to overgraze and destroy their pasture. Two well-managed female goats can provide milk year round for a family of six. Male goats, of course, must also be available. When supplies exceed the family's needs, cheese and other milk products can be made. For more detailed information on raising goats see Lindahl (1978).

Soymilk is an inexpensive milklike food that has some of the advantages of milk, and can be prepared on the small farm. Soymilk contains about the same kind of protein as cow's milk, but has less fat, carbohydrate, calcium, phosphorus, and riboflavin and more iron, thiamin, and niacin. Soybean milk is often fortified with calcium lactate, but this is impractical for the subsistence farmer.

The following recipe will provide enough soymilk for 1 day for a family of four to six people: Wash 2 cups (about 500 grams) of dried soybeans. Soak the seeds overnight in 10 cups (1.75 liters) of water. Discard the soaking water and wash the seeds in fresh water. Measure the volume of the swollen soybeans and put aside three times that volume in a container. Grind the seeds as finely as possible (using the best hand or electric mill or blender available). Mix the measured water with the beans during the grinding process. Strain the ground soybean-water mixture through a cloth filter bag or a piece of cotton cloth. Squeeze the filter gently at first, then more firmly until the liquid has been removed. Heat the liquid in a double boiler and maintain the temperature near boiling for one-half hour. Cover the liquid and store in a cool place. If refrigeration is not available, soymilk should be used as quickly as possible; it is as perishable as animal milk.

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