DEVELOPMENT OF FEED AND FOOD PRODUCTION SYSTEMS FOR SUBSISTENCE ECUADORIAN INDIAN CULTURE

By

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DEDICATION

This dissertation is dedicated to God the Father, Son, and Holy Spirit, the Triune God, who has influenced my life in so many ways. May He use it to accomplish His purposes.

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The dietary protein of inhabitants in Ecuador's Amazon rain forest has been obtained primarily from hunting-gathering activities. Increased colonization of traditional hunting grounds has begun to diminish the supply of wild meat.

The primary objective of this study was to develop production systems with the capacity to satisfy the subsistence requirements of a tribal family of six and the nutritional needs of their Rhode Island Red chicken flock containing 45 hens and 90 young meat birds.

The study was conducted in Ecuador's northeast region around Limoncocha located in the continuously moist, humid Amazon river basin. The tribal groups involved were lowland Quichua, Cofan, and Secoya, who were utilizing subsistence agricultural practices on small, hand-worked land areas.

Preliminary screening of crop kinds and cultivars was accomplished at Limoncocha. Surveys were conducted to describe indigenous agricultural practices. Demonstration plots in tribal areas were planned using

information generated at Limoncocha. These plots were designed to introduce new crops to the Indians and observe their response to them. Rhode Island Red chickens (Gallus gallus) were placed on kudzu [Pueraria phaseoloides (Roxb.) Benth.] pastures and fed supplemental grains.

Ten human and 10 poultry diets were formulated to create systems available for selection by farmers. The crops used were known to grow in the area. Rows in the linear programming matrix were designed for the computer to calculate the levels of 20 nutrients in each of the diets which, when meeting standards, would insure adequate nutrition. Values representing levels of nutrients in one kilogram of each crop were placed in the columns of the linear program matrix to satisfy the needs of chickens and humans and maximize nutrient production from the farm. Nutrient producing land was the limiting resource. The matrix was also designed to evaluate a production unit containing one poultry and one human diet the farmer might select.

Daily egg production from 10 of the 17 flocks studied was less than 30 percent. Maize (Zea mays L.) indigenous yields were 163 g/m^2. Peanuts (Arachis hypogaea L.) were frequently devastated by rodents but when undamaged could produce 4 tons per hectare. Common beans (Phaseolus vulgaris L.) under indigenous management produced 40 g/m^2 dry seeds weighing 20 g/100 seeds. Cowpeas [Vigna unguiculata (L.) Walp.] were observed to be more disease resistant and vigorous than common beans. The Chenise Red cowpea cultivar produced 180 g/m^2 dry seed weighing 8 g/100 seeds. The comparatively small seed size was a hinderance to rapid acceptance of this cultivar. Larger seeded cowpea cultivars with lower yields and less resistance to water damage were selected by the tribespeople. Much interest in the new cultivars or crops was shown when the tribespeople planted seed produced in the demonstration plots.

Poultry research showed 54 percent egg production was realized from birds on kudzu supplemented with fish meal. Fish meal spoils rapidly in the tropical environment and therefore cannot be recommended. Maize supplementation registered the second best production of 35 percent. This level was not much different than that experienced within indigenous agriculture.

The computer calculations showed two plantings each year of one hectare of land area will adequately feed a family of six and a flock of 135 chickens. Nutrient production from the farm can be maximized by producing jackbean (*Canavalia* spp.), soybean [*Glycine max* (L.) Merr.], or peanuts.

Adequate supplies of food and feed can be produced from agricultural activities in the event wild meat supplies should no longer be available. Nutrients can be produced in adequate quantities and proper ratios to meet the needs of humans and chickens within the subsistence agricultural pattern of Ecuadorian Indian culture.

INTRODUCTION

Increased population on a world scale with its concomitant pressure on the world resources has been a long time concern to many people. In 1798 ~~1978~~ Malthus predicted world famine in the near future (Sanchez, 1976). Not many people heeded the warning. More recently there are those who are making the same prediction. Now even more members of the world community are becoming concerned.

An increase of population and decrease in food supply is a future problem of Ecuador's Amazon rain forest—a result of an increased interest in the area through the discovery of petroleum and building of roads. With the construction of a road to service the pipeline, and the pressure of overpopulation in the mountains, serious thought needs to be given to the proper management of this newly opened reserve to serve the agricultural and social needs of the country. Extensive information gathering and careful planning will be necessary to insure the wise development of the region.

The colonists moved in with high expectations and knowledge of the production systems fitted to the area of their origin but not suited to the new site. As individuals and groups began gathering existing, scattered information appropriate to the needs of the newcomers, the realization came that very little knowledge exists.

Mankind has developed a large body of technological information. Unfortunately most of the agricultural work has been done in temperate zones. Much research is required to start with the temperate technology to adapt it to the humid tropics. Sterling Wortman, vice-president of the Rockefeller Foundation, cautions scientists to understand the area where they are working (Anonymous, 1975). He urged direct involvement at the operational level. Jean Mayer continued the theme by suggesting consideration be given to the importance of rabbits, goats, eggs, fruit, and other such items not usually considered when world trade items are discussed (Anonymous, 1975).

Inhabitants of Ecuador's Amazon rain forest, like many in similar environments elsewhere, have developed a system which is in balance with the ecology of the area and effectively supplies food for subsistence. It is a mixture of protein producing hunting-fishing activities and agricultural husbandry supplying carbohydrate for the diet and some income from the sale of eggs, chicken, and beef cattle. This production system has served well to supply the needs of the tribal groups living along the rivers of the previously unexplored Amazon Basin. No doubt the practices developed within this system reflect principles of management which should be understood before major changes are suggested.

The recent colonizing of traditional hunting grounds has upset the historic stability of the system. Food from the forest is becoming less available. New food and feed production systems must be developed which are properly fitted to the climate, soils, and anthropology of the region.

The research should concentrate on solving the problems of subsistence agriculture. This system is understood by the Indians and colonists whose most pressing and immediate need is adequate food production. Commercial agriculture is a future and less important consideration at this time because the required agricultural infrastructure is being developed. The technology necessary must be more fully developed before successful, large scale agriculture can become a reality in the region. Excluded from this discussion are all plantation crops with the well developed technologies produced from years of research.

Solving subsistence production problems will give valuable information for specific soils, climates, crop adaptability and management practices. If mistakes are made the losses will not be enormous. Thus, a body of information will emerge giving a solid base upon which crop production systems can be developed. The increased capacity of properly designed systems will produce surpluses for distribution outside the humid forest.

The government of Ecuador, in consultation with the Food and Agriculture Organization of the United Nations, determined each family in the rain forest requires 50 ha. of land. This would provide an area large enough to maintain pastures for beef cattle and produce food from a slash and burn agricultural system. Dr. John Bishop, working in the area, observed the Quichuas allow eight years to elapse before planting an intensive crop a second time. He also observed a family requires one hectare of firewood a year for meal cooking. There are indigenous tree species that could be cultivated and with good management would insure a perpetual supply of fuel. Research planning should consider this context.

It appears protein production is the critical area in which change must take place. The modification of habitat for wild animals, lending to their eventual disappearance, and the fact the major carbohydrate source is low protein manioc, requires that attention be given to agriculturally produced protein. One approach to the problem would be to grow protein rich crops for direct human consumption or indirect intake through meat and eggs produced by the crops fed to domestic animals.

First one should determine what protein rich crops can be grown. Then management practices must be developed to fit the crop. Both the physical environment and the social needs must be considered. The crops finally selected should be managed in such a way to insure continuous production over the years, with minimum inputs brought in from outside.

The focus of research must not be exclusively on protein; carbohydrate production must also be maintained. To insure adequate nutrition requires the improvement of agricultural practices already followed as well as introducing new, adapted crop species about which very little information exists. Feed and food production systems fitting the activities of subsistence agriculture must be developed to insure an undiminished food supply to the Indians. Perhaps surpluses could be produced even with the loss of protein from the forest.

Many individual crops must be surveyed to ascertain climatic adaptation as well as the ability to meet the needs of the various tribes living in the forest. The rain forest Quichua Indians are the best agriculturists in the area and even they have some problems. It has been observed the pole type common bean (_Phaseolus_ _vulgaris_ L.) grown presently seem to be poorly adapted to the environment as shown by the sparse number of leaves on the plant and low yields (600 kg/ha). Cowpea (_Vigna_ _sinensis_ L.) is represented in some fields by too few plants to have any influence on yield. It seems cowpeas are hardier and better adapted to the research area than the common beans. This finding agrees with a statement in the literature noting the existence of ample evidence that adapted cowpea varieties are more productive than common beans at lower elevations in the Americas (Rachie, 1974).

Work must be done on other crops as well but the needs vary according to the tribe. Peanuts (Arachis hypogaea L.) have been grown successfully with yields up to 4000 kg/ha by an Auca Indian named Dayuma (Table 65). She learned the culture of peanuts from the Quichua tribe who are the peanut farmers of the jungle. The members of the Cofan Indian tribe enjoy eating peanuts but have no production experience. The closely related Secoya tribe and Siona tribe have even less experience with the crop. All Indian tribes have planted seed of a tall-growing local maize. The introduction of high lysine maize might contribute to improved nutrient production compared with the local maize or an improved non-opaque maize. Sunflower (Helianthus annus L.) or sesame (Sesamum indicum L.) might also contribute to protein quantity and quality to supplement or substitute for diminishing jungle protein.

Jackbeans (Canavalia spp.) and velvetbeans (Stizololium spp.) will grow in the humid tropics. The question might be asked, "What place do they have in a food-feed system?" Velvetbean could have a dual purpose. It would be used mainly as a green manure crop but the beans could be used for poultry feed or possibly, if properly cooked, as a human food.

Poultry constitutes an important source of protein and is already well-understood by people throughout the tropical world. Increasing dependence on this source of food could be used as a substitute for the diminishing forest protein. Present poultry management practices of the Indians allow the chickens to roam freely to scavenge for whatever can be found. However, chickens are monogastric animals which means they are unable to manufacture certain amino acids which must come from the feed intake. The quantity of nutrients obtained from foraging is difficult to evaluate as is the carrying capacity of chickens per unit ground area. The assumption has been made that if production of chicken meat and eggs is to be increased sufficiently to relieve some of the loss of forest protein, the hens will have to receive greater quantities of farm produced, high-quality protein supplements. The question is which crops can be used and can they be grown in the area?

The need to increase poultry production was evident upon the conclusion of an interview with a colonist living at Limincocha. He had a flock of six hens and three roosters. He was collecting one egg every other day. The birds ate only what they could find. He observed the rate of lay doubled when maize was scattered on the ground. This represented a 17% production from the flock.

A better understanding of present practices and the production realized from indigenous management is needed. A pool of information must be developed that will increase feed production for poultry, which in turn will increase bird production, to make more food available for human consumption.

All the discussion has been focusing on the second sentence of a familiar saying, "If you give a man a fish you feed him for a day. If you teach him how to fish you feed him for a lifetime." The research reported here was designed to teach ourselves first (develop a body of information) so men can be taught to produce their own food.

LITERATURE REVIEW

Crop Characteristics—General

Maize

Maize is the third most important crop in the world. Traditionally a very small amount is exported, and mainly is consumed in the country where it is grown. Maize is an important staple in the tropics in human diets (Purseglove, 1975).

This crop was the basis for Azetec and Mayan cultures within the slash and burn system. It was planted in randomly placed holes, in untilled soil. Maize was discovered in the new world and soon spread throughout the tropical world. In some tropical sections of Africa where it could be grown,maize is considered the preferred grain over sorghum and millet which are grown only in dry climates where maize is not adapted.

Reasons given for the wide acceptance of the crop are: high yields per hour of labor input, the nutrients are concentrated, ease of transport, protective husk cover, no special machinery required for harvest or shelling, and no loss due to shattering. In addition, if dried properly it stores well. It can be eaten when in the milk stage or allowed to dry to use as a grain. Humans in great numbers have shown a preference for this cereal. Frequently it is used in tortillas. In many Andean countries maize is made into a drink by chewing the grain to introduce enzymes which begin the fermentation of the starches.

On a dry weight basis it has as many calories as rice. Maize is deficient in tryptophan, lysine, and niacin but rich in thiamine. Populations whose main diet consists of maize may develop pellagra resulting from niacin and tryptophan deficiencies. This grain is high in energy, low in fiber, and is easily digestible.

A large number of cultivars exist which adapts the crop to a wide range of environments. Maize is best adapted to the warmer parts of the temperate regions and humid subtropics. It is considered marginal in semi-arid climates and the ever-wet tropical evergreen rain forests. The crop grows best on well-drained, well-aerated, deep, warm loams and silt with organic matter and high levels of nutrients. Periods of clear warm weather between rain storms are conducive to best growth. In the tropics 600 to 900 mm of rainfall during the growing season, but not less than 200 mm, are required. Temperatures at tasseling should be between 21-30° C.

Eberhart (1974) described a system for producing synthetic varieties by intercrossing lines known to combine well to produce plants with good characteristics and high yields. The farmer can save seed from a synthetic for growing a new crop for three or four generations after which he must obtain new seed.

A mutant gene which causes the endosperm to be floury was observed to increase lysine and tryptophan and referred to as high lysine or opaque 2 maize. Feeding studies have shown kwashiorkor and marasmus were prevented when malnourished children were given this maize.

Rice

Rice (*Oryza sativa* L.) is one of the three most important crops of the world. Often it is the main source of calories and is eaten with pulses, vegetables, and meat.

The husks are removed by pounding with a pestle in a mortar. The object is to keep the grain intact. Brown rice emerges when only the husk is removed. To produce white rice further milling removes the outer parts including the aleurone and germ layers. This process removes much of the protein, fat, minerals, and vitamins, including vitamin B_1 and thiamine which prevent beriberi.

In upland rice production, soil type is a very important consideration. It must be able to store large quantities of moisture. Deep soils are needed to allow the development of extensive root systems. This crop is more tolerant of acid soils and water logging than many of the other cereals. It is suited to rotations with oilseed crops, cassava (Manihot spp.), taro (Colocasia esculenta L.), maize, sorghum, and legumes grown during the drier times of the year.

It is customary to harvest each panicle with a knife. Sickles are becoming more prevalent. The panicles are then spread out to dry in the sun. After drying some it is threshed at which point it is likely to contain 18 to 20 percent moisture. It is important that drying is not rapid or the grain will check causing more broken kernels when milled. Rough rice (paddy) can be stored quite successfully at 13 to 14 percent moisture. Higher moisture levels result in mold development (Purseglove, 1975).

Sorghum

Sorghum is thought to originate in the north-east quadrant of Africa. It is considered likely that Sorghum bicolor developed in Ethiopia as selections were made from Sorghum arundinacea which existed as wild grasses. They are considered to be annuals or tufted perennials without rhizomes. The selections have proven valuable for food production. This species was further divided according to use for forage or grain production, the latter identified by the more compact inflorescence.

This crop is the fifth most important world cereal. It is the main staple in the drier parts of Africa, India, and China. Sorghum is an excellent choice in areas too dry for maize. It has good drought resistance, and also can withstand waterlogging so can be used in wet soils. It has been replaced with maize in some areas indicating sorghum is a less popular grain. If maize can be grown in an area, introduction of sorghum likely will be futile (Purseglove, 1975).

In some areas of the world sorghum is grown for food and is too valuable to be fed to animals while in other areas it is used for chicken feed. Eberhart (1974) considers this crop an energy foodstuff because 70 percent of the grain is starch. The quantity of protein is about the same as that found in maize. It is deficient in the essential amino acids of lysine and methionine. Two Ethiopian lines were observed to be high in lysine showing protein efficiency ratios (PER) equal to those recorded for opaque 2 maize.

Common Beans

Common beans are primarily used in the dry form but in some locations of the tropics the leaves are used as a pot herb. In Latin America and Africa this crop supplies most of the protein consumed by humans. In India the people prefer other pulses. Common beans were believed to originate in Mexico and Peru contemporary with maize. These two crops were paid in tribute to Aztec kings when this culture flourished. The Spaniards and Portuguese carried the beans from its origin to the old world in the 16th century.

The hundreds of cultivars are divided into bush and climbing types. There are varying lengths of vines making the distinction somewhat difficult at times. Generally the climbing types require a longer season to mature. Seed colors and sizes vary. The Pinto bean is an example of the four types of seeds recognized. This bean has a pinkish-buff testa with small brown spots and are from 1-1.5 cm long. This group is known as medium field beans. Pea or navy beans, 8 mm or less in length, belong to a second group. The remaining two groups are red kidney beans with seeds 1.5 cm long and the narrow beans with seeds 1-1.5 cm long.

Common beans do not grow well in the ever-wet tropics but are adapted to the practice of seeding near the end of rainy seasons in the wet-dry tropics. Excessive rains cause flowers to drop and high humidity encourages fungal diseases. In tropical Africa beans are planted as an intercrop with maize, sweetpotatoes, cotton, or coffee. Seed used for planting is a mixture of cultivars, often with mixed colors.

C. A. Francis (1974) observed field beans are the most important food grain legume based on world use. Since beans store well when dry, a significant quantity enter world trade. Beans are interchangeable in nutritional value with other food grain legumes. All are high in total protein but somewhat deficient in the sulfur containing amino acids. Beans are rich, however, in lysine and tryptophan which supplement the low levels in the cereals. For this reason maize and beans make a good combination.

Cowpea

According to Purseglove (1974) the term cowpea includes not only the Vigna sinensis [(L.) Savi ex Hassk.] referred to as the common cowpea but also to Vigna unguiculata [(L.) Walp.] known as the catjang cowpea grown in Africa and Asia and the Vigna sesquipedalis [(L.) Fruw.] known as the asparaguspea or yard long bean which is grown primarily for its immature pods. Consideration here focuses on the V. sinensis, the seed of which is so variable that classes were created to describe it. The black-eye group of seeds are not crowded in the pod and are white with a black hilum. The crowder type has a testa color black, speckled, or brown. The group referred to as cream produce seed with that color. The final grouping contains pods that are purple and seeds with buff or maroon eye.

Cowpeas will grow under wider climatic conditions than common beans. The asparagusbean can grow under higher rainfall conditions than the common cowpea. They will grow on a great variety of well-drained soils which includes very poor acid soils. In Africa it is common to broadcast the seed and thin the stand later using the plants pulled up as pot herbs. Cowpeas are the second most important pulse crop in Africa with common beans in first place. Some breeding work has been done with this crop in the USA. One hybrid contains resistance to nematodes, cowpea wilt, and charcoal rot.

Jackbean or Swordbean

According to Purseglove (1974) the jackbean is also known as the horsebean with the scientific name of Canavalia ensiformis [(L.) DC]. It is a native of Central America and the West Indies and is distributed throughout the tropics. It is a hardy, deep-rooted crop with drought resistance and shade tolerance (Purseglove, 1974).

The swordbean (<u>Canavalia gladiata</u> [(Jacq.) DC]) is similar to the jackbean but grows wild in Asia and Africa where it originated. It has been grown primarily in India but is distributed throughout the tropical world and used as a vegetable. Commonly it trails on walls or trees near houses.

Soybean

<u>Glycine max</u> [(L.) Merr.] is thought to originate from a hybridization of two wild growing legumes in southern China. Soybeans have been used in China since before written records and have been grown in Manchuria, Korea, and Japan for centuries. Not much interest was shown elsewhere in the world until the 20th century. The increase of acreage in the United States was stimulated by the need for edible oils and fats during World War II. The crop has been introduced in most tropical countries recently with little interest shown in Africa, India, and the West Indies because the dried soybeans are difficult to cook. Since other adapted pulses and oilseeds exist to meet the dietary needs, little incentive exists to accept this new crop. Brazil introduced soybeans and now is producing over 10 million tons a year (Purseglove, 1974).

The soybean is one of the most important sources of oil and protein in the world. In eastern Asia where soybeans have been used for years it is utilized as a green vegetable. Leng and Whigham (1974) reported that nutrition from immature soybeans compares favorably to shelled green beans, peas, cowpeas, and broadbeans. Inhibitors to digestion are not a hindrance at this stage of development. Purseglove (1974) reported that Asians also eat soybeans as a ripe seed either whole, split, or sprouted. In addition they process the grain to produce soya milk which is valuable as a protein supplement for infants and can be used to produce curds and cheese if desired. Leng and Whigham (1974) reported that the raw, mature seed contains factors which inhibit or retard protein digestion. This problem can be overcome by heating the seeds. One practice is to boil the seeds in water for 30 minutes which will effectively denature the inhibitors.

As an industrial crop soybeans compare favorably with such other oilseed crops as peanuts, sesame, and sunflower in yields and value per unit of land area. As a protein crop soybeans are quite good.

Leng and Whigham (1974) wrote the climate required for soybeans is similar to that needed by maize. Moisture is needed for germination, but soybeans can withstand short periods of drought during the vegetative phase. A combination of high temperatures and low rainfall should be avoided because this reduces grain and oil yields along with a reduction in quality. Providing the soil does not become waterlogged a wet season will not damage the crop. Optimum growing temperatures are from 20 to 25° C.

Purseglove (1974) observed many cultivars are recognized in the Far East. There is a wide variation in time to maturity; height and plant type; seed size, color, oil, and protein content; and the uses to which the crop is put. Black soybeans are richest in protein and lowest in oil content. The yellow seeds are the reverse which reflects the fact protein content varies inversely with oil content. Protein content can vary from 27-50 percent, higher than any other pulse and most other foodstuffs. In addition the seeds contain large quantities of the B complex vitamins. However, the protein is somewhat deficient in the sulfur containing amino acids.

Peanuts

Peanuts as a source of vegetable oil is second only to soybeans. Purseglove (1974) observed India is by far the largest producer. Most of this is consumed locally with a very small part entering world trade, which is also true throughout the tropics. The groundnut project started in 1946 in East Africa was expected to increase world production of fats; however, it became a lesson teaching the importance of adequate research before mass production is planned. Disease was the problem in one area. In another, rainfall was low and irregular with the prevalence of drought years. The conclusion of those involved in the plan was that peanuts do not lend themselves very well to mass production. This conclusion was not supported in northern Nigeria. The same year large quantities of peanuts had been produced in that area. The production had been so abundant there was a shortage of transportation equipment to move the peanuts from the production areas (Sanchez, 1976). The major oversight in the East African attempt was to be unaware of the weekly rainfall probabilities. Sanchez (1976) believes this failure illustrates average rainfall values are inadequate data for use by planners.

Hammons and Caldwell (1974) discovered peanuts are thought to have originated in eastern Bolivia in the Plata basin and spread throughout the tropics from there. The crop is grown in large quantities in some of the tropical countries of Asia, Africa, and South America.

Peanuts are used frequently as a subsistence crop. Peanut protein contains considerable quantities of lysine and tryptophan which are in short supply in the cereal and starch crops. The cereal and starch crops contain fairly high levels of methionine and cystine which are in short supply in peanuts; thus peanuts balance the cereal and starch crops. Peanuts have the additional advantage of containing large quantities of calcium, phosphorus, and iron along with the vitamins of thiamine, riboflavin, and niacin. Vitamin A and ascorbic acid are deficient in peanuts.

Peanuts are a warm season crop grown in areas with 1000 mm of rain a year. Purseglove (1974) cautioned there should be at least 500 mm of rain during the growing season but hot dry weather is required for ripening and harvesting. Hammons and Caldwell (1974) reported that the crop is not adapted to areas with continuous heavy rainfall because it is so difficult to cure the crop after harvest before molds form. Savanna lands or similar ecological zones are ideal. Within this environment it is best to select loose soils with the well-drained, sandy loams being desirable for ease of peg penetration and pod formation. Well-drained soils minimize mold damage while pods are still in the soil. Heavy soils hinder peg penetration, make digging difficult, adhere to the kernels, and stain them. This crop makes efficient use of residual fertility and grows well without fertilization following such heavily fertilized crops as cotton, maize, and sorghum. High levels of calcium must be present in the soil or added at pegging to avoid pods containing poorly formed kernels.

Sunflower

The origin of sunflower is said to be in the southwestern United States. Sunflower was an important source of nutrition to the Indians in that region long before the discovery of the New World. The largest acreages now are found far from the U. S. origin in the northern Caucasus, Ukraine and Volga river regions of Russia. Sunflower also produces well in the Balkans and Argentina (Purseglove, 1974).

Zimmer and Caldwell (1974) observed subtropical production of sunflowers in Ethiopia, Morocco, Tanzania, and Turkey. In these areas they are grown in rotation with maize, sorghum, and millet. Sunflower is also intercropped with peanuts and the food grain legumes. Sunflower is almost as tolerant of heat and drought as sorghum and millet. The crop seems to be adapted to all savanna regions in the tropics and subtropics. It grows well under climatic conditions of sunny weather, intermittent rainfall, moderate to low relative humidity, and a wide range of soils. Few varieties have been developed specifically for the tropics. Yields presently are from 200 to 350 kg per ha. The low value was reported from some tropical countries. I believe these yields could approach the upper part of the range with adapted varieties and suitable management. Purseglove (1974) observed that this crop is not adapted to the wet tropics because too much rainfall during the early stages of growth or cool, wet weather at ripening favors the development of the fungus Botrytis cinerea.

Zimmer and Caldwell (1974) described the crop as having a well branched tap root system extending laterally for several meters. The tap root of this crop is not as deep as many tap rooted plants. The result of this root configuration is the crop requires deep, well drained soils which maintains the crop in poorer soils under drier conditions than can be survived by shallower rooted crops.

Classification of sunflowers is on the basis of use for oil production or consumption. When compared to the confectionary group the seeds of the oil class are smaller, darker, and have a lower hull content.

The varieties used for food have heavier hulls which do not adhere as tightly to the kernel making decortification easier. The protein quality of sunflower kernels has a net dietary value of 93 percent compared to egg protein. This value compares to 62 percent for soybean and 69 percent for peanut. Sunflower protein is slightly deficient in lysine but is more nearly balanced in its amino acid content than most other vegetable proteins. Sunflower seed is high in calcium, phosphorus, and iron. It also contains high levels of thiamine, riboflavin, and niacin.

Hybrids have been produced but have a narrower ecological adaptation compared to the open-pollinated varieties. In those areas where sunflower is to be developed, selection of open-pollinated varieties is the better choice and should be conducted under conditions representative of the area.

Bird damage is a troublesome problem. Purseglove (1974) found that breeding programs have selected for peduncles with crook-neck characteristics. The head hangs facing downward making feeding by the birds difficult. Other characteristics used in selection have been single large heads, early maturity, large kernels with low hull content for chewing as well as resistance to insect and disease damage.

Zimmer and Caldwell (1974) observed the heads are mature when the backs are yellow and the outer bracts turn brown. In drier climates curing can take place in the heads if bird damage is not a problem. Heads must be harvested before they drop to the ground if this practice is to be followed. If bird damage is imminent, harvest can take place after the seeds are mature. Special care is required to dry the seed to 10 percent moisture to avoid the formation of mold.

Sesame

According to Purseglove (1974) sesame comes from a weed growing in Africa. Today the crop is grown in Africa, Asia, and parts of Latin America where it is used for oil production and food. In Africa and Asia the fried seeds are eaten in soups and when mixed with sugar are consumed as a sweetmeat. In West Africa the young leaves are used in soup as a vegetable. Over a broader area the stems are burned for fuel and various parts used in native medicines.

India is the largest producer of the crop with very little entering world trade. Little breeding work was done on the crop until a single plant with indehiscent capsules was observed in Venezuela in 1943. From this discovery single-stemmed plants were developed which ripens more uniformly from base to tip.

Yermanos (1974) found it common to plant seed lots containing mixed colors. Creamy white seeds are preferred in world trade because the seed coat is thin and can be removed easily by abrasion. Other seed colors are dark-red, brown, and nearly black. After the thin seed coat is removed the kernel is quite high in protein making up 22 percent of the weight of the seed. The amino acid profile is unique among grain legumes and oilseeds because it contains ample supplies of the sulfur containing amino acids of methionine and cystine but like other seeds is low in lysine. Sesame protein can supplement the food grain legumes in human diets. Sesame combines well with cereal, banana, and other starchy diets. Sesame is effective when used to extend such scarce foods as meat, milk, eggs, and fish.

The crop grows best in areas of moderate to abundant rainfall but is not recommended in rain forest conditions. Savanna environments best fit the requirements of this crop. The crop will grow where there is limited rainfall if the soils are deep and store moisture well. Sesame is not a legume, so it requires nitrogen either from the soil or applied fertilizer. Sesame is a good crop for subsistence farming because it is easily harvested and processed by hand. The wide range of maturities allows it to be used as a major crop during a long season or a secondary crop in a relay multiple cropping system.

Wingbean

Wingbean requires 180 to 270 days from planting to fruiting. The crop has few pests and average yields of 400-500 kg per ha of seed have been recorded with records of up to 2500 kg per ha. The seeds have been used as a pulse but fresh green pods, leaves, and tubers were used as vegetables. Because of versatility this crop should be exploited much more than presently (National Academy of Sciences, 1971).

Crop Characteristics as Chicken Feeds

Pasture

Pasture can only substitute for 10 percent of the dry matter in a poultry diet. If the mash and grain intake are limited, 22 percent of the concentrate can be saved by utilizing pasture. This practice could be dangerous if applied to laying hens. The rate and efficiency of lay might decrease. The conclusion of Bird (1948) was that 13 to 20 m^2 of permanent pasture was required per bird. Pasture can reduce the amount of concentrate required by broilers but only takes the place of alfalfa meal and vitamins in the laying and breeding mashes.

When commenting on the nutrient value of pasture, Tribe et al. (1963) observed the levels of energy and nutrients are low and percent fiber high. Even though digestive systems enlarge to accommodate a high fiber diet, an insufficient amount of nutrients could be ingested. The result is decreasing growth rates and egg production. Chicks younger than eight weeks consume little herbage. Chickens prefer legumes to grass when selection is possible and leaves are consumed before stems.

Pasture is a good source of riboflavin, thiamine, nicotinic acid, vitamin C, and vitamin E. The content of calcium and phosphorus depends on the soil fertility on which the grass is growing, and soils in the tropics often contain less nutrients than those in the temperate zone.

Protein Rich Crops

In the selection of protein rich feedstuffs for poultry diets one must consider protein, mineral, vitamin, and energy levels along with the possible presence of toxic factors. The value of plant protein is not only evaluated by the amount present but also by the amino acid distribution.

Liener (1953) discovered that most legumes contain not only trypsin inhibitors but hemagglutins. Hintz and Hogue (1964) added to the list a number of substances called an antivitamin E factor found in common beans. They are identified by the name Phaseolus Antagonists to Tocopherol (PAT). One group is alcohol soluble and heat stable with the second responding in the reverse.

Tannins are known to be toxic and are present at high levels in the bird resistant sorghums. Scott et al. (1969) wrote the tannins in peanut skins depress the nutritive value of that feedstuff. Lease et al. (1960) showed sesame meal interferes with the biological activity of zinc. Cuca and Sunde (1967) found that sesame binds calcium probably as a result of the high phytic acid content forming a chelate with calcium.

Soybean. Soybeans contain 37.9 percent protein, the highest of all common seeds. The crop is low in calcium with no Vitamin D and very little carotene. Raw soybeans decrease the utilization of carotene which increases the amount of that vitamin required in the diet. Riboflavin and thiamine levels are lower than those found in the cereal grains. The niacin concentration is greater in soybeans than maize (Morrison, 1959).

Since soybeans are likely to be grown in areas where processing is unavailable it is important to look at the research done with raw, unextracted beans. There seems to be some disagreement concerning the effectiveness in diets. Upon reviewing the literature, Morrison (1959) concluded raw soybeans should not replace more than one-third of the animal protein supplements.

Latshaw (1974) concluded there is no concensus on the question of the need to heat soybeans before feeding them to hens. He expressed the belief that raw soybean protein can be present in fairly large quantities in layer diets without any harm. He supported this by quoting the results of Summers et al. (1966) showing no difference in egg production or egg quality between hens receiving raw soybeans and those fed soybean oil meal. Different results were reported by Hill and Renner (1963) who found raw soybeans did not maintain maximum production confirming results reported by Rogler and Carrick (1964).

Ham et al. (1945) observed the trypsin inhibitor in raw soybeans restricted the normal response of chickens. Yen et al. (1973) concluded chicks fed soybean cultivars demonstrating low trypsin inhibitor activity gained faster and more efficiently than chicks consuming diets containing raw Clark or Harsoy cultivars containing normal levels of the inhibitor.

Sunflower. Sunflower seed is often used in birdseed mixtures and has been recommended for poultry diets. Halman (1943) concluded the seed was an excellent substitute for cereal grains. On an equal weight basis sunflower gives more energy than maize.

Cereal Grains

Maize and grain sorghum lead the other grains in net energy levels. The protein level is low and so is the quality as measured by the amino acid profile. As a class the grains are not rich in phosphorus or calcium. Vitamin D is lacking and with the exception of yellow maize none contain any significant vitamin A. This group is fairly rich in thiamine but low in riboflavin. Vitamin E is quite high in all members (Morrison, 1948).

Maize. Maize is considered to be one of the best cereals for all classes of livestock. Apart from the higher vitamin A content there is no nutritional difference between white and yellow maize. If the diet was carefully formulated to insure an adequate supply of nutrients yellow corn could make up to 75 percent of the diet though the more common levels would be around 60 percent (Morrison, 1948).

Harms and Waldroup (1962) observed methionine was the limiting amino acid in an opaque 2 maize-soybean oil meal diet. When regular maize was substituted the diets were deficient in both methionine and lysine.

This difference could only be produced when the protein level of the diet was suboptimal at 11 percent.

Chi and Speers (1973) observed only slight differences in weight gains over normal maize diets when chicks were fed either opaque 2 or regular maize in diets with protein levels at 14, 18, and 22 percent. These researchers concluded the protein quality of the opaque 2 maize was similar to its genetically related normal maize. Gains in weight and feed conversions were no different when the maize protein was formulated in equal amounts in soybean meal diets.

Rice. The quality of protein in rice is similar to that of wheat. Its amino acid profile resembles other cereals. The digestibility of the protein in the whole grain is 96.5 percent. Lysine levels are low. The levels of vitamins A, C, and D are very low but considerable quantities of vitamins D, B, and E are present.

Hinton (1948) showed over 50 percent of the thiamine of the grain was in the embryo and 35 percent in the aleurone layer emphasizing the importance of brown rice being selected when formulating diets. Rough rice was described by Morrison (1959) containing fiber equal to that in oats but carrying lower protein than maize.

Other Crops

Papaya [Carica papaya (q.v.)] fruits have been fed to pigs with good results but must be supplemented with concentrates. Cowpeas are often too expensive to feed to most animals but have been given to poultry. No toxicities have been reported. As this feedstuff becomes a greater part of the diet, pig weight gains decrease (Gohl, 1975).

Jackbeans and swordbeans are quite similar. The seeds of the former are considered to be edible but will be somewhat poisonous if large quantities are ingested. The crop is used mainly as a human food of green manure. Raw pod and seed meals should not exceed 30 percent of cattle diets due to the fact that large intake levels are toxic. If the pods and seeds are heat treated they are harmless (Ghol, 1975). Rachie (1974) observed that the apparent toxin is hydrocyanide produced after a severe temperature change. Purseglove (1974) recommended toxin removal by boiling in salt water. Gohl (1975) observed that swordbean seeds contain the toxin saponin yet have the same application as jackbean.

Velvetbean seeds can be added to the diets of all classes of livestock. Pigs are not able to use more than 25% uncooked velvetbean in their diet (Gohl, 1975). Purseglove (1974) observed these seeds are eaten in times of famine but can be consumed after boiling in repeated changes of water and the testa is removed.

Diet Formulation—Human

The diet of the consumer is an important factor determining the selection of crops grown by subsistence producers. The formation of adequate diets requires a knowledge of nutrient levels considered toxic or deficient.

Nutrient Limits

Pike and Brown (1975) observed simple protein deficiency in humans probably never existed. Whenever kwashiorkor was observed energy deficiency symptoms were present. The current thinking is to refer to formerly discussed protein deficiencies as protein-calorie malnutrition. Possibly simple protein malnutrition could exist only in populations consuming starchy, low protein foods. In these special cases the symptoms are those associated with protein deficiency which are: changes in the texture and pigmentation of hair, pellagra-type dermatitis, and other less obvious symptoms.

Energy needs are determined by observing the work done by the body and the heat lost from the body. Protein requirement is determined by the need for the individual amino acids which are the building blocks used to construct protein molecules. The amount and proportions of the essential amino acids in the diet is an important consideration because these cannot be manufactured by the body. One of the measures of protein quality is the amino acid score. The score generally correlates with biological studies. In practice it is calculated by adding together the milligrams of lysine, methionine, cystine, and tryptophan in one gram of protein in the diet and dividing by the content of those amino acids in the protein of a high quality reference food such as milk or egg. The answer is multiplied by 100. The lower the score the lower the quality of the protein (Pike and Brown, 1975).

Minerals too must be present in the diet. Hegsted et al. (1952) concluded that nine out of ten men in a Peruvian prison required less than 400 mg of calcium a day. This level is well below the recommendations but calcium equilibrium can be maintained at this level by some people who have adjusted to low calcium intakes over a long period of time. Phosphorus is often discussed with calcium since there seems to be a ratio to be maintained between them. The significance of this ratio in the diet is not clear. The recommendations for both minerals were set at 800 mg per day giving a one to one ratio.

The requirement for sodium is not known but the usual intake of adults is 6 to 18 grams a day. Adults need about 2.5 grams of potassium a day and the usual diet generally is adequate. Manganese requirements are unknown, but no deficiencies have been observed with the usual intakes of 2.5 to 7 mg per day. Magnesium deficiencies are not expected because this element is present in adequate quantities in most foodstuffs.

The amount of fat in the diet should not exceed 35 percent of the total calories because high fat diets were linked to heart disease. Clinical deficiencies of vitamin A will appear if intakes are below the range of 23 to 40 IU per kg of diet. Nicotinic acid or niacin deficiencies appear when intakes are below 4.4 mg per 1000 calories of energy. For riboflavin 0.6 mg per day is adequate. A choline deficiency is not likely to appear because plants are well supplied. Panothenic acid needs were estimated to be from 5 to 20 mg a day which is usually found in the diet.

Consumption Limits

William Waters (personal communication), having many years of contact with jungle Quichuas, supplied information used in the linear program to establish food consumption limits. He stated a family of two adults and two children will eat from two to four baskets of yuca a week with each basket weighing from 60 to 70 pounds. A family of six will use six heads of cooking bananas a week. They will eat two to three boiled eggs per person per week. Three to 10 chickens will be eaten by the family during a six month period. White common beans, boiled in the soup, are consumed at approximately two pounds of dry beans per week. Peanuts are scarce but enjoyed. The people boil mature kernels and eat as many as they can find.

In the northeast of Brazil people were observed to eat per person per year about 12 kg rice, 47 kg beans, 8 kg corn flour, 60 kg yuca and yuca flour, 6 kg chicken meat, 3 kg eggs, and 10 kg bananas according to the Getulio Vargas Foundation report (1970). From another food consumption study nation-wide figures for Colombia (1971 data) showed each person consumed on the average 53 kg of yuca in a year. The other figures were 80 kg cooking bananas, 23 kg rice, 44 kg potatoes, 41 kg corn, and 31 kg unrefined brown sugar.

Diet Formulation—Poultry

Nutrient Requirements

Information in the literature and provided from personal contacts was helpful when calculating maximum or minimum nutrient levels. These values were used in the linear program when selecting high quality diets.

Energy and protein needs and the relationship between the two will be discussed in sections to follow. Scott et al. (1969) observed excess magnesium can be a problem when dolomitic lime is fed. Research showed if there is more than 0.7 percent magnesium in the diet the droppings are likely to be extremely wet. Performance is affected when the level reaches 1.0 to 1.2 percent. When the level reached 1.96 percent it was found to be very detrimental. Phosphorus could safely range up to 7.5 percent above requirements. Calcium could range 10 percent and vitamin A 100 percent above suggested requirements (B. L. Damron, personal communication).

Diet Specifications—Growth

Determining quality of starter, grower, and laying diets, evaluated by linear programming, is possible when feeding principles are available. When feeding young chickens the objective is to produce strong, well matured birds at minimum cost yet spending enough to obtain good results and achieve a mortality level as low as possible (Heuser, 1955). Schaible (1970) summarized the rate of growth depends on such factors as species, sex, age, characteristics of diet fed, and air temperatures. Males grow more rapidly than females. Assuming the diet is properly formulated the more feed consumed the more rapidly an animal gains weight. Gains decrease per kg of feed taken in as the birds become older. Schaible observed the results of research that showed for every 2.3 kg (5 lb.) of additional feed consumed there was a gain in weight equal to 80 percent of the previous body weight. This relationship produced a curve of diminishing returns. As the chicken becomes heavier more and more of the feed is used for maintenance and less for growth.

Heuser (1955) concluded the first month or six weeks of the chick's life is the time weekly gains are the greatest. During the second month or six week period the rate of gain is reduced by 50 percent. During the remaining time of development there is often a steady decrease in the rate of growth until maturity is reached. These periods are referred to as starting, growing, and developing periods, respectively.

The period of most rapid growth is the time in the chick's development when most of the difficulties are likely to occur. When the birds are beyond two or three months of age the danger is reduced. If growth were delayed due to nutritional inadequacies the loss could be made up later if the proper diet was fed. There is, of course, a point of nutrient storage and stunting beyond which recovery is not possible. The exact location of this point was not known.

Research has shown (Scott et al., 1969) the energy content of a formulation is clearly a factor determining the amount of feed ingested.

When a diet is adequate in all nutrients the animal will maintain a constant intake of metabolizable energy to meet its needs. The level is determined by size of bird, activity, environmental temperature, and stage of development. If the energy requirement is known the amount of feed consumption can be predicted quite closely. From this information the concentration of protein and other nutrients required for adequate nutrition can be specified.

A table showing average daily feed consumption of White Leghorn pullets during each of the first 22 weeks of development was presented by Scott et al. (1969). The mean of all these figures indicated a bird consumed at a rate of 50 grams a day of feed containing adequate levels of amino acids and a metabolizable energy density of 3000 Kcal per kg. Titus and Fritz (1971) presented a table giving the amount of feed required to attain certain live weights. A flock of male and female birds being fed the average amount per bird would require 12 kg to produce a 2.3 kg animal.

Calculations of data in a table presented by Scott et al. (1969) showed the authors considered the consumption of metabolizable energy of a layer type chick from zero to six weeks of age to be 71 kilocalories per day per chick. From six to 12 weeks of age the average chick was thought to consume 155 kilocalories a day. When this bird reaches 12 and 22 weeks of age daily consumption is expected to increase to 201 kilocalories. This level is required to maintain normal growth and development.

Chicks do not perfectly match energy intake with need, observed Scott et al. (1969). As the energy concentration of a diet increases the energy consumption of the chick will become greater with the resultant increase in fat deposition. Fat accumulation occurs even though feed consumption decreases somewhat. Schaible (1970) confirmed this phenomena when he reported results of feeding experimental diets designed to insure adequate nutrient intakes, varying only in the concentration of energy compared to protein content. As the carbohydrate/protein ratio increased from 35 to 70 it was found that body fat increased 2.5 times. The rate of gain in weight remained the same. These data indicated chicks were able to increase energy intakes to a certain extent in order to obtain sufficient levels of protein. The diet with the higher ratio was over-consumed. If feed is expensive and no premium is paid for fat chickens, the cost of production becomes too high.

Chicks under practical conditions are not able to consume enough feed to meet their energy needs if the diet contains less than 2600 kilocalories of metabolizable energy per kilogram. The recommended energy content of a layer type leghorn chick diet should fall within the range of 2600 to 3350 kilocalories of energy per kilogram. Broiler diets were allowed to increase to 3400 kilocalories. This range will insure adequate energy intake capacity of the bird (Scott et al., 1969).

When feeding broiler chicks the preferred practice for the first six weeks would be to formulate the diets within the lower range of energy density. This practice will insure adequate nutrient intake to produce lean chickens. If a fattening period is desired the diet should be formulated during the seventh and eighth week to contain energy levels as high as possible even to the point protein intake would be somewhat below required levels. Under these conditions the broiler would eat more calories than needed partly as a result of the high energy content of the diet and partly due to the slightly deficient protein level.

Excess energy is not excreted but is stored as fat. Diets grossly high in energy severely restrict the adequate intake of nutrients. The fact carbohydrate rich crops cannot be used to meet protein needs is illustrated by the present practice of the Indians and past experience in other countries with farm flocks receiving mainly maize diets. Before understanding this principle the farmers thought maize "burned up" hens. However, high maize diets were grossly high in energy but low in protein.

High levels of maize can be used if protein levels are balanced to produce the optimum ratio of energy to protein. When discussing protein requirements Heuser (1955) found the protein content of the diet for the starting period, during the first month or six weeks, should be approximately 20 percent to insure rapid early growth. Scott et al. (1969) indicated that 7 grams of protein per chick per day was the average consumption during the 22 week growing period of White Leghorn chicks.

Most practical diets utilize such carbohydrate rich feedstuffs as maize and other cereals at levels as high as possible. Protein rich feedstuffs and ingredients rich in minerals and vitamins are supplied at carefully calculated amounts to properly supplement these nutrients found in the cereals to produce a nutritionally adequate diet.

Diet Specifications—Egg Production

Scott et al. (1969) divided egg production into three phases. Phase I begins at about 22 weeks. This phase is the most critical period of the productive life of the bird. During this period physiological maturity is reached, egg production increases to 85 percent, and egg size increases from 40 to 60 grams in the White Leghorn pullets. Adequate nutrition is important so the hen can maintain the health and build extra tissues required for maximum production during the remaining stages of production. Phase II extends from approximately 42 to 60 weeks of age, beginning when mature weights have been attained and ending when egg production becomes less than 65 percent marking the beginning of Phase III. Peak production of White Leghorn hens is attained when 32 to 36 weeks of age. Production would be expected to drop below 55 percent about 15 months after production began, or when the hens are approximately 82 weeks old.

Scott et al. (1969) observed the White Leghorn hen can adjust feed consumption to satisfy its daily energy requirement of from 300 to 320 kilocalories if the diets contain energy levels within the range of 2500 to 3300 calories per kilogram. The average consumption of metabolizable energy by Rhode Island Red (RIR) laying hens is 360 calories a day. This figure should be reduced by 10 percent for hens in hot climates. The daily requirement to use in calculations is 325 calories (Scott et al., 1969).

Many researchers believe chickens eat enough to satisfy their requirement for energy. Other specialists state chickens eat until they are full. The energy needs of the chicken limiting consumption is the position taken in this research. If energy requirement truly limits feed intake then the amount of feed consumed is inversely related to the energy concentration in the diet. If feed consumption is thus limited then the concentration of other nutrients in the diet in relation to the energy density is an important consideration. If the percent protein, for example, in the diet is too low an insufficient amount of protein will be consumed when the chicken leaves the feeder with its energy needs satisfied.

The metabolizable energy:protein ratio was designed to insure adequate protein intake when energy requirements are met. This ratio is calculated by dividing kilocalories of metabolizable energy per kilogram of diet by the percent protein in that diet. If the desired ratio value and metabolizable energy are known the percent protein to achieve in any diet can be calculated which will insure adequate protein nutrition.

Protein is required to build the tissue reserves and continue maturation during Phase I. This higher requirement is shown in the recommended daily amount of protein required during the three phases of 18, 16, and 15 grams, respectively. The general protein requirement of 18 to 19 grams per day given for White Leghorn hens applies to birds weighing two kilograms when mature. Daily protein requirements should be increased 1.5 grams for each one kilogram increase in mature body weight of the bird.

Evaluation of Production Systems—Linear Program

The linear programming capability of the computer was utilized to maximize nutrient production. The program also computed the benefits derived from many combinations of farm systems. These applications were possible due to developments in the fields of mathematics and computer technology.

Foruier, a French methematician, in 1826 formulated one of the earliest mathematical models designed to minimize or maximize values in the field of mechanic and probability theory. These models were used by Kantorovich in 1939 to solve production problems. Further development did not occur until World War II when large-scale military operations forced the use of linear programming. In 1947 George Dantzig developed the simplex algorithm used presently by the MPSX package program of IBM. In 1949 T. C. Koopmans assembled researchers to discuss linear programming which appeared two years later in book form. Since then applications in many fields were made (Sposito, 1975).

Beneke and Winterboer (1973) observed applications of linear programming in the fields of industry, business, and agriculture. The usefulness of the mathematical model would have been limited if the electronic computer had not become available. With many people working on refinements linear programming has become a useful tool for decision making in many fields.

MATERIALS AND METHODS

Area of Research

The research took place in three population centers located in the northeast rain forest of Ecuador on the western edge of the Amazon basin. These centers are located within the area bounded on the south by the Napo River and on the north by the Aguarico River between longitudes 76.5° and 76.7° West.

The entire area is covered with tropical rain forest vegetation broken only by many cleared areas for new fields, roads, and petroleum wells. The climax vegetation contains a diverse number of evergreen tree species. Almost 2500 species have been identified in the Amazon (Sanchez, 1976). The tallest trees in this three layer, moist tropical forest are 30 m high. There is no grass in the lowest layer which is composed of tree saplings reaching heights of 14 m. The central layer spreads its branches and leaves approximately 22 m above the ground (Sanchez, 1976).

Seventeen years of meteorological data were available for analysis. The monthly distribution fits the description of a rainy climate classification. There are fewer than two months with less than 100 mm precipitation. There are no intense dry periods to distinguish seasons. Long time residents recognize the two less wet seasons each year which, according to Figure 1, are unequal in length. The longest set season extends from March to July and the shortest occurs during October and November.

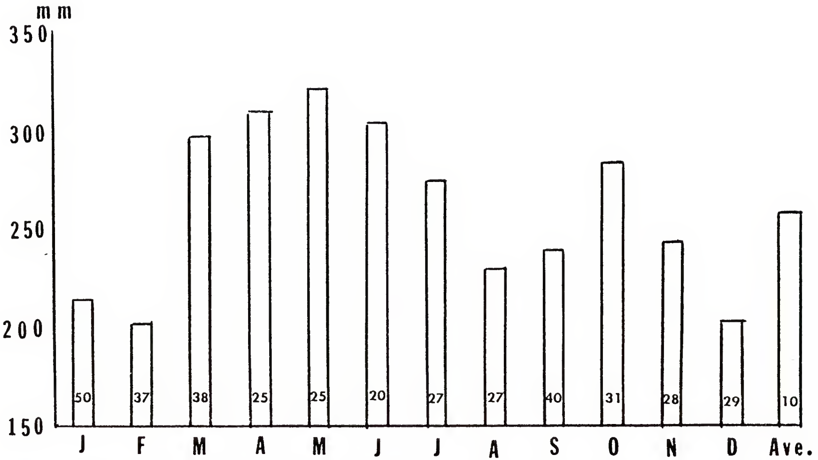


Fig. 1. Monthly rainfall statistics of data gathered in Limoncocha, Ecuador, from Jan. 1961 to Feb. 1978. Bars indicate monthly means with the last bar giving the mean based on yearly total. The figures in the bar are the percent coefficient of variability.

The annual rainfall (Table 1) ranged from 2700 mm in 1961 to greater than 3700 mm in 1972. From 1961 through 1967 the total yearly amount ranged from 2700 to 3100 mm. During 1968-1977 the low was 3200 mm and the high was 3700 mm with the exception of one year.

Humidity readings in the morning are commonly in the high nineties. The afternoon values commonly range from the high sixties to low seventies (Table 2). Mean temperatures show little variation around the mean of 27° C (Table 3), ranging from 21° C to 32° C.

The map in Figure 2 indicates the location of the experimental sites in the northeast rain forest of Ecuador. This area is the western edge of the Amazon River basin. Limoncocha is located approximately 160 kilometers from Quito, the capitol city of the country.

The Indians living in and near Limoncocha are Quichuas with two centers of origin. A small part of the group, referred to as downriver Quichuas, are indigenous to the area. Most of the inhabitants migrated down river from the Pano-Tena area, the main center of the rain forest section of the tribe.

In San Pablo two related tribes live in their own section of the village. The language of the Secoyas and Sionas are sufficiently similar that some communication can take place between the groups. The Cofan Indians in Dureno speak a related language which contains fewer common words than found in the two languages in San Pablo.

Soils are volcanic ash deposits of recent origin. They are grey in color, fertile, level, and well drained (Barral et al., 1976). Both Limoncocha (76.6° West, 0.4° South) and San Pablo (76.5° West, 0.2° South) soils are predominately dystrandepts, dystropepts, and vitrandepts with high fertility. This ground can be used to grow all tropical crops.

Table 1. Limoncocha, Ecuador, monthly and yearly rainfall from Jan. 1961 through Feb. 1978. Location: longitude 76.6° West and latitude 0.4° South.

Year	Month of Year												Yearly Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1961	132	282	247	320	270	246	167	144	91	365	248	198	2708
1962	192	207	179	217	381	285	352	238	222	288	175	189	2927
1963	55	183	291	401	268	334	269	192	132	188	278	172	2763
1964	30	91	225	449	311	419	282	267	242	235	132	262	2945
1965	214	186	445	285	216	211	219	232	194	338	257	269	3066
1966	229	99	150	239	370	256	417	119	329	139	253	281	2879
1967	235	72	238	312	434	226	315	178	155	405	248	80	2899
1968	325	129	258	462	361	333	213	183	341	344	153	142	3294
1969	206	250	127	274	145	331	191	354	100	135	281	210	2604
1970	273	215	225	385	463	297	238	249	211	261	234	202	3252
1971	358	245	346	282	311	288	219	192	234	352	388	124	3339
1972	372	160	549†	270	245	368	343	223	241	428	267	265	3730
1973	195	310	415	162	311	247	311	249	370	184	326	180	3261
1974	211	215	348	147	279	340	326	351	389	300	142	121	3219
1975	309	231	406	340	343	411	255	270	146	277	338	231	3607
1976	339	177	280	289	401	286	274	227	397	300	274	199	3442
1977	45	249	316	389	352	329	283	221	212	263	317	299	3275
1978	125	353											

† Rainfall one day (March 25, 1972) 179.3 mm was a record high.
Source: Weather data collected by the Summer Institute of Linguistics.

Table 2. Selected daily maximum, minimum, and weekly mean relative humidity at Limoncocha presented.

Week Beginning	Category	Days of the Week							x̄ Daily Humidity
		1	2	3	4	5	6	7	
		- - - - - - - - - - - -			%	- - - - - - - - - - - - - -			
Dec. 19, 1960	Max.	92	96	93	95	91	95	95	78
	Min.	66	70	70	59	57	58	60	
Dec. 26, 1960	Max.	95	95	90	87	91	91	91	77
	Min.	52	55	53	66	59	75	79	
Jan. 2, 1961	Max.	96	100	96	95	95	90	91	75
	Min.	68	58	52	59	47	44	63	
Jan. 9, 1961	Max.	95	95	100	96	95	95	96	85
	Min.	69	73		83	66	74		
Jan. 16, 1961	Max.	95	95	90	95	95	96	90	84
	Min.	86	73	68		66	79	68	
Jan. 23, 1961	Max.	95	95	96	96	95	91	96	85
	Min.	86		58	59	91	77	75	
Jan. 30, 1961	Max.	90	95	91	96	91	95	95	82
	Min.	72	68	65	79		63	72	

Table 3. Selected daily maximum, minimum, and weekly mean temperatures at Limoncocha presented.

Week Beginning	Category	1	2	3	4	5	6	7	$\bar{x}$ Daily Means
		- - - - - - - - - degrees C - - - - - - - - -							
Dec. 19, 1960	Min.	20	21	20	19	20	19	19	26
	Max.	33	33	32	32	32	33	33	
Dec. 26, 1960	Min.	21	20	21	21	23	22	22	27
	Max.	33	33	32	33	32	31	27	
Jan. 2, 1961	Min.	22	22	22	21	19	19	21	27
	Max.	31	33	32	32	33	33	31	
Jan. 9, 1961	Min.	21	22	22	22	21	22	21	26
	Max.	30	31	31	28	31		26	
Jan. 16, 1961	Min.	21	21	20	22	21	23	22	26
	Max.	26	31	31	30	31	26	32	
Jan. 23, 1961	Min.	22	22	23	22	22	23	22	27
	Max.	27	32	32	32	31			
Jan. 30, 1961	Min.	22	22	23	20	22	21	21	26
	Max.	31	32	32	31	24	32	29	

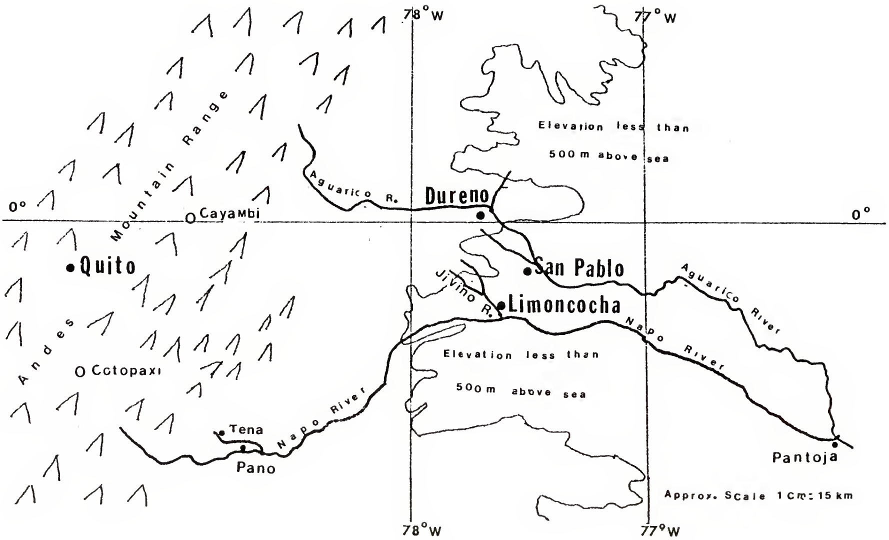


Fig. 2. Northeast section of Ecuador in relation to the location of Quito, the capitol city. Names in green indicate the location of the demonstration plots.

Dureno (76.7° West, 0.1° North) land is classified predominately dystropepts and oxic on which only crops known to grow well should be planted (Sourdat and Custode, 1977).

The agricultural soils in the experimental area are slightly acid, well drained, sandy loams approximately one meter deep. The soils on all research plots appeared to be deposited by stream activity. In Limoncocha there are no rocks nor pebbles. Only the experimental site at Dureno could be classified as an active flood plain. The remaining locations of research were too high for flooding to take place under present conditions. The pH and nutrient levels in the soils are presented in Table 4. The PANO soil was located in the foothills of the Andes as shown in Figure 2.

Research Categories

The categories of experiments designed and completed are presented in Figure 3. The arrows pointing toward the center indicate the intention of the research to assist the Indians. Observation of indigenous systems took place as opportunities arose throughout the study period. Poultry experiments were operational toward the end of the period because time was required to import and mature a flock of Rhode Island chicks while pastures were prepared and grain produced for use in research. Tribal experiments were initiated as information became available.

The purpose of research done at Limoncocha was to make preliminary selections of kinds and cultivars of crops. A breeding flock of Rhode Island Red chickens was used to produce chicks for research and distribution to Indians.

Table 4. Soil analyses. Nutrient extractions were made with sodium bicarbonate and disodium EDTA in the soil lab of the Instituto Nacional de Investigaciones Agropecuarias (INIAP) at Santa Catalina.

Identification	pH	N	P	K	Ca	Mg	Zn	Cu	Fe	Mn
	- - - -	- - - -	- - - -	- - - -	micrograms/m^2 in soil	- - - -	- - - -	- - - -	- - - -	- - - -
Airstrip sides[†]	6.6	18	16	257	1510	245	3.3	5.7	80	2.9
BEGRA	6.1	13	14	160	1750	265	3.6	6.4	73	8.8
BEGRA 2	6.0	25	23	210	1675	405	4.1	5.8	100	8.2
MUCOX I & II	6.3	16	22	385	2400	260	3.8	5.7	98	18.2
MUCOX III & IV	6.2	11	28	240	2000	180	4.4	4.5	100	11.7
PETRI	6.4	6	20	410	2500	350	3.5	4.5	52	9.7
VACO	6.3	11	17	350	2375	285	3.8	6.1	100	16.7
SANEX	6.5	13	7	90	1350	90	1.9	6.9	46	3.8
DUEX	6.5	22	18	80	1950	115	1.6	8.1	140	7.8
LUCIANO-Dureno	6.6	28	15	90	2375	160	2.6	6.4	100	3.4
PANO	4.5	93	5	55	175	55	2.0	1.3	100	18.9
SANOB	6.1	28	19	125	2000	175	2.0	1.3	57	8.2

[†] Average of 10 samples collected and analyzed by Jorge Caceres, INIAP Soil Scientist (soil sample numbers 10381-10398).

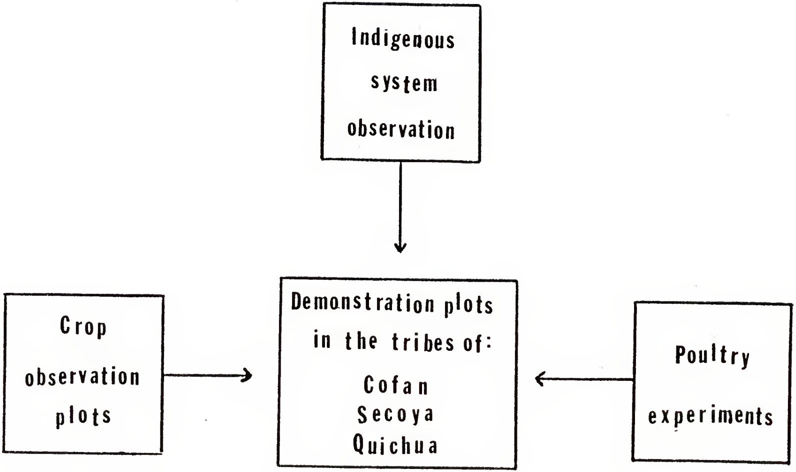


Fig. 3. Information flow in the research.

New crops and concepts were introduced to tribal locations by planting demonstration plots. Selections of cultivars by Indians and management practices used were observed. Selection without benefit of suggestions from individuals outside the tribe indicated the grower was interested. Introduction was considered complete if the crop was replanted using seed produced by the farmer.

Table 5 and 7 list the experiments conducted within the categories described. Some represent more than one planting or observation. The dates and meaning of each entry describe the code name. The experiments are discussed in more detail in the sections which follow.

Crop Observation Experiments

BEPESO was the first experiment evaluating crop genera and cultivars. Ten varieties of peanuts from the University of Florida and five local varieties were planted in single rows each 15 meters long. Seeds were hand planted at a spacing of 30 cm between the local varieties and 50 cm for the Florida varieties. There were no replications of the imported varieties due to insufficient seed. Two replications of the local varieties were planted. Table 8 presents the cultivers used, where obtained, and seed size. Sorghum seed used in BEPESO was purchased in Quito under the Asgrow label. Rico and Gravis varieties were each planted in three 40 meter rows with one meter between rows. The stand was spotty as a result of poor germination. The plots contained 201 Rico and 25 Gravis plants.

Pulse crops were planted 10 cm between seeds and 50 cm between rows. Row length varied from five meters to more than 40 meters in some cases depending upon the amount of seed available. Chickpeas were represented by an unnamed cultivar sold in a sprout kit. Gainesville

Table 5. Crop observation experiment code name description. The source of letters in the code is underlined.

Code	Meaning	Dates Planted
BEPESO	Bean, peanut, sorghum	July 28, 1975
PEOB2	Peanut observation 2	July 28, 1975
BEVA	Bean, variety obs.	Oct. 25, 1975
BEGRA	Bean, grain crops	Jan. 6, 1976
BEGRA2	Bean, grain crops 2	Feb. 7, 1976
MUCOX	Multiple crop exper.	Sept. 22, 1976
BETRIA	Bean trial A	Dec. 3, 1976
VACO	Various crops	Dec. 3, 1976
BETRIB	Bean trial B	Jan. 25, 1977
BETRIC	Bean trial C	Jan. 14, 1977
COBEF	Corn, bean, Bean failed	Aug. 21, 1975
COLY 73	Corn, high lysine '73 CV	Dec. 23, 1975; Mar. 4 & 12, Apr. 7, May 7, 1976
COLY 75	Corn, high lysine '75 CV	Feb. 20, July 6, Dec. 4, 1976; Jan. 26, Feb. 1977
COVA	Corn variety trial	Dec. 23, 1975
YUFER	Yuca fertilizer trial	July 1970
RITRI	Rice trials	Various dates 1963, 1965, 1969, 1970
NIRI	Nitrogen rice trial	Feb. 24, 1972
PEOB	Peanut observation	Dec. 30, 1975
PETRI	Peanut trial	Sept. 1, 1976
PEVA	Peanut variety trial	Jan. 26, Feb. 26, 1977

Table 6. Tribal demonstration plots and poultry experiments code name description. The source of letters in the code name is underlined.

Code	Meaning	Date Planted
QUIEX	Quichua experiment-Quichua	Oct. 4, 1976
SANEX	San Pablo experiment-Secoya	Oct. 6, 1976
DUEX	Dureno experiment-Cofan	Aug. 20, 1976
DUPE	Dureno peanuts-Cofan	Aug. 20, 1976
PORE	Poultry research	Apr. 3, 1976-July 12, 1977
KUPI	Kudzu poultry iinvestigation	Feb. 17-July 15, 1977

Table 7. Indigenous systems surveys code name description. The source of letters in the code name is underlined.

Code	Meaning	Tribe	Dates
QUIPI	Quichua poultry invest.	Quichua	Dec. 6, 1976-Jan. 31, 1977†
SILOB	Silvario observ.	Quichua	Dec. 14, 1976-Sept. 16, 1976‡
ELOB	Eladio observ.	Quichua	Aug. 27, 1976†
TRIOBA	Tribal observ. A	Quichua	Jan. 26, 1976‡
DANRI	Daniel rice field	Quichua	Aug. 25, 1976‡
VIOB	Victor maize observ.	Quichua	Sept. 10, 1976†
AUCA	Auca observ.	Auca	Jan. 1976†
SANOB	San Pablo observ.	Secoya	Oct. 18, 1976-Feb. 16, 1977†
SMADA	Smale farm data	Quichua	Dec. 30, 1976‡
COFOB	Cofan observation	Cofan	Dec. 8 & 22, 1976†

† Observed
‡ Harvested

Table 8. Peanut cultivars planted July 28, 1975, in the BEPESO experiment.

Variety Name	Source	Seed Size g/100 Seed †
- - - - - - - - - - - - -	Ecuador origin	- - - - - - - - - - - - -
Rosita	Quito store	42
Pepon	Quito store	59
Blanco	Quito store	44
Charapoto	Quito store	44
Commissary	Limoncocha com.	57
- - - - - - - - - -	University of Florida origin	- - - - - - - - - -
New Mexico Val A.	Breeder seed	38
Florgiant	74 Breeder seed	104
Early Runner	74-303	62
Starr	74-502	46
Tamnut 74	74-509	46
Tifspan	74-504	50
Va. Bunch 67	74 Crop	56
Florunner	74 Breeder seed	71
Altika	74-4027	108
NC-Fla. 14	74-4047	118

† Weighed before planting.

Pea was the label assigned to seed given by an individual in Gainesville, Florida, who thought it might be adapted to Amazon conditions. Other material used in this experiment originating in the USA were two cultivars of cowpeas named Red Hull Pinkeye and Blackeye Pea. Ecuadorian material found in the cooler at Limoncocha was assumed to originate with the Instituto Nacional de Investigaciones Agropecuarias (INIAP), a research institution in Ecuador. The names of cultivars fitting this description were Red Pea, Line 20304, Cuarentin, Pata de Paloma, Blackeye Pea, Light Brown Bean, Verdura China, and Top Crop. There were no replications of these varieties and germination varied widely from a low of zero.

Four varieties of soybeans were planted 10 cm between seeds and 50 cm between rows. Kanrich and Late Giant Black were edible soybeans but Jupiter and an unnamed bean were grain soybeans. The latter was sold in a sprout kit. Kanrich was sold under the Burpee label. Late Giant Black and Jupiter were from Dr. G. M. Prine and Dr. Kuell Hinson, respectively, members of the Agronomy Department at the University of Florida. All but Jupiter variety were planted in rows five meters long or more. Two rows of Jupiter each 25 meters were planted.

Norman was the variety of pigeonpea planted originating in the USA. This cultivar was planted one meter between rows and 50 cm between seeds in one 40 meter row. A small-seeded (4 grams per 100 seed) and a larger-seeded mungbean (6 grams per 100 seeds) were planted in 50 cm row widths with 5 cm between seeds in rows about 5 meters long.

Observations were recorded during the development period of crops in the BEPESO experiment. Notes were made of days from planting to vine formation, resistance to disease, days to first flower, and length of center stem and branch length. Maturity pattern was observed by making multiple harvests of ripe pods which were counted, weighed, and shelled to obtain shelling percent, seed size, and yield per plant. Yields per m^2 were calculated when stands were fairly uniform. Yields of cowpeas, mungbean, and vegetative soybeans were based on data from one unreplicated plot. Jupiter yields were calculated from data representing four sample areas 2.5 and one area 9.5 square meters. Pigeonpea yields were measured from 10 marked plants. All the sorghum plants were harvested to measure yield of that crop.

Peanut observations in BEPESO were set apart with the code name PEOB2. A five plant sample considered representative of the majority of peanut plants was selected. The central stem was measured and noted if pegs were present. Each cotyledonary branch was measured and pods counted and weighed. Pods were shelled and weighed to establish the shelling percent, pod, and seed size. Total plant yield was calculated by adding yield from the colyledons to the amount harvested from the other sections of the plant. Yields based on land area were not possible due to the irregular competition resulting from a poor stand.

BEVA was planted to study a second time those cultivars showing promise in BEPESO and provide for additions. Six mungbean, 20 cowpea, and 25 common bean cultivars were provided by the Boliche Station of INIAP. Some of the seed had been mailed in INIAP by the Centro Internacional de Agricultura Tropical (CIAT) located near Cali, Colombia. Tables 9-11 list the source and varieties of the various crops used in this trial.

A 13-40-13 fertilizer was applied at a rate of 165 kg per ha and disced in before planting. Sixty plots one meter by five were laid

Table 9. Cowpea cultivars used in BEVA.

Variety	Seed Color	g/100 Seeds	Source
73 Sin - 5424	Brown spots	10	INIAP
73 Sin - 6435	White	17	INIAP
73 Sin - 6441	Black	11	INIAP
73 Sin - 6442	White	21	INIAP
73 Sin - 8487	Red	12	INIAP
73 Sin - 8488	Red	11	INIAP
73 Sin - 8491	White	11	INIAP
73 Sin - 8495	White	9	INIAP
73 Sin - 8498	Red	14	INIAP
73 Sin - 8502	White	15	INIAP
73 Sin - 8506	Brown	8	INIAP
73 Sin - 8512	Brown	14	INIAP
73 Sin - 8520	White	16	INIAP
73 Sin - 8512	Black	13	INIAP
P-R-V-71-10R-3	Red	14	INIAP
P-R-V-71-10R-58	Red	18	INIAP
Brown Crowder	Brown	16	INIAP
Super Cream	White	20	INIAP
Chenise Red	Red	8	INIAP
C.P.	White	22	INIAP
Blackeye	White	19	Florida
Gainesville Pea	White	19	Florida
Red Pea	Red	10	Limoncocha
Red Hull Pinkeye	Red	--	Limoncocha
Light Br. Pea	Brown	20	Limoncocha

Table 10. Common bean cultivars from INIAP used in BEVA.

Variety	Seed Color	g/100 Seeds
72 Vul-20886	Brown	21
72 Vul-21314	Brown	37
72 Vul-26779	Black	28
73 Vul-5805	Black	21
73 Vul-5866	White	19
73 Vul-6142-I-M	Red	24
73 Vul-6281	White	27
73 Vul-6388	Black	24
73 Vul-6390	Red with white spots	43
73 Vul-6406	Black	22
73 Vul-6706-I-T	White	35
73 Vul-58181	Black	22
27R (Honduras)	Red	55
P-133-A	Black	22
T-5-R	Red	31
P-1-A	Red	27
P-425-R	Black	22
P-459-R	Black	22
L-32-1	Black	22
R-P-896	Brown	22
IGM	Spots	68
IBM	White	19
Seafarer	White	22
CAR-M	Stripes	29
Frutilla	Red spots	44

Table 11. Mungbean cultivars used in BEVA.

Variety	g/100 Seeds	Source
73 AUR-6430	4.0	INIAP
73 AUR-6441	5.0	INIAP
73 AUR-6443	5.5	INIAP
M-61-INDIA	4.0	INIAP
BERKEN	3.5	INIAP
T-9	6.0	INIAP
Large seed	5.5	Limoncocha
Small seed	3.0	Limoncocha

out to allow for one replication of all varieties in rows one meter wide and 10 cm between plants. The entire plot was the harvest area. Seed color and size observations were made before planting. Plant vigor was noted both five and 52 days after planting. Insect damage and vine characteristic were recorded 21 days after planting. Vine length was measured 94 days after establishment of the experiment.

BEGRA and BEGRA2 were designed to introduce cultivars not available previously and continue the screening of others that had been under observation. BEGRA land was laid out in plots seven meters by two meters. Two replications of Bicolor, White, and Red local peanuts, Rico sorghum, Jupiter soybean, and Portoviejo 2 sesame were planted. Cowpea and mungbean plots were one meter by seven. Both experiments contained two replications. The cowpea varieties used were: Gainesville Pea, 73 Sin-6435, and 73 Sin-8498. The mungbean varieties were T-9, 73 Aur-6430, and Large Seed Mung. One common bean variety, 73 Vul-5866,was planted. Rice was planted in a corner of the area not used by the other treatments. The rice rows were 30 cm apart in which was planted INIAP 6, a green revolution rice variety developed in the Philippines by IRRI. It was planted with a Planet Jr. planter.

The peanut seeds were planted 10 cm apart and the other crops, except rice, were spaced 5 cm between seeds. This plot was near the airstrip in which only low growing crops could be planted. Plant populations at harvest time varied somewhat according to the success of the variety. The crops and plants per m^2 ranges were: peanuts 10.3 to 14.4, beans (excluding soybeans) 6.7 to 18.3, soybean 2.0 to 4.5, and sorghum 9.2 to 10.8.

Tables 12 and 13 list all unreplicated crops planted in BEGRA2. There were 90 cm between all rows. The crops planted in 25 m long rows were pigeonpea, wingbean, yardlong bean, and lima bean. Wingbean seeds were planted 20 cm between seed. All others were planted 10 cm between seeds. Yardlong was thinned to 20 cm between plants, and pigeonpea to 30 cm between plants. Rows of common beans and cowpea were 6 m long. The plant populations of cowpea varied from 1.1 to 9.1 plants/m^2 and common bean from 1.5 to 7.2.

Data collected from both BEGRA and BEGRA2 for mungbeans, cowpeas, and common bean were date first leaves appeared, date of first flower, and growth habit. In BEGRA flower color and date plant began to vine were added. The additional data collected for the above crops in BEGRA2 were seed size, seed quality after harvest, pod and seed weight from which was calculated shelling percent, date plants began to climb, and length of the bottom branch. The peanut information in BEGRA collected was date of cracking, center stem height, number and grams of pods, number and grams of kernels, seed size, and shelling percent. Sesame and sorghum information collected was date the first leaf appeared and center stem height. The date the first flower appeared in sesame was noted. Soybean data collected included height of center stem and date of first flower. Yield in both experiments were measured and the plot size which varied widely, was noted in order to calculate g/m^2 production. MUCOX contained eighty-one plots each 4 m by 5 m arranged on well prepared soil. The monoculture cowpea treatments consisted of four replications of Chenise Red, two of Sin 6441, and one each of Sin 6435 and Sin 6506. The plants were arranged in 50 cm rows and a 15 cm spacing within the row. The cultivars were considered to be the most promising.

Table 12. Cowpea cultivars used in BEGRA2.

Name	Name
73 Sin-5424	73 Sin-8512
73 Sin-6435	73 Sin-8520
73 Sin-6441	73 Sin-8521
73 Sin-6442	P-R-V-71-10R-58
73 Sin-8487	Red Pea (Chenise)
73 Sin-8488	Super Cream
73 Sin-8491	Brown Crowder
73 Sin-8495	Chenise Red
73 Sin-8502	Red Hull Pinkeye
73 Sin-8506	

Table 13. Crop kinds used in BEGRA2.

Phaseolus	Crop	Variety	Source
73 Vul 6406	Wing Bean	S-1	INIAP/Africa
73 Vul 58181	Wing Bean	S-2	INIAP/Africa
CAR-M	Wing Bean	S-3	INIAP/Africa
IBM	Pigeon Pea	Norman	US
Kentucky Wonder	Pigeon Pea	Coastal	Ecuador
Panamito	Lima Bean	Coastal	Eduador
Yellow Local			
White Local			
Red Local			

BETRIA was planted on well prepared land in plots five meters long by two meters wide. Icatui and 73 Vul-6406 were the only common bean varieties. Jupiter soybean and Brown Crowder cowpea were the other crops. All were planted with spacings described in the previous experiments. VACO was planted the same day including four rows each of two local varieties (one red, the other yellow). The local varieties failed as a result of heavy disease attack. Four rows of sunflower were planted but germination was poor. Sesame was planted in 30 to 60 cm rows. Plants were thinned to 10 cm between plants at a later time. Jupiter soybeans were planted with a precision planter with 60 cm between rows. Yield of both sesame and soybeans were measured by six sample plots randomly distributed over the crop area. After the sesame was harvested the weeds present were identified and recorded to have a record of weeds that take over after the crops are harvested. The unthreshed sunflower heads were placed in the sun to dry. Mold formed making yield measurements impossible.

BETRIB was the final cowpea experiment. The plots were 3 m long and 2.4 m wide allowing four rows 60 cm between. Supercream, Red Hull, Sin 6435, Sin 6442, Sin 8512, and Sin 8521 were planted with a precision planter in two replicates and later thinned to 10 cm between plants. Sin 6442 was selected from five cultivars by two men in San Pablo. Supercream was one of two cultivars selected by a Quichua tribesman. The remaining cultivars were selected from the MUCOX experiment using standards Indians consider desirable such as: large seed, acceptable yield, and a weak vining growth habit.

Data collected from BETRIA and BETRIB were grams of pods and seeds required to calculate shelling percent. Populations within BETRIB varied from 3 to 12 plants/m^2. Yield data was based on harvests from 7 to 10 m^2 plots.

BETRIC consisted of one 3 m row containing 10 plants. Species identification is uncertain. Jackbean (Canavalia ensiformis) is assumed to be the correct name as distinct from swordbean (Canavalia gladiata). The seed was obtained from a Quichua father whose agricultural high school son introduced the crop. The plants, grown by the Quichua, were vigorous and productive. The number and weight of seeds in each pod were recorded. Yield was estimated assuming the crop would be planted in one meter rows.

COBEF became a maize trial when the associated cowpea seed did not germinate. Thirty-six plots 6 x 9 m in size were established after the maize had been seeded with the maize planter. The desired spacing was 30 cm between plants in rows 90 cm apart. The maize seed was used from INIAP with a petigree of Ver 181-Ant GPO2-x-Ven-1 Opaco 2 Hard endosperm PR-73-B Lote-5. The plant population measured at harvest varied from 1.2 to 2.0 plants/m^2. The number and weight of the ears were recorded, along with size of harvest plot and plant population. From this was calculated the shelling percent, ear weight, and yield.

A significant improvement was achieved in high lysine maize during 1975 at CYMMIT, the International Maize and Wheat Improvement Center, in Mexico. CIAT supplied a small amount of seed for research at Limoncocha and five experiments were established after multiplication of seed was accomplished. Plant populations varied from less than one to nearly eight plants/m^2. Yields were measured from sample plots. Those plantings were assigned the name COLY75.

COVA consisted of four maize cultivars. The 1973 line of high lysine maize was the only opaque maize in the experiment. Pichilingue 504, VS 2, and INIAP 515 were the regular maize cultivars used. There were six replications, each containing four rows with the center two as the harvest rows. The seed was hand planted in rows 90 cm apart, with five seeds per hill, spaced 75 cm apart to be thinned to three plants per hill. Plant counts indicated populations varied from one to five plants/m^2. The plots were 3.6 by 7 m with a harvest area of 2 by 6 m. The same data collected in COBEF was recorded in this experiment. Yields were analyzed to obtain means, standard deviations, and coefficients of variation for each variety.

YUFER, established in 1970, was a fertility trial using local yuca. Six replications of eight fertilizer treatments were designed using plots 7.8 by 4.5 m, with a harvest area 2.7 by 5.2 m. The yuca stems, with at least three nodes, were pushed into the ground at an angle to the soil surface in rows 1.3 m apart and 90 cm between plants. The yield data from this experiment were used in the linear program discussed elsewhere.

RITRI was planted November 13, 1969, to estimate rice yields within indigenous agriculture. The data were used in the linear program.

NIRI treatments included five levels of nitrogen applied to the three rice cultivars INIAP 1, 2, and 6. Yield of each cultivar was averaged across nitrogen levels when the statistical analysis indicated no significant difference between nitrogen levels. The mean yield of INIAP 1, 2, and 6 was used in the linear program to represent production of green revolution rice cultivars.

PEOB incorporated newly received peanut material and many cultivars used in BEPESO to generate additional information to identify adapted varieties. Peanut seed obtained locally appeared to be a mechanical mixture of three indigenous varieties if identification were based on seed color. The origin was Sarayacu, a day's travel by canoe up-river from Limoncocha. The seed was separated by color and named accordingly. S. (Sarayacu) Red seeds weighed 50 g/100. The seeds of S. White were 63 g/100 compared to 65 g/100 for S. Stripe. The percentage each color seed was present in the mix presented in order was 25.6 percent, 20.9 percent, and 53.5 percent. The Romulo variety used in PEOB was a red coat peanut used in the Limoncocha area by a Quichua farmer with that name. Its seed weight of 50 g/100 seed was identical to that of S. Red assumed to be the same cultivar. S. Stripe is believed to be the same as the speckled Commissary cultivar.

The seed originally purchased in Quito was identified by common names given by the personnel in the store. Charapoto could be Tarapoto, an INIAP recommended variety. Pepon is a Spanish word meaning "large seed" describing the seed size of this cultivar as recorded in Table 8. Rosita, referring to seed coat color, appeared to be similar to Charapoto. The imported varieties used in PEOB were Early Runner, Va Bunch 67, NC-Fla. 14, Florgiant, and Florunner.

Four rows of each cultivar were arranged in unreplicated plots. The plots were 3 by 7 m with a two row harvest area of 8.4 m^2. Populations varied from 0.6 to 8.1 plants/m^2.

A sample of five plants was removed from the harvest area of all plots and analyzed as described in BEPESO. All plots except Altika, in which there were insufficient material, produced sufficient material to supply an additional sample of 10 plants. The pods were stripped off, counted, weighed, and shelled. The number of kernels and weight per plant were recorded. The pods from each plant and number of plants remaining in the harvest area were noted.

PETRI was planted using seed produced in PEOB. Eleven cultivars were replicated four times. The local cultivars were S. Red, Romulo, Tarapoto, Commissary, and Rosita which were classified as short season cultivars. The imported medium season cultivars were Early Runner, Florunner, and NC-Fla. 14. The long season cultivars were Altika, Florgiant, and Pepon. These were promising cultivars observed in previous experiments planted for further selection. Cultivars showing little promise in previous experiments included in PETRI were Blanco, S. White, and Va Bunch.

Germination was uneven across the cultivars. Stand counts in the harvest area were made 131 days after planting. During the first harvest representative plant of each cultivar was measured to determine the length of central stem and one colyledonary branch. Ten plant samples of representative plants were taken from each harvest area. The numbers of pods per plant remaining in the harvest area were noted. The 10 plant sample provided data to calculate seed size, shelling percent, and pod size. Plant density, grams of pods per plant and m^2 were calculated from the larger sample of data.

PEVA was designed to test peanut response to increased rainfall conditions. Cultivars were selected on the basis of seed origin and size, vegetative cycle, and production of high yields in the research area. Altika, NC-Fla. 14, and Florgiant were the cultivars originating outside Ecuador. Pepon and Tarapoto were considered of Ecuadorian origin outside the Amazon jungle. Indigenous cultivars used were S. Stripe, S. Red, Romulo, and Commissary considered to be variations of three cultivars used by the Indians.

The first four mentioned produced seeds larger than 100 g/100 seed when produced in the research area. Those cultivars with vegetative cycles greater than 130 days (observed in PEOB) were Altika, Pepon, and Florgiant. NC-Fla. 14 was classified midseason requiring 122 to 130 days to complete the vegetative cycle. Tarapoto, S. Stripe, S. Red, Romulo, and Commissary were given the short season classification. All selections in PEVA were considered to produce acceptable yields.

Each cultivar was replicated three times in four row plots 2.4 x 3 m. Seeds were planted 15 cm apart in 60 cm rows. The plants were thinned to 30 cm within the row after emergence was complete.

During the experiment a heavy infestation of beetles appeared producing minimal damage to the plants. Ninety-seven days after establishing the experiment, representative plants of each cultivar were measured to determine the length of the central stem and cotyledonary branches. The presence of pegs on the central stem was also noted. Leaflets from each cultivar were traced 51 days after planting, selected from the third node on the cotyledonary branch.

Guard row plants were inspected to determine harvest date. Browning in a large proportion of pods was considered an indication the crop had reached maturity. The population at maturity varied from four to ten plants/m^2. Five plants were analyzed for the number and grams of pods and kernels on each plant. The number and grams of pods, on each remaining plant in the harvest area, were recorded, along with the date of harvest. Calculation procedures described in PETRI were repeated with the addition of mean, standard deviation, and coefficient of variation figures.

VACO was planted to observe the response of various crops: sunflower, soybean, sesame, and common beans. The crops with the exception of sesame were planted using spacings previously described. Sesame was planted in both 30 and 60 cm rows to determine optimum spacings. Sunflower yields were calculated in terms of the fresh head, which was easily weighed. To determine the percentage of the fresh head likely to be dry seed, 15 heads were weighed fresh, the seed separated, dried, and weighed. The mean figure was 38 percent, with a standard deviation of 9.5 percent.

Tribal Demonstration Plots

A series of demonstration plots in tribal locations were designed to test information developed in Limoncocha. Other purposes of the plots were to introduce appropriate information and observe tribesmen's response. The treatments in QUIEX were the most complex because Quichua agriculture is the most advanced of indigenous agriculture in the research area.

The experiment was established on a newly hand-cleared area in a manner typical of preparing yuca ground. Stumps were present and planting was with a dibble stick on undisturbed soil.

High lysine maize (1973) and regular maize VS 2 were selected along with Supercream, 10R58, and Chenise Red cowpeas and Tarapoto peanuts. Four treatments were applied in four replications on plots 4.5 x 5 m. These crops were all associated in two, three, and four crop relationships. The treatments were VS 2 maize-Chenise Red, 73 high lysine maize-10R58, 73 high lysine maize-Supercream-Tarapoto, and 73 high lysine maize-Supercream-Tarapoto-Yuca. These treatments were to duplicate the associations of two, three, and four crops the Quichuas often make. Treatments differed from Quichua agriculture by using higher plant populations and substituting cowpeas in the place of the poorly adapted common bean. These changes were thought to be necessary to increase production of food and feed. The two maize cultivars were selected as having possibilities for introduction. Supercream cowpea was highly rated by the INIAP personnel at the Boliche Station and has a large seed. The cowpea cultivars 10R58 in previous trials showed promise due to the vigor of the plant. The seed showed some resistance to water damage when ripe as well as have a fairly good size and produced a good yield. Tarapoto was tested to determine if this peanut cultivar should be introduced. The yuca was the sweet type used locally and was planted to give competition to the other crops in the treatment. Sesame and sunflower were planted in two replications for observation by the researcher and Quichua farmer. Spacings used are shown in Table 14.

Multiple harvests of cowpeas were made to observe ripening pattern noting the grams of production in both the unshelled and shelled state. From this was calculated the shelling percent. From five to 10 plant samples of peanuts were studied to obtain the number and grams of pods and kernels from each plant from which could be calculated shelling percent and grams per pod and plant. The plants remaining in the harvest area were harvested and picked, and grams of yield were determined. The ears of maize were harvested, counted, weighed, shelled, and the seed weighed. Means, standard deviations, and coefficients of variation were calculated for all these crops.

Table 14. Planting plan for QUIEX. The crop and cultivar spacings at planting and plant population desired after thinning.

Crop	Cultivar	Between†			Thin To
		rows	sites	Per Site	
		--- cm ---			plts/m^2
Maize	Opaque 73	150	20	2	3.3
Maize	V.S.2	120	20	2	4.2
Cowpea	Supercream	20-130	10	2+	13.2
Cowpea	10R58	20-130	10	2+	13.2
Cowpea	Chenise Red	60	10	2+	16.7
Peanuts	Tarapoto	50-100	20	2	13.2
Sesame	Portoviejo	50	10	2+	20.0
Sunflower	Mammoth	75	30	2	4.4
Yuca	Local	150	90	1	0.7

† Range indicates rows are not uniformly spaced.

Since the Secoyas were considered to be good farmers, although unequal to the Jungle Quichuas, SANEX was designed to contain a less complex arrangement of treatments. Monocultures of sesame, peanut, maize, and cowpea were planted. Two cultures of peanuts were used (Tarapoto and Sarayacu Stripe) and three of cowpea (Sin 6442, 5424, and 8520). The 1975 high lysine maize was planted in monoculture but also in association with Tumbes cowpea. This cowpea cultivar was obtained from the coast of Ecuador as a local cultivar used extensively there. Chinese Red cowpea was used only in association with the VS 2 maize or Mammoth sunflower. There were a total of 10 treatments in two replications. The 3.6 x 5 m plots were over planted so thinning could produce the distances indicated in Table 15.

The data collected from cowpeas were grams of pods and seed from which shelling percent was calculated. Plant population was determined at harvest time to calculate yield per plant. Multiple harvests were made to observe maturity pattern. All the pods from the peanut harvest area were weighed. Two hundred pods were selected as being representative and were weighed and shelled. The kernel number and weight were determined. The number of plants and the size of the harvest area were noted to facilitate calculations of pod size, shelling percent, seed size, plants and yield per square meter and grams of pods per square meter.

The agriculture of the Cofan Indians is the least developed of three tribes in the research area. DUEX/DUPE was an experiment planted among the Cofan Indians on August 26, 1976, and other dates. Two subsequent plantings of maize were necessary. No yield data was available from SIN 6435 or Brown Crowder because they were over ripe when the

Table 15. SANEX crops and planting information.

Crop	Between		Plants Per
	rows	plants	
	- - - - cm	- - - -	m^2
Sesame	60	15	11
Sunflower	50	20	10
Maize	120	25	7
Peanuts	50	25	8
Bush Beans	60	25	20
Maize/	120	25	7
Cowpea	40-80[†]	25	20
Sunflower/	50	25	8
Cowpea	50	10	20

[†] Range indicates rows were not evenly spaced.

demonstration plot was harvested. Brown Crowder was planted later at Limoncocha in BETRIA to produce some data describing this cultivar. The 1975 high lysine corn seed did not germinate after either planting in August 20 or September 10, 1976. Part of the problem was damage from pigs and chickens. Both animals were accustomed to these crops. The peanuts, cowpeas, and sesame were not disturbed.

The maize was planted in hills 90 cm apart in rows with the same spacing. Five seeds were planted with the intention of thinning the stand to three plants per hill or a population of 3.7 plants/m^2. The Portoviejo 2 sesame cultivar was planted in rows 60 cm apart. Later the stand was thinned to 15 plants per linear meter to give a population of 25 plants per square meter. Tarapoto peanut, considered an introduction, and Commissary, a local peanut used by the Quichuas, were planted in 60 cm rows with 10 cm between seed. The plan was to thin to seven plants per linear meter to obtain a stand of 12 plants per square meter. Cowpeas were planted in 60 cm rows with 5 cm between seeds to be thinned to 12 plants/m of row or 20 plants/m^2. Some of the Brown Crowder was thinned but SIN 6435 required no thinning.

There were four peanut rows in each plot with the center two the harvest rows. Five representative plants were taken from each harvest row of each plot in the first three replications. This produced a 10 plant sample to generate pod and kernel number and weight data. Plant measurements were made to determine length of central system and cotyledonary branches. The plants remaining in the harvest row were evaluated for the number and grams of pods on each plant. In the fourth replication only the weight and number of pods per plant were evaluated from the harvest row. The standard calculations were made and placed under the title DUPE. Three pairs of sesame rows were harvested, shelled, and the weight of seed was recorded. The plants were counted and the area measured. The yield and plant population at harvest time were calculated from this data.

Tribal Observations

Crops. Observations of indigenous crop management practices were made among a number of Quichua farmers. SILOB was a survey designed to measure field size and plant populations of common beans, local peanuts, and yuca. A map was made of the plant spacing and location of the three component crops in an area 3 x 2.5 m. Plant populations were determined from 11 plots having the approximate dimensions of 3 x 3 m, 6 x 6 m, and 3 x 4 m. A map of pole locations was made from one 3 x 2.5 m plot in a monoculture of common beans. Numbers of pods and plants at each stake were noted. Three plots 15 and 18 m^2 were harvested along with one containing 63 m^2 and pod numbers and weights were determined. Weight per pod and seed size plus shelling percent and yield were calculated. Five plots in a maize field near by were measured for plant population and yield of ears and grain.

ELOB was observed near SILOB. A map of 2 x 3 and 2 x 4 m plots were made of a multiple crop of common beans, local peanuts, and yuca. Four other plots were sampled to determine plant populations of these associated crops. Yields were not measured.

TRIOB included a number of observations. TRIOBA was one observation designed to record the per pole yield of common beans from 13 sites. Data were recorded to report the pod and seed weights from which could be calculated seed production per site and seed size.

DANRI was a measurement of rice yields one Quichua received from a field he managed. The field size was measured with a tape. Four plots averaging approximately 15 square meters in size were measured and the plants counted to determine plant population. The object in VIOB was to determine plant density and yield of maize at harvest time.

Peanut production under indigenous conditions was measured in Tiwaneno in Dayuma's patch in which yuca was the associated crop. Three plots approximately 3 m^2 in size were observed to determine yield of peanuts and the individual plants were characterized. Measurements were made of number and grams of pods and kernels. From this was calculated pod and seed size and yield. This observation was given the title AUCA. The observation of corn, peanuts, and cowpeas among the Secoyas has been described under SANEX.

Yuca yields were measured in SMADA which was a simulation of Quichua agriculture. Before the yuca was ready, peanut yields were determined in this association of crops. Six plots were established, each 6 x 6 m. The number of yuca and peanut plants was recorded. At time of harvest the number and grams of pods and kernels was determined to calculate the yield data already described. Much later, when the yuca was ready, seven new plots 3 x 3 m were established. The number of plants was observed and the grams of tubers were recorded. From this was calculated the tuber size, yield per plant, and yield per square meter.

SANOB was designed to record planting patterns a Cofan Indian followed. One planting was a monocrop of local maize. The second planting was made with seed from the demonstration plot along one side. A map was made to record the arrangement one person developed using introduced cultivars. The field contained two cultivars of peanuts and two of cowpeas as monocrops, and an intercrop of maize and peanuts.

Management of the peanut crop by Cofan Indians was the observation made in COFOB. A number of plantings was observed. Plant spacings were approximately 20 cm within the row and 50 cm between rows.

Chickens. QUIPI was a survey to produce a description of indigenous poultry production within the environs of Limoncocha. A questionnaire (Table 16) was developed to guide the observations and interviews made by the researcher. Not all questions were used at many sites.

Regular visits were made to collect egg production data from the 17 flocks in the study to supplement data obtained from the questionnaire. The production records are not fully accurate because the values recorded were recalled by the flock manager over a period from one to four days in the past. It is not the custom to collect eggs every day, but only on occasion when they are required for a meal or a trade.

Supplementation treatments began 14 days after the research began. All flocks received water, mineralized salt, and whatever could be found on the ground. The salt was a commercially mineralized preparation sold under the name Agroleche.

The treatments were designed to represent categories of nutrients and be reproducible by the Indians. Four flocks received no additional supplementation to serve as checks. The addition of energy to seven flocks was achieved by feeding maize. This treatment was to represent practices followed by Indians. Unground sunflower added to the diet of four other flocks represented protein supplementation. Both protein and energy additions to the diet were made by giving sesame and maize to two flocks.

Table 16. Questions used in QUIPI survey to obtain information concerning poultry management practices of the Quichuas in the Limoncocha area.

Survey Questions and Observations
1. Who collects the eggs and pens the chickens?
2. How many (a) hens and (b) roosters do you have?
3. How many eggs do you receive a day?
4. Are the chickens penned each night?
5. What do you feed the chickens?
6. Do the chickens have access to water?
7. Do the chickens have access to salt?
8. How many chickens would you like to have?
9. Why do you want this many?
10. When is the laying season?
11. How often do you set eggs?
12. How many hens do you set?
13. How many eggs are set under each hen?
14. What is the condition of the coup?
15. What breed are the chickens?
16. Where did you obtain your chickens?

Poultry Experiments

Two experiments were conducted at Limoncocha to develop information which the Indians could utilize. PORE was the first one which had as its main objective to grow a flock of birds for use in future research and produce hatching eggs for distribution to the Indians. Three hundred unsexed Rhode Island Red (RIR) chicks were imported from Miami, Florida. They were hatched April 3, 1976, and flown directly to Quito, Ecuador. There they were fed and brooded for a few nights before being trucked a day over the road to meet a plane that flew them to Limoncocha on April 8. Observations on this flock continued until the middle of July 1977.

The chicks were brooded with infrared lights. An Onan generator was run from 9:00 P. M. to 7:00 A. M. to supply electricity when the 65 KW generator was shut down for the night. When the chicks were one month old supplemental heat was removed.

Diets were formulated from locally produced feedstuffs with the exception of fish meal and supplements. Imported balanced feeds were too expensive. All diets were constructed to conform as closely as possible to the standards established by the National Research Council of the United States (NRC). The energy and protein contribution of each feedstuff along with the percent in the diet are indicated in Table 17. Other nutrients were calculated when formulating the diet. The nutrients calculated were arginine, lysine, methionine, cystine, tryptophan, calcium, phosphorus, fat, and fiber. General tables were used when making calculations. It was not determined how closely these values represent the amount actually in the feedstuff.

Table 17. PORE diet formulations. The identification numbers indicate distinct formulas producing some variation in content of metabolizable energy (ENMT) and protein (PRT). H. L. = high lysine, Reg. = regular.

Title	% in Diet	Amt. in Diet		% in Diet	Amt. in Diet		% in Diet	Amt. in Diet	
		ENMT	PRT		ENMT	PRT		ENMT	PRT
Diet No.	- - - - -	1	- - - -	- - - - -	2	- - - -	- - - - -	3	- - - - -
H. L. Maize	64.7	2221	7.0	66.7	2289	7.2	75.0	2574	8.1
Peanuts	10.9	574	2.8	12.8	674	3.3	7.0	369	1.8
Fish Meal	24.4	698	14.9	20.5	586	12.5	18.0	515	11.0
Vit. Mix	0.6						0.5		
Totals	100.6	3493	24.7	100.0	3549	23.0	100.5	3458	20.9
Diet No.	- - - - -	4	- - - - -	- - - - -	5	- - - - -	- - - - -	6	- - - - -
H. L. Maize	75.0	2574	8.1	72.0	2475	7.8	73.0	2505	7.9
Peanuts	8.0	421	2.1	9.0	474	2.3	9.0	474	2.3
Fishmeal	17.0	486	10.4	19.0	543	11.6	18.0	515	11.0
Salt				0.7			0.3		
Vit. Mix				0.2			0.1		
Totals	100.0	3481	20.6	100.9	3488	21.7	100.4	3494	21.2
Diet No.	- - - - -	7	- - - - -	- - - - -	8	- - - - -	- - - - -	9	- - - - -
Reg. Maize	28.5	959	2.5	35.0	1178	3.0	37.5	1262	3.2
Rough Rice	28.5	758	2.1	35.0	931	2.6	37.5	998	2.7
Peanuts	14.2	748	3.6	10.0	527	2.6			
Fish Meal	28.8	824	17.6	20.0	572	12.2	25.0	715	15.3
Bone Meal	0.3						0.5		
Salt	1.0			0.2			0.1		
Vit. Mix	0.2			0.1			0.2		
Totals	101.5	3289	25.7	100.3	3208	20.3	100.8	2975	21.2

(Continued next page)

Table 17 - continued.

Diet No.		10			11			12	
Reg. Maize	38.9	1309	3.4	17.0	572	1.5	42.0	1414	3.6
Rough Rice	38.9	1035	2.8	61.0	1623	4.5	42.0	1117	3.1
Fish Meal	22.2	635	13.5	22.0	629	13.4	15.0	429	9.2
Totals	100.0	2979	19.7	100.0	2824	19.3	99.0	2960	15.8
Diet No.		13			14			15	
Reg. Maize	37.0	1245	3.2	40.0	1346	3.4	40.2	1353	3.4
Rough Rice	37.0	984	2.7	40.0	1064	2.9	40.2	1069	2.9
Fish Meal	21.0	601	12.8	16.0	458	9.8	14.1	404	8.6
Salt				0.2			0.4		
Vit. Mix				0.03			0.08		
Lime							5.0		
Totals	95.0	2830	18.7	96.2	2868	16.1	100.0	2826	14.9

Upon arrival on April 8, 1976, the chicks were weighed. On May 7 when they were five weeks old another weighing was made. The pullets were weighed a third time at 23 weeks of age when laying began. Egg production records were kept to observe how well hens could produce when consuming diets designed for production conditions. Common to all diets was the requirement that they contain locally produced feedstuffs plus imported fish meal, bone meal, and vitamin mix.

KUPI was a series of three experiments designed to determine the effectiveness of kudzu pasture and type of supplementation required. In the first experiment five adult RIR hens were placed in a 5.5 m^2 area of kudzu beginning on Feb. 17, 1977.

Six shelters were built to protect the hens at night from predators and provide a place to protect feeders and waterers from the rain. Woven wire fencing was put up in the kudzu to divide the pastures in 18 sections to be used to supply kudzu to each group of hens. The fencing was arranged to guide the hens to the proper section of the range shelter in which they were receiving the supplementation designed for them.

The range shelters were designed with a single pitch roof of metal. The side with the entrance from the pasture was 0.6 m high and the front entrance was 1.1 meters high. The dimensions of the floor area of each shelter was 2.5 by 1.1 m. This shelter was divided into three sections of 1.1 by approximately 0.8 m to hold five hens when they were not on pasture. Two nests placed side by side on one wall were provided, each measuring 0.3 x 0.3 x 0.3 m. The bone meal and salt feeders were of wood and measured 10 x 30 cm and 8 cm deep. A divider was placed in the center to separate the bone meal from the salt. The feeders for the supplement were 30 x 10 x 12 cm. Water was supplied in one gallon plastic waterers. All chickens received salt, bone meal, and water free choice.

The hens stripped all the leaves from the kudzu plants in their pastures in three or four days. The purpose of this experiment changed to one of measuring kudzu consumption and pasture area required. The amount of kudzu consumed was calculated from a number of samplings. An estimation of the amount present when the chickens entered the pasture was made by harvesting and weighing six 1 x 2 m plots immediately outside the pasture fence. These samples were dried and weighed again to determine dry weight as percent of fresh weight. Three 1 x 2 m plots were harvested in the pasture after the chickens had intensively grazed the areas. Fresh and dry weights were determined. From this data was calculated the amount of kudzu consumed and the area required for poultry pasture.

The second KUPI experiment was designed to realize the original objectives of the first trial. One goal of this experiment was to discover a poultry feeding system that was simple, could be duplicated by the Indians, and would maintain an acceptable level of egg production. Pasture supplemented only with water, salt, and bone meal was considered the easiest feeding system.

All chickens in the trial received these feedstuffs free choice. One of the treatments was pasture only without supplementation. The literature contained references to the low energy content of pasture. High lysine maize supplementation fed free choice was considered to add energy to the diet. Another treatment considered the high fiber and low nutrient concentration of pasture by supplementing with a feedstuff containing high levels of energy and protein. Unextracted sesame was considered adequate to meet these specifications. Fish meal was supplied on a free choice basis to supplement the lack of protein in pasture.

Ten hens divided in two groups were used for each treatment. The pasture size was determined from information generated in the first KUPI experiment. It was calculated one hen would require a maximum of 2.6 m^2 of pasture for each week the experiment was in progress. If 60 m^2 of pasture were available per treatment this would maintain five hens from 4.5 to 6 weeks. Therefore, eight new kudzu pastures 10 x 6 m were established with a shelter placed on one edge centering at the dividing fence of each pair of pastures.

The experiment continued over a period of three weeks. Diet 15 (Table 17) was fed to all birds in the experiment while they were adjusting to new conditions. This diet was received before removal from the PORE experiment. A record was kept of the daily egg production and the amount of feed consumed. Kudzu consumption was evaluated by determining the square meters of area on which the kudzu had been completely grazed.

Fresh hens from PORE were selected to use in the third KUPI designed to determine which supplements Indians could utilize to improve egg production. Another purpose was to observe the response, measured by egg production, to supplementing pasture with both maize and sesame. Perhaps this combination of energy rich feeds plus one rich in protein would be more effective than either one alone. Two remaining treatments were designed to observe the usefulness of sunflower or pigweed (_Ameranthus spinosa_) as pasture supplements.

Pigweed was considered recognizing the increased interest in the world to utilize the grain produced by this prolific weed. Initially the inflorescences were fed directly as harvested. Since the chickens did not consume the pigweed grain the heads were passed through a hand grinder to make them more palatable.

High lysine maize and sesame were fed in separate feeders within the same house, they were fed free choice as were the other treatments. Sunflower was another treatment thought to have merit because the protein quality was fairly high and the crop grew well in the area. Both the maize and sunflower were cracked before feeding to the chickens.

The chickens used in this experiment were allowed to graze on the same pastures used in the second experiment. The kudzu consumption of these birds was not estimated. Each treatment was replicated three times. Similar data were collected as in the previous experiments.

Linear Program

The linear programming capability of the computer was used to model the production from the farm of a family living within a subsistence environment. The Amhdal 470 V/6 computer located at the University of Florida was used for this work. This system uses IBM 370 compatible systems and hardware (northeast Regional Data Center, 1977). The programming language used and designed by IBM is called the Mathematical Programming System 360 (MPS).

The data used by the linear program were arranged in a matrix with each element having a column and row coordinate. The rows were the linear equations. Each column was a list of figures indicating levels of all row items present in one unit of that particular column.

Columns

The first group of columns was considered to serve a warehouse function, holding the exact kinds and amounts of crops required with no excesses remaining. The feedstuffs purchased and crops grown were the source of material. Crop production was limited by the amount of land available. The list of crops available for selection by the program is presented in Table 18. The support for the land requirement figures plus other pertinent information is listed as well. Not included are the feedstuffs purchased such as mineralized salt, lime, bone meal, and vitamin mix. Data concerning these items are presented in the discussion of the rows.

Eggs and chicken meat were not listed yet were available for selection. No land was considered necessary to produce these products. The limit on the amount of poultry products available for selection was the predetermined number of chickens and eggs the system could produce.

The second column section contained crops and purchased feedstuffs suitable for feeding to chickens. White rice was excluded from consideration because too much work is involved to prepare it for chicken feed. Peanuts were excluded because they were considered used more effectively as human food. Yuca was excluded because it was thought the Indians would consider it too valuable as a human food. The yuca fed to chickens is being discarded by the family at the conclusion of a meal.

Human foods were listed in the third section. Here rough rice was excluded as being too fiberous for consumption in this form. Sorghum and sunflower were also excluded for the same reason.

Table 18. Crops available as nutrient carriers within the linear program.

Crop	Cultivar	Experiment or Author Quoted	Yield		Computer Name‡
			g/m^2	m^2/kg	
Regular Maize	VS-2	MUCOX	177	5.6	CNRGB-1K
High Lysine Maize	75 H. L.	Coly+HYLS	144	7.0	CNHLB-2K
Yuca	Local	SMADA+Fer. Trial	1929	0.5	YUCAB-3K
White Rice	Local	†	69	14.5	WLORIB4K
White Rice	Grn. Rev.	†	208	4.8	WGNRIB5K
Rough Rice	Local	RITRI	108	9.3	RLRIB-6K
Rough Rice	Grn. Rev.	NIRI	323	3.1	RGRIB-7K
Sorghum	Rico	PEOB+MUCOB	283	3.5	SORGB-8K
Cowpea	Chenise	MUCOX	91	11.0	COWPB-9K
Soybean	Jupiter	BEPESO	327	3.1	SOYBB10K
Mungbean	Lg. Seed	BEPESO	111	9.0	MNGBB11K
Jackbean	Introduc.	BETRIC	642	1.6	JAKBB12K
Peanuts	Tarap+Blanco	4 Trials	254	3.9	PRANB13K
Sesame	Poroviejo	5 Trials	87	11.5	SESMB14K
Sunflower	Mammoth	VACO	43	23.3	SUNFB15K
Velvetbean	Local	Gohl, 1975	35	28.6	VELBB49K
Papaya	Local	Gohl, 1975	500	2.0	PAPYB45K
Kudzu	Tropical	KUPI	208	4.8	KUDZB28K
Cooking Banana	Local	Simmonds, 1966	344	2.9	PLATB29K

† Considered to be 64 percent of rough rice weight.
‡ Used in the warehouse section of the matrix.

The selling section, consisting of the fourth and final group of columns, contained crops and poultry products that might sell. Polished rice was not included because the farmer does not have easy access to a rice mill. He could only sell rough rice. All the items purchased, because they could not be produced on the farm, were also excluded from this section. The locally produced fruits were not considered for sale partly because no prices for these products have been established.

Rows

Each value in the matrix had a column coordinate as discussed but was further defined by the row location. The units varied according to the row being considered. In all cases the figures represented the number of row units contained in one column unit.

Objective rows. The first two rows in the matrix were the objective rows. These contained the energy and protein figures to be maximized by the program. By placing these values in the selling section of the columns any land remaining after people and chickens had been fed would be used to produce the maximum amount of these nutrients.

Accounting rows. The next group of rows were designed to account for various features of the program. The first row contained values representing the amount of land required to produce one kilo of a crop. These values represented the cost of using any crop because land was limited. The purpose of this row and the remaining rows in this section is shown in Table 19.

Feeding rows—chickens and people. The next two row sections contained the nutrient values required to feed and satisfy chickens and people. Two columns of figures in these row sections were negative.

Table 19. Counting row information. The purpose of the counting rows is given with the common and computer names and units.

Name	Units	Computer Names	Purpose †
Land	Sq. meters	LND2-SQM	Limit land used
Chicken land	Sq. meters	LNDCKSQM	Land used for egg and meat prod.
Food prod. land	Sq. meters	LNDHUSQM	Land used for family food
Crop sale land	Sq. meters	LNDSLSQM	Land used for sale crops
Energy con-chick	MCal	ENCSCKMC	Energy used by chickens
Energy con-human	MCal	ENCSHMMC	Energy used by humans
Energy sold	MCal	ENSOLDMC	Energy sold off farm
Gross energy-total	MCal	ENGRTOMC	Total energy prod. by system
Protein con-chick	Grams	PRTCSCKG	Protein used by chickens
Protein con-human	Grams	PRTCSHMG	Protein used by humans
Protein sold	Grams	PRTSOLDG	Protein sold off the farm
Protein-total	Grams	PRTTOTGM	Total protein prod. by system
Chicken sales	Sucres	CKNSLDSU	Money from chicken sales
Crops sold	Sucres	CRPSLDSU	Crop sales where prices available
Gross revenue	Sucres	GROSSREV	Gross revenue from sales
Feedstuffs bought	Sucres	STUFBTSU	Cost of feedstuff purchased
Net revenue	Sucres	NET--REV	Gross revenues-feedstuff bought
Chickens eaten	Sucres	CKNEATSU	Sale value of chickens eaten
Crops sold	Kg	CROSLDKG	Weight of all crops sold
Crops eaten	Kg	CRPEATKG	Weight of crops eaten-human, chicken
Birds eaten	Number	BRDEATNM	Number of birds eaten
Birds sold	Number	BRDSLDNM	Number of birds sold
Eggs eaten	Number	EGGEATNM	Number of eggs eaten
Eggs sold	Number	EGGSLDNM	Number of eggs sold

† Aside from limiting land this section is used to evaluate how the farm family is benefiting from the computer selection. This section was used to monitor the accuracy of relationships within the matrix.

They represented the requirements, over a period of 180 days, of either people or chickens for the nutrient in each row. The remaining figures in each row were positive to indicate the amount of a particular nutrient available in one kilogram of carrier to reduce the requirement level represented by the negative value.

The columns of negative numbers representing human and poultry nutrient requirements will be discussed first. One unit of human requirement was created by a family of six consisting of a very active male and a very active lactating female. The youngest child of the family was one year old. The second oldest was a four year old. The third child was an 11 year old and the oldest was a male 15 years old. The literature support for the recommended daily allowances (RDA) and calculations required to produce values to use in the linear program are presented in Tables 20 to 22. Table 21 presents the steps taken to generate values from the raw data of protein requirement for young people using standard weights and egg protein as the carrier of those requirements. Egg was selected on the assumption the amino acid profile in this standard protein was the same as the profile required by young people.

One unit of poultry requirement was created by a flock of 135 birds consisting of 35 laying hens, seven hens not in production, three roosters, and 90 chicks to be sold for meat at the end of the semester or used as replacement birds. The figures were constructed by multiplying the values in Table 23 by the number of bird days in the semester. Consumption data for this table was created by using the same multipliers on the daily consumption figures shown in Table 24 for growers and in a

Table 20. Human recommended daily nutrient allowances (RDA) information, sources, and notes in support of data in Table 22.

Item	Child 1 Year	Child 4 Years	Female 11 Years	Male 15 Years	Lact. Female 23-50 Years	Male 23-50 Years
Energy	34	34	34	34	18	†
Protein	34	34	34	34	34	34
Meth-Cyst.	§	§	§	§	34	34
Lysine	§	§	§	§	34	34
Tryptophan	§	§	§	§	34	34
Calcium	31	31	31	31	89	89
Phosphorus	¶	¶	¶	¶	89	¶
Potassium	#	#	#	#	89	89
Sodium	- - - - - - - - - Usual intake 6-18 g/day-RDA unknown†† - - - - - - - - - - - -					
Magnesium	89	89	89	89	89	89
Manganese	- - - - - - - - Usual intake 2.5-7 mg/day-RDA unknown†† - - - - - - - - - - - -					
Zinc	89	89	89	89	89	89
Vitamin A	32	32	32	32	32	32
Panothenic A	#	#	#	#	89	89
Choline	- - - - - - - - Usual intake 400-900 mg/day-RDA unknown†† - - - - - - - - - - -					
Niacin	89	89	89	89	89	89
Riboflavin	89	89	89	89	89	89
Fat	- - - - - - - - - Less than 35% of the calories†† - - - - - - - - - - - - -					
Fiber	- - - - - - Crude fiber intake 24.8 g/day in rural Africa‡‡ - - - - - - - - - -					
Amount cons.	41	41	41	41	41	41

† Very active 65 kg male (FAO-WHO, 1973). ‡ Protein score 100%. § See Table 20 for values. ¶ Same as calcium values. # Adult male value (Pike and Brown, 1975). †† Pike and Brown (1975). ‡‡ Cummings (1973).

Table 21. Requirements of selected amino acids for young people as derived from the information indicated.

Sex	Age	Weight †	Egg Protein Intake ‡		12.4 Percent Protein Eggs	Amino Acid Requirement		
						Meth-Cyst§	Lysine §	Tryptophan§
	years	kg	g/kg day	g/day	g/eggs/day	- - - -	mg/day	- - - -
Male	1	11.4	1.27	14.5	117	838	1009	215
Females	4	17.5	1.06	18.6	150	1076	1295	276
Female	11	37.7	0.76	28.7	231	1657	1994	425
Male	15	52.3	0.59	30.9	249	1787	2151	459

† Weight tables (FAO-WHO, 1973).
‡ Safe levels of egg protein (FAO-WHO, 1973).
§ FAO (1972).

Table 22. Daily requirements of each individual in a family of six and total nutrients required for the family during a period of 180 days. References giving source of information is listed in other tables.

Nutrients	Units	Child 1 Year	Child 4 Years	Female 11 Years	Male 15 Years	Lact. Female 23-50 Years	Male 23-50 Years	Family Total
Gross energy	MCal	1.36	1.83	2.35	2.9	2.2	3.5	2745
Protein	grams	16	20	29	37	46	37	33264
Meth-Cyst.	grams	0.84	1.08	1.66	1.79	0.7	1.1	1288
Lysine	grams	1.01	1.30	1.99	2.15	0.5	0.8	1403
Tryptophan	grams	0.22	0.28	0.43	0.46	0.2	0.3	323
Phosphorus	grams	0.5	0.5	0.7	0.7	1.2	0.5	738
Potassium	grams	2.5	2.5	2.5	2.5	2.5	2.5	2700
Calcium	grams	0.5	0.5	0.7	0.7	1.2	0.5	738
Sodium	grams			Based on 6 g/person day				6480
Magnesium	grams	0.2	0.2	0.3	0.4	0.5	0.4	333
Manganese	mg			Based on 2.5 mg/person day				2700
Zinc	grams	0.01	0.01	0.02	0.02	0.03	0.02	16
Vitamin A	IU	835	1000	1650	2500	2500	2500	2000000
Pan Acid	mg	5-10	5-10	5-10	5-10	5-10	5-10	5440
Choline	mg			Based on 400 mg/person day				432000
Niacin	mg	9	12	16	20	17	18	16560
Riboflavin	mg	0.8	1.1	1.3	1.8	1.7	1.6	1494
Fat	grams			See note below†				100764
Fiber	grams			Based on 24.8 g/person day				26784
Amount cons.	kg	0.2	0.2	0.4	0.4	0.4	0.4	360

† 2545 MCal gross energy/kg x 35% = 901 MCal fat divided by 8.84 MCal/kg soybean oil (Caribbean Food and Nutrition Institute, 1974) x 1000 g/kg = 100764 g fat. Maximum percent calories in the diet to be fat = 35% (Pike and Brown, 1975).

Table 23. Suggested allowances for starting and growing chickens (Titus and Fritz, 1971) and practical levels for light breed laying hens (Scott et al., 1969). Margins of safety exist. Young stock is not expected to make maximum early growth.

Item	Unit	Young Stock			Layers
		Starter 0-8 weeks	Grower 8-26 weeks	Mean weighted†	
Metab. energy	MCal/kg	2.75	2.53	2.6	3.1
Protein	%	20	16	17	16
Meth-Cyst.	%	0.75	0.53	0.6	0.6
Lysine	%	1.10	0.82	0.9	0.6
Tryptophan	%	0.20	0.15	0.2	0.2
Phosphorus‡	%	0.70	0.60	0.6	0.7
Potassium	%	0.20	0.17	0.2	0.2
Calcium	%	1.00	1.00	1.0	3.3
Sodium	%	0.15	0.15	0.2	0.2
Magnesium	mg/kg	500	500	500	500
Manganese	mg/kg	55	55	55	35
Zinc	mg/kg	50	50	50	50
Vitamin A	IU/kg	2200	2200	2200	8800
Pan. acid	mg/kg	11.0	10.0	10.3	6
Choline	mg/kg	1145	1145	1145	860
Niacin	mg/kg	27.0	13.5	16.9	20
Riboflavin	mg/kg	4.0	3.0	3.3	2.2
Fat §	%	15	15	15	15
Fiber	%	10	10	10	10
Xanthophyll	mg/kg	11	11	11¶	35#

† Grower weighted 3 x starter because fed 3 times as long.

‡ Should contain 0.5% inorganic phosphorus.

§ Based on statement 10% or above no a problem for chicks if ME/prot. around 13.2 kcal/g (Scott et al., 1969).

¶ Give a light pigmentation to broiler skin-one class less than normal (Titus and Fritz, 1971).

To produce a NEPA of 2.5 (Titus and Fritz, 1971).

Table 24. Estimated feed consumption of growers using values given by Scott et al. (1969) for White Leghorn pullets.

Age in Weeks	Grams/ Bird Day	kg/90 Bird Week	Age in Weeks	Grams/ Bird Day	kg/90 Bird Week
1	8	5.0	13	60	37.8
2	13	8.2	14	61	38.4
3	19	12.0	15	63	39.7
4	27	17.0	16	64	40.3
5	32	20.2	17	65	41.0
6	41	25.8	18	66	41.6
7	48	30.2	19	67	42.2
8	49	30.9	20	68	42.8
9	49	30.9	21	69	43.5
10	53	33.4	22	70	44.1
11	57	35.9	23-26	70[†]	176.4[‡]
12	59	37.2			
Total					874
Mean				53.4	

[†] Assume consumption remains the same.

[‡] Value for four weeks.

footnote (§) to Table 25 for mature birds. The relationship of both energy and protein totals in Table 25 to the consumption figures is shown in a footnote (†) to that table.

The suggested allowances listed in Table 23 contain a margin of safety. It is possible some values of formulated diets could be somewhat lower yet produce diets considered to be adequate. Some of these data are for White Leghorns yet is applied to Rhode Island Reds. Precision is not possible because of the uncertainty of nutrient levels in feedstuffs used in the field. The figures presented were considered sufficiently accurate to serve as a realistic standard to evaluate formulated diet quality.

Production from the flock was calculated assuming 35 hens laying at a 50 percent rate would, in 180 days, produce 3150 eggs. Assuming a hatching percent of 50, 180 eggs were set aside to produce 90 chicks. The eggs were considered to weigh 56 grams of which 89.3 percent was edible. This value approximates the figures given by Romanoff and Romanoff (1949) for a 58 gram egg of which 11 percent was shell. Thus, 20 eggs were required to produce one kilo of edible egg. Adult birds and six month old birds were considered to contain 1.5 kilos of edible meat per bird. The edible eggs produced for distribution from the warehouse section was 148.5 kg numbering 2970. The 90 birds produced 135 kg of meat. The transfers within the linear program were arranged to distribute this food between human consumption and sales. Products not selected for human consumption were sold.

The discussion within the human and poultry nutrient section shifts to a description of the positive numbers associated with the nutrient carriers. The linear program selected from the list of crops those

Table 25. Chicken nutrient allowances based on data in previous tables. Nutrient levels calculated on basis of consumption level shown here and suggested allowances presented elsewhere. Totals are used in the linear program.

Item	Units	90 Chicks 180 Days	45 Birds 180 Days	Total 180D135B
Metab. energy	MCal	2272	3013	5285
Protein	g	1488580	155520	304100
Meth-Cyst.	g	5244	5832	11076
Lysine	g	7866	5832	13698
Tryptophan	g	1748	1944	3692
Phosphorus	g	5244	6804	12048
Potassium	g	1748	1944	3692
Calcium	g	8740	32076	40816
Sodium	g	1748	1944	3692
Magnesium	mg	437000	486000	923000
Manganese	mg	48070	34020	82090
Zinc	mg	43700	48600	92300
Vitamin A	IU	1922800	8553600	10476400
Pan. Acid	mg	9002	5832	14834
Choline	mg	10000730	835920	1836650
Niacin	mg	14771	19440	34211
Riboflavin	mg	2884	2138	5022
Fat	g	131100	145800	276900
Fiber	g	87400	97200	184600
Xanthophyll	mg	9614	34020	43634
Consumption[†]	kg	874[‡]	972[§]	1846

[†] Provides a diet with 2600, 3100, and 2860 kilocalories/kg of energy and a protein level of 17, 16, and 16%, respectively, for each group of birds represented in the three columns.

[‡] See previous table for calculation details. It is pointed out Leghorn data is being used in part to estimate Rhode Island Red requirements.

[§] Average consumption assumed to be 120 g/bird day. Research showed 180 g/bird day was consumed when kudzu pasture was available.

carriers and the required amounts necessary to satisfy the needs while remaining within the constraints. One of the constraints was human and poultry requirements were to be satisfied before any crops were sold.

The amount of crops required to satisfy the nutrient needs of either chickens or people depended upon the concentration in the carrier. These values and sources of the information are indicated in Tables 26-29. How well the Indians will accept the amounts and kinds of crops selected by the computer is an important factor in the success of any diet.

Tables 30 and 31 contain the nutrients present in crops harvested at Limoncocha. The fish meal was from the material used for formulating the diets fed to the growing Rhode Island Reds. The analysis was not available when the linear program matrix was constructed so could not be used for that purpose. The information is presented to facilitate comparison with tabular data when evaluating the quality of diets discussed in the results and discussion section.

Which foods Indians are likely to select is difficult to predict. The decision was made to formulate 10 diets for human consumption and 10 diets for chicken consumption. Each diet would have its own set of strengths and weaknesses for the Indians to consider. With 20 diets as possibilities the chances are greatly increased some will be selected to meet future needs.

The diets selected by the computer in the manner described required refinements difficult to design the program to produce. A Hewlett-Packard HP-97 programmable printing calculator was programmed to calculate and print the total amount of energy, protein, methionine-cystine,

Table 26. Nutrient content of carbohydrate rich crops used in the linear program as listed in the literature.

Nutrient	Units	Reg. Maize	H. L. Maize	Rough Rice	White Rice
Gross energy	Kcal/kg	3610 †	3610 †	3325 ‡	3630 †
Metab. energy	Kcal/kg	3370 §	3430 §	2660 ¶	3100 ¶
Protein	%	8.6 §	10.8 §	8.0 ¶	6.7 †
Meth-Cyst.	Mg/100 g	380 §	290 §	270 ¶	328 #
Lysine	Mg/100 g	240 §	380 §	300 ¶	299 #
Tryptophan	Mg/100 g	90 §	110 §	100 ¶	90 ¶
Calcium	Mg/100 g	20 §	20 §	90 ¶	24 †
Total phosph.	%	0.28 §	0.2 §	0.36 ¶	0.12 ¶
Potassium	%	0.31 §	0.36 §	1.0 ¶	0.13 ¶
Sodium	%	0.01 ¶	0.01 ¶	0.03 ††	0.03 ¶
Magnesium	Mg/100 g	110 §	130 §	140 ††	50 ¶
Manganese	Mg/100 g	0.5 ¶	0.5 ¶	1.8 ¶	1.1 ¶
Zinc	Mg/100 g	1.0 ¶	1.0 ¶	1.5 ¶	0.2 ¶
Vitamin A	IU/kg	2200 §	2200 §		
Panothenic A	Mg/100 g	0.57 §	0.48 §	0.33 ¶	0.33 ¶
Choline	Mg/100 g	52.8 §	52.8 §	80 ¶	90 ¶
Niacin	Mg/100 g	2.2 §	2.0 §	3.03 ††	1.6 †
Riboflavin	Mg/100 g	0.11 §	0.11 §	0.05 ¶	0.03 †
Fat	%	3.8 §	4.0 §	1.7 ¶	0.4 †
Xanthophyll	Mg/100 g	1.5 ‡‡	1.5 ††		
Fiber	%	2.5 §	3.7 §	9.0 ¶	0.4 ¶

† Caribbean Food and Nutrition Institute, 1974.
‡ Metabolizable energy x 1.25.
§ IMC Chemical Group, 1976
¶ Scott et al., 1969.
# FAO, 1972.
†† Titus and Fritz, 1971.
‡‡ Tergas and Popenoe, 1971.

Table 27. Nutrient content of selected feed or foodstuffs used in the linear program as listed in the literature.

Nutrient	Units	Sorghum	Platano	Yuca	Papaya
Gross energy	kcal/kg	3430 †	1320 †	1450 †	390 †
Metab. energy	kcal/kg	2744 ‡			311 ‡
Protein	%	10.1 †	1.2 †	1.2 †	0.6 †
Meth-Cyst.	mg/100 g	270 §	52 ¶	45 ¶	
Lysine	mg/100 g	204 ¶	46 ¶	67 ¶	24 ¶
Tryptophan	mg/100 g	90 §	13 ¶	19 ¶	8 ¶
Calcium	mg/100 g	39 †	0.1 #	0.03 ††	0.02 #
Total phos.	%	0.3 §	0.39 #	0.23 ††	0.23 #
Potassium	%	0.35 §	8 †	33 †	20 †
Sodium	%	0.001 ‡‡	0.02 #		0.003 #
Magnesium	mg/100 g	130 §	33 #		
Manganese	mg/100 g	1.3 ‡‡		1.6 ‡‡	
Zinc	mg/100 g	1.7 ‡‡			
Vitamin A	IU/kg	733 §§	12500 †		17500 †
Panothenic A	mg/100 g	1.1 §			
Choline	mg/100 g	66 §			
Niacin	mg/100 g	4.0 †	0.5 †	0.6 †	0.3 †
Riboflavin	mg/100 g	4.0 †	0.5 †	0.6 †	0.3 †
Fat	%	3.3 †	0.1 †	0.3 †	0.1 †
Xanthophyll	mg/100 g	0.15 §§			
Fiber	%	2.5 §	0.4 †	1.0 †	0.9 †

† Caribbean Food and Nutrition Institute, 1974.

‡ Gross energy x 80%.

§ IMC Chemical Group, 1976.

¶ FAO, 1972.

Watt and Merrill, 1963.

†† Morrison, 1948.

‡‡ Scott et al., 1969.

§§ Titus and Fritz, 1971.

Table 28. Nutrient content of protein rich crops used in the linear program as listed in the literature.

Nutrient	Units	Soybean	Peanut	Cowpea	Sesame	Sunflower
Gross energy	kcal/kg	3350 †	5640 †	3410 †	5840 †	5750 †
Metab. energy	kcal/kg	3510 ‡	4512 §	2728 §	4670 §	4600 §
Protein	%	38 †	26 †	24.1 †	17.6 †	22.4 †
Meth-Cyst.	mg/100 g	1077 ¶	704 ¶	528 ¶	988 ¶	504 ¶
Lysine	mg/100 g	2653 ¶	1036 ¶	1599 ¶	585 ¶	536 ¶
Tryptophan	mg/100 g	532 ¶	305 ¶	254 ¶	287 ¶	202 ¶
Calcium	mg/100 g	208 †	69 †	77 †	1212 †	410 #
Total phosphorus	%	0.6 ‡	0.39 #	0.46 #	0.62 ††	0.52 ‡‡
Potassium	%	1.5 ‡	0.54 #	1.3 #	0.73 ††	0.66 ‡‡
Sodium	%	0.35 #	0.56 #	0.27 #	0.06 ††	
Magnesium	mg/100 g	220 #	180 #	260 #	181 ††	
Manganese	mg/100 g	3.2 #	1.6 #	4.0 #		2.0 #
Zinc	mg/100 g	2.0 ‡	1.6 #			1.7 #
Vitamin A	IU/kg	1500 †	264 #	500 †		500 #
Panothenic A	mg/100 g	1.45 ‡	4.4 #			
Choline	mg/100 g	280 ‡	237.6 #			
Niacin	mg/100 g	2.1 †	17.2 †	1.9 †	4.0 †	7.6 †
Riboflavin	mg/100 g	0.3 †	0.13 †	0.23 †	0.25 †	0.19 †
Fat	%	18.0 †	47.5 †	1.2 †	52.2 †	26.4 #
Fiber	%	5.0 ‡	2.4 †	4.9 †	10.3 ‡‡	29.0 ††

† Caribbean Food and Nutrition Institute, 1974.
‡ Scott et al., 1969.
§ Gross energy x 80%.
¶ FAO, 1972
# Titus and Fritz, 1971.
†† Watt and Merrill, 1963.
‡‡ Morrison, 1948.

Table 29. Content of selected nutrient carriers used in the linear program as listed in the literature.

Nutrient	Units	Jackbean	Velvetbean	Eggs	Chickens	Kudzu
Gross energy	kcal/kg	3310 †	3125 ‡	1630 †	2460 †	2010 #
Metab. energy	kcal/kg	2650 §	2500¶	1300 §	1970 §	1610 §
Protein	%	25.4 †	32.8††	12.9 †	18.1 †	15 ‡‡
Meth-Cyst.	mg/100 g	627 ††	688 ††	717 ††	764 ††	400 ‡‡
Lysine	mg/100 g	1348 ††	2037 ††	863 ††	1590 ††	600 ‡‡
Tryptophan	mg/100 g			184 ††	205 ††	170 ‡‡
Calcium	mg/100 g	96 †	270 §§	54 †	10 †	1500 ‡‡
Total phosphorus	%		0.36 §§	0.23 ¶¶	0.2 ##	0.3‡‡
Potassium	%			0.14 ¶¶	0.32##	2.49‡‡
Sodium	%			0.12 ¶¶	0.07##	0.02 ‡‡
Magnesium	mg/100 g		200 §§	20 ¶¶	23 ##	290 †††
Manganese	mg/100 g			0.4 ¶¶		1.5 ‡‡
Zinc	mg/100 g			1.4 ¶¶		1.6 ‡‡
Vitamin A	IU/kg	500 †		11800 ¶¶	670 †	18000 ‡‡
Panothenic A	mg/100 g			0.66 ¶¶		2.2 ‡‡
Choline	mg/100 g			176 ¶¶		80 ‡‡
Niacin	mg/100 g	2.1 †		0.1 †	7.7 †	3.8 ‡‡
Riboflavin	%	0.15 †		0.3 †	0.14 †	1.2 ‡‡
Fat	%	1.3 †	5.7 ‡‡‡	11.5 †	18.7 †	1.5 ‡‡
Xanthophyll	mg/100 g					60 ‡‡
Fiber	%	8.2 ‡‡‡	6.4 ‡‡‡	0 †	0 †	30 ‡‡

† Caribbean Food and Nutrition Institute, 1974.
‡ Metabolizable energy x 1.25.
§ Gross energy x 80%.
¶ Metabolizable energy for swine (Gohl, 1975).
# Alfalfa value (Commercial Solvents Corporation, 1974).
†† FAO, 1972.
‡‡ J. L. Milligan, 1972, Poultry feeds and feeding for Peruvian selva tribes. Instituto Linquistico de Verano, Tribal Affairs Department, Lima, Peru.
§§ National Academy of Sciences, 1971.
¶¶ Titus and Fritz, 1971.
Watt and Merrill, 1963.
††† Alfalfa value (Titus and Fritz, 1971).
‡‡‡ Morrison, 1948.

Table 30. Nutrient content of cereal crops grown at Limoncocha.

Nutrient	Units	Rice Paddy	Maize			
			1975HL	1973HL	VS2	local
Protein	%	9.0	10.3	9.2	11.1	10.6
Methionine	mg/100 g	200.0	360.0	190.0	220.0	210.0
Lysine	mg/100 g	360.0	550.0	390.0	360.0	390.0
Tryptophan	mg/100 g	60.0	100.0	100.0	70.0	70.0
Calcium	mg/100 g	60.0	30.0	20.0	10.0	40.0
Phosphorus	%	0.2	0.3	0.3	0.3	0.3
Potassium	%	0.1	0.1	0.3	0.3	0.2
Sodium	%	0.1	0.6	0.2	0.3	0.1
Magnesium	mg/100 g	120.0	110.0	100.0	110.0	110.0
Manganese	mg/100 g	1.0	0.5	0.5	0.5	0.4
Zinc	mg/100 g	2.4	3.4	3.1		6.7
Fiber	%	11.2	3.7	3.5	3.8	3.7
Mositure	%	9.8	10.4	11.1	12.4	9.5

Source: Analysis made in INIAP laboratories on March 10, 1978, at the Santa Catalina Experiment Station south of Quito.

Table 31. Content of nutrient carriers produced in Limoncocha except fish meal which was manufactured in Eduador.

Nutrient	Units	Sesame Porto-viejo 2	Sunflower Mammoth	Cowpea Chenise Red	Peanuts	Pig Weed *Ameranthus spinosa*	Fish Meal Ecuador
Protein	%	20.5	18.2	24.6	31.1	21.2	43.1
Methionine	mg/100 g	1510.0	910.0	400.0	410.0	260.0	1260.0
Lysine	mg/100 g	640.0	780.0	1650.0	1260.0	640.0	2470.0
Tryptophan	mg/100 g	390.0	170.0	240.0	680.0		470.0
Calcium	mg/100 g	870.0	180.0	120.0	60.0	1300.0	4830.0
Phosphorus	%	0.6	0.5	0.2	0.4	0.5	1.2
Potassium	%	0.2	0.5	0.2	0.3	4.0	0.2
Sodium	%	0.7	0.6	0.7	0.4	0.0	0.2
Magnesium	mg/100 g	280.0	230.0	80.0	200.0	790.0	210.0
Manganese	mg/100 g	1.7	1.8	0.5	1.0	10.2	7.9
Zinc	mg/100 g	5.9	8.4	2.7	6.0	4.6	26.6
Fiber	%	13.0	35.7	7.9	17.3	22.3	1.9
Moisture	%	5.6	12.4	10.0	7.0	6.8	8.9

Source: Analysis made in INIAP laboratories on March 10, 1978, at the Santa Catalina Experiment Station south of Quito.

lysine, and tropotophan present in any human diet plus give the protein score to evaluate quality. The protein score was important in human nutrition because the amount of protein required for an adequate diet varies with quality. The amounts of crops required by the revised diets were placed in the computer program in such a way that further modifications were impossible. The total of each nutrient in the diets was calculated. The information in the accounting section was produced displaying benefits realized by the Indian farmer.

The HP-97 program used to modify poultry diets was similar to the program developed for human diets. The nutrient levels of energy, protein, methionine, cystine, lysine, and tryptophan were determined as before. The change was the addition of calculations useful when evaluating the quality and practicality of the proposed poultry diets.

One value printed by the HP-97 calculator was the energy density expressed in kilocalories of metabolizable energy per kilogram of diet. Only values within the recommended range would be accepted. Another figure produced was the grams of feed consumed per bird day. This rate of consumption was compared to the predicted daily consumption per bird day based on the energy in the diet and energy requirement of the average bird in the flock. Both the actual and predicted consumption figures had to be very close before a diet would be considered practical. Other measures calculated were the percent protein in the proposed diet and the metabolizable energy-protein ratio. The protein value made it possible to accept diets containing levels within range of the recommendations. The ratio was to monitor the relationship between energy and protein levels to prevent the utilization of diets containing unhealthy excesses of either.

These poultry diets were placed in the computer program as were human diets. Mineral and vitamin deficiencies of poultry diets were satisfied by the computer program selecting the proper supplement and amount. The names of the commercial supplements available for purchase and nutrient levels are presented in Table 32. Both the human and poultry diets were formulated to contain all the food or feedstuffs required to insure adequate nutrition for 180 days.

Transfer rows. The transfer rows were placed in the last section. Here the material available in the warehouse section was distributed to other column divisions in the matrix. This partitioning was accomplished by setting all these rows equal to zero.

Table 32. Nutrient content of vitamin and mineral carriers used in the linear program as listed in the literature.

Nutrient	Units	Min. Salt	Lime	Bonemeal	Vit. Mix
Phosphorus	%	5.0 †		12 ‡	
Calcium	mg/100 g	12000 †	37300 §	24000 ‡	
Sodium	%	20.4 †			
Magnesium	mg/100 g	100 †	800 §		
Manganese	mg/100 g	10 †			3500 ¶
Zinc	mg/100 g	5 †			1500 ¶
Vitamin A	IU/kg				5000,000 ¶
Panothenic A	mg/100 g				350 ¶
Niacin	mg/100 g				1000 ¶
Riboflavin	mg/100 g				250 ¶

† Information on the tag of a bag of mineralized salt sold in Ecuador under the trade name of Agroleche.

‡ Scott et al., 1969.

§ Information printed on the bag of lime sold in Ecuador under the trade name of Agrocal.

¶ Philips-Durphar, No Date.

RESULTS AND DISCUSSION

Crop Observation

Common bean yields and observations are recorded in Table 33. CAR-M and 6406 produced the highest yields at acceptable levels. Local cultivar yields were not high enough to recommend continued planting.

Tables 34 and 35 show cowpea yield levels were generally higher than those recorded for common beans. The vines were observed to be more vigorous and disease resistant. Cowpeas should replace common beans because cowpeas are a more productive selection reflecting a better fit to the climate. One hindrance to rapid acceptance is the Indians are more accustomed to the larger seed size of common beans. Size data in the cowpea tables show the seeds are smaller and less desirable.

Table 36 presents summary data generated during the course of the research describing the higher yielding cowpea cultivars. This list was used when planning the cultivars to be planted in the tribal demonstration plots.

Yields used in the linear program considered representative of the research area are compared in Tables 37 and 38 to values in the literature. Maize yields were better than those reported for Ecuador and about the same as the South American figure. This experimental yield value was produced from open pollinated cultivars improved by INIAP specialists. No fertilizer was used on any of these crops which would explain lower levels than recorded for the USA.

Table 33. Common bean observations. Plant population data were recorded 87 days after planting.

Cultivar	Yield	Seed size	Seed color	Population	Experiment Name
	g/m^2	g/100		plts/m^2	
CAR-M	57	22	BrStr.	8.7	BEGRA2
IBM	32	14	White	7.0	BEGRA2
ICATUI	15		Black		BETRIA
ICATUI	7		Black		MUCOX
6406	15		Black		BETRIA
6406	55		Black		MUCOX
6406	43	14	Black	7.2	BEGRA2
5866	23		White		BEGRA
58181	17	17	Black	1.5	BEGRA2
Ky.Wonder	8	22	White	3.3	BEGRA2
Panomito	6	14	White	4.6	BEGRA2
Yellow local	15	20	Yellow	4.1	BEGRA2
Red local	5	18	Red	2.8	BEGRA2
Local	40		Mixed		MUCOX

Table 34. Cowpea cultivars observed in BEGRA2.

Cultivar	Seed				Shel-ling	Vine Rating‡	Popu-lation§
	yield	size	color	quality†			
	g/m^2	g/100			%		$plts/m^2$
5424	113	10	Br. spots		59	2	6.5
6435	102	10	White	4	47	1	6.9
6441	120	10	Black	5	60	2	8.7
6442	28	12	White	4	56	3	1.1
8487	72	10	Red		49	2	8.5
8488	96	10	Red	3	60	2	6.9
8491	61	11	White	3	60	2	6.1
8495	36	7	White		67	1	4.1
8498	60	11	Red				
8502	50	12	White	2	65	3	5.9
8506	70	7	Brown	2	74	3	3.9
8512	198	13	Brown	2	65	2	9.6
8520	65	14	White		60	2	3.9
8521	43	11	Black	5	50	2	4.3
P-R-V-71-10R-58	99	13	Red	2	67	2	5.4
Super Cream	82	17	White	4	77	2	7.0
Brown Crowder	166	14	Brown	3	67	1	9.1
Chenise Red	180	8	Red	2	68	2	8.9
Red Hull Pinkeye	100	14	Red	4	71	1	6.5
Red Pea (Chenise)	55	8	Red	2	71	1	2.4

† 1 = No blemishes, 2 = a few seeds off color, 3 = half seeds off color, 4 = most seeds off color, 5 = all seeds off color. Obs. on harvest 84 days after planting.

‡ 1 = vine with few branches, 2 = vine with many long branches, 3 = bush observation made 131 days after planting.

§ 94 days after planting.

Table 35. Cowpea cultivars observed in monoculture in MUCOX and BETRIB.

Cultivar	Seed Yield		Shelling
	g/m^2	g/100	%
	MUCOX		
Chenise Red	91[†]	7.0	69
6435	47	14.7	73
6441	35	8.7	67
8506	23	5.7	65
8512	46	13.0	65
	BETRIB		
Red Hull Pinkeye	24		59
Super Cream	6		48
6435	20		65
6442	17		65
8512	18		58
8521	12		52

[†] Value used for land requirement of cowpea in the linear program.

Table 36. Characteristics of promising cowpea cultivars. Local common beans are included for comparison. This summary was used when selecting cultivars for further testing in intercrop systems.

Crop	Cultivar	Days to 1st Harvest	Vine Size	Seed color	Seed size	Seed yield
					g/100	g/m^2
Cowpea	10R58	87	heavy	red	13	99
Cowpea	5424	80	medium	br. spots	10	113
Cowpea	6435	72	light	white	10	102
Cowpea	6441	72	heavy	black	10	120
Cowpea	6442	87	light	white	12	73
Cowpea	8506	72	heavy	brown	7	70
Cowpea	8512	72	medium	brown	13	198
Cowpea	8520	99	medium	white	14	65
Cowpea	8521	72	medium	black	11	43
Cowpea	Brown Crowder	72	medium	brown	14	166
Cowpea	Chenise Red	72	light	red	8	180
Cowpea	Red Hull	72	light	red	14	100
Cowpea	Supercream	87	medium	white	17	82
Common Bean	Yellow Local	48	light	yellow	20	15

Table 37. Crop yields reported from various parts of the world gathered and reported by FAO (1977) compared to yields used in the linear program.

Crop	Linear Program	Ecuador	South America	USA	World
	- - - - - - Grams per square meter - - - - - - - -				
Maize-reg.	177	96	165	549	283
Reg. rice	108				
HYV rice	323	273	179	524	243
Sorghum	283		270	305	118
Sunflower	43		84	118	106
Sesame	85	175	49	71	31
Soybeans	327	117	173	172	138
Common bean	41†	43	52	130	52
Peanut	289	73	121	276	96
Cassava	1921	1373	1230		904

† Yield of local cultivar recorded in MUCOX.

Table 38. Crop yields not reported by FAO (1977) as found in the publications indicated.

Crop	Yields From Experiments	Range in Literature	High in Literature	Source
	- - - - - - - -	g/m^2 - - - - - - - -	- - - - - - - -	
Cowpea	91[†]	45-68	284	Purseglove, 1974
Mungbean	111[†]	45-57	114	Rachie, 1974
Pigeonpea		57-114	205	Rachie, 1974
Yard long	11[‡]	45-65	284	Purseglove, 1974
Lima bean	11[‡]		136	Purseglove, 1974
Wingbean	0[‡]	40-50	250	NAS, 1975

[†] Used in linear program.
[‡] Listed in Table 53.

The unfertilized high yielding cultivars (HYV) of rice were higher than all figures in the table with the exception of those realized in the USA. Sorghum yields were average as were those of common bean. Sunflower did not yield well by comparison to other world figures. Sesame yields were higher than all figures presented except that reported for Ecuador. These latter yield figures were in all probability from crops grown on the coast in a drier climate. Soybeans produced exceptionally well. Unfertilized peanuts gave yields close to those reported for the United States. Cassava yields produced on new land gave better than average yields. The yields of cowpeas (Chenise Red) and mungbean were very good. Swordbean yields were outstanding.

Mungbean observations presented in Table 39 show the Large Seed cultivar was the most productive. Further work was suspended due to the small grain size.

Table 40 presents the soybean yield differences from the BEPESO and VACO experiments which are hard to explain. The nutrient levels present in the VACO soils as shown in Table 41 were similar to the average values for the area presented in the top line of the same table. Rainfall totals did not account for the differences in yields. Total rainfall from August through November 1975 (Table 1), received by BEPESO were 1080 mm, compared to 800 mm on VACO from December 1975, through March 1976. Years earlier top soil was removed from the VACO area. Perhaps the resulting increased clay content accounts for the lower yields because of soil texture or mineral fixation.

The yields from BEPESO were accepted with some caution to be representative of future yield levels. A footnote in Table 40 indicates the mean yield was used in the matrix of the linear program.

Table 39. Mungbean yields produced within BEGRA and BEPESO.

Cultivar	Seed Size	Yield	
		BEPESO	BEGRA
	g/100	g/m^2	g/m^2
T-9	5		9
'73 AUR-6430	4		20
Large Seed	4	111†	55
Small Seed	3	60	

† Figure used in linear program for land requirement.

Table 40. Soybean yields observed in BEPESO.

Rep. No.	Seed Yield		Plot Size	Populations	
	g/m^2	g/plant	m^2	plants/m^2	
1	365	19.6	9.5	10.7	10.0
2	320	24.1	2.5	16.0	15.3
3	328	24.7	2.3	12.0	16.7
4	305	23.0	2.5	14.7	10.7
5	319	24.0	2.4		
$\overline{x}$	327 [†]	23.1		13.3 [‡]	
S	23	2.0		2.7 [‡]	

[†] Figure used in the linear program for the land requirement.

[‡] The eight sample plots these parameters represent are distinct from the plots from which the rest of the data are derived.

Jackbean yields are presented in Table 41. After four harvests were made the plants remained vigorous, were flowering, and setting pods. The fresh seed weight was high. The mature pods measured approximately 38 cm by 3 cm. The vigor of the plant and high yields indicate this crop fits the climate of the continuously humid tropics, but amount of acceptance by the Indians is difficult to estimate at this time.

Peanut data are presented in Tables 42 to 46 and show that many cultivars produced between 1.5 and 2.5 metric tons unshelled peanuts per hectare. In Table 44 the higher yielding cultivars are summarized. Romulo, Sarayacu Stripe, and Sarayucu White (PEOB) ranged from about 300 to short of 425 g/m^2. The imported cultivars of Altika, NC-Fla. 14, and Florunner (PETRI) produced unshelled yields greater than 290 g/m^2. In PEVA only Sarayacu Red produced above 300 g/m^2. The data show the local cultivars fit the environment. Altika and NC-Fla. 14 introductions could be considered if the production of larger kernels was desired.

The selected yields considered to be representative of production in the area are shown in Table 47. The values in the table were combined to produce a yield figure to use in the linear program.

Yields of high lysine and regular maize are shown in Table 48. These yields compare well with those reported in SILOB (Table 58) but were less than VIOB (Table 60). Perhaps the increased yields in the latter were the result of a population of nearly five plants/m^2. The populations reported in Table 48 were half this density, also possibly the local cultivars are better fitted to the environment. The high yield recorded for the local cultivar (Table 48) supports this concept.

Table 41. Jackbean production observed in BETRIC. The first harvest was made 154 days after planting. The final harvest in the data was made 21 days later with young pods and new flowers present on the vines. All weights were fresh weights.

Harvest	Pod	Seed		Seed/Pod	Yield	Seed Size
No.	No.	No.	g	No.	g/m^2	g/100
1	38	433	923	11.4	308	213
2	27	430	768	15.9	256	179
3	4	42	95	10.5	32	226
4	7	59	137	8.4	46	232
Total	76	964	1923		642 †	
$\bar{x}$				11.6		212
S				3.2		23.7

† Value used for land requirement of Jackbean in the linear program.

Table 42. PEOB2 peanut yield data. Local cultivars were purchased in a Quito store. The imported cultivars came from Dr. A. J. Norden, University of Florida.

Cultivar	Pod Yield	Yield Rank[†]	Shelling	Kernel Size	No. Reps.
	g/plt		%	g/100	
Quichua Cultivars					
Blanco	128	7	63	85	1
Commissary	103	10	59	67	1
Local Cultivars					
Charapoto	169	4	57	67	1
Pepon	288	1	51	127	1
Rosita	125	8	61	78	1
Imported Cultivars					
Altika	158	6	54	134	1
Early Runner	42	15	73	69	1
Florgiant	164	5	59	146	1
Florunner	59	14	60	75	1
NC-Fla. 14	253	2	51	123	1
NM VALA	105	9	56	57	1
Starr	78	11	63	54	1
Tamnut 74	69	13	52	44	1
Tifspan	73	12	49	51	1
Va Bunch	173	3	76	92	1

[†] 1 = highest yield.

Table 43. PEOB data. Cultivars are grouped according to origin as explained in Table 42.

Cultivar	Pod Yield	Yield Rank[†]	Popu-lation	Days to Harvest	Stem Length		Kernel Size	Shel-ling	Reps.
					central	coty			
	g/m^2		$plts/m^2$		- - - cm - - -		g/100	%	no.
- - - - - - - - - Quichua Cultivars - - - - - - - - -									
Blanco	205	9	6.3	101	50	68	67	72	1
Commissary	303	5	6.5	101	68	90	66	76	1
Romulo	422	1	6.2	98	72	86	74	58	1
S. Red	410	2	6.9	101	64	79	80	70	1
S. Stripe	325	3	5.6	101	69	84	80	74	1
S. White	295	6	6.1	101	60	72	74	72	1
- - - - - - - - - Local Cultivars - - - - - - - - -									
Charapoto [‡]	289	7	6.0	101	74	82	64	74	1
Pepon	65	13	2.1	134	50	60	109	65	1
Rosita	276	8	6.3	112	60	74	68	61	1
- - - - - - - - - Imported Cultivars - - - - - - - - -									
Altika	10	15	0.6	136	53	52	74	34	1
Early Runner	118	11	3.8	122	34	55	68	68	1
Florgiant	120	10	4.2	136	53	57	85	46	1
Florunner	117	12	4.0	126	31	45	73	57	1
NC-Fla. 14	320	4	8.1	122	40	48	101	39	1
Va Bunch	24	14	1.7	136	45	48	43	45	1

[†] 1 = highest yield.

[‡] Same as Tarapoto. Used to calculate land requirement in the linear program. See Table 44 for more details.

Table 44. PETRI experiment data. Cultivars are grouped according to origin. See Table 42 for details.

Cultivar	Pod Yields[†]	Yield Rank[‡]	Population	Kernel Size	Shelling
	g/m^2		plts/m^2	g/100	%
Quichua Cultivars					
Commissary	292	3	5.2	68	63
S. Red	109	11	2.1	58	56
Local Cultivars					
Pepon	212	7	4.0	122	52
Romulo	279	5	6.9	77	62
Rosita	146	10	4.1	68	66
Tarapoto[§]	154	9	7.2	71	72
Imported Cultivars					
Altika	294	2	8.8	123	55
Early Runner	262	6	5.9	65	67
Florgiant	196	8	2.8	119	60
Florunner	291	4	6.5	69	62
NC-Fla. 14	428	1	8.6	126	49

[†] Four replications.
[‡] 1 = Highest yield.
[§] Same as Charapoto.

Table 45. PEVA experiment data. See Table 42 for more details.

Cultivar	Pod Yield†	Yield Rank‡	Population	Vegetative pegs§	Vegetative stem	Vegetative coty	Shelling	Seed Weight
	g/m^2		plts/m^2		cm	cm	%	g/100
Quichua Cultivars								
Commissary	142	8	5.3	+	87	108	55	64
S. Red	367	1	10.2	0			62	65
S. Stripe	252	3	9.1	0			53	72
Local Cultivars								
Pepon	274	2	6.5	0	47	52	34	105
Romulo	176	6	6.4	0			50	65
Tarapoto¶	219	4	6.7	+	95	90	56	67
Imported Cultivars								
Altika	146	7	5.3	0	64	60	39	92
Florgiant	136	9	7.3	0	65	68	54	93
NC-Fla. 14	189	5	6.6	0	47	48	36	118

† Three replications.
‡ 1 = Highest yield.
§ + = Pegs present on central stem and 0 = pegs absent.
¶ Same as Charapoto.

Table 46. Summary of selected peanut yields reported in PEOB, PETRI, and PEVA.

Cultivar	PEOB		PETRI		PEVA	
	yield	rank † (15 cult.)	yield	rank † (11 cult.)	yield	rank † (9 cult.)
	g/m^2		g/m^2		g/m^2	
- - - - - - Local Cultivars - - - - - -						
Romulo	422	1	279	5	176	6
S. Red	410	2	109	11	367	1
S. Stripe	325	3			252	3
S. White	295	6				
Pepon	65	13	212	7	274	2
- - - - - - Imported Cultivars - - - - - -						
Altika	10 ‡	15	294	2	146	7
NC-Fla. 14	320	4	428	1	189	5
Florunner	117	12	291	4		

† 1 = Highest yield.

‡ Low yields attributed to weak plants.

Table 47. Peanut yield calculation to determine land requirements. An INIAP recommended cultivar (Tarapoto) and Blanco, a local cultivar, were selected.

Experiment	Cultivar	Yield	Reps.
		g/m^2	No.
PEOB	Tarapoto	289	1
SANEX	Tarapoto	234	2
DUPE	Tarapoto	178	4
MUCOB	Tarapoto	310	4
PEOB	Blanco	205	1
MUCOB	Blanco	307	4
$\bar{x}$		254[†]	
S		56	

[†] The value used in the linear program.

Table 48. Maize yields observed in COVA, COLY75, and MUCOX.

Cultivar	Population	Ears	Shelling	Grain Yield	Experiment	Planted	Reps.
	plts/m^2	no/plts	%	g/m^2	name	date	no.
Ven2	2.3	1.2	80	117	COVA	Dec. 23, 1975	6
VS2	3.5	0.6	75	130	COVA	Dec. 23, 1975	6
INIAP 504	2.0	1.2	81	134	COVA	Dec. 23, 1975	6
INIAP 515	2.1	0.8	83	115	COVA	Dec. 23, 1975	6
75 H. L.[†]	1.9	1.1	77	162 [‡]	COLY75	July 6, 1976	16 rows
75 H. L.[†]	2.1	0.7	74	126[‡]	COLY75	Dec. 4, 1976	3
75 H. L.[†]	2.4	0.8	74	118 [‡]	COLY75	Jan. 26, 1977	4
75 H. L.[†]	3.3	0.8	82	168 [‡]	COLY75	Feb. 23, 1977	4
Local	2.5		84	201 [§]	MUCOX (Mono)	Sept. 22, 1976	4
VS2	2.9		77	152 [§]	MUCOX (Mono)	Sept. 22, 1976	4

[†] H. L. = High lysine.

[‡] Values used to determine land requirement for 1975 CV of high lysine maize in the linear program. Mean = 144 g of grain/m^2.

[§] Values used to determine land requirement for regular maize in the linear program. Mean = 177 g of 15% moisture grain/m^2.

The value in Table 49 giving the local rice yields shown in Table 49 are similar to the level observed in the DANRI (Table 61) observation. The green revolution rices (INIAP 1, 2, 6) produced yields three times those harvested from local cultivars (Table 47).

Yuca data in SMADA was based on observation from seven 9 m^2 plots (Table 50) along with YUFER data. The lower yields of YUFER could be explained by lower soil fertility.

The YUFER experiment was conducted on land that had produced yuca the year before and had demonstrated nutrient deficiencies. The SMADA and YUFER yields were combined to produce a figure for use in the linear program.

Sesame yields are presented in Table 51. The 95 percent confidence intervals in VACO show the mean yields from the 30 cm rows with the higher plant population were significantly lower than yields from the 60 cm spacing. The main stem of plants in the closer rows were slender which reduced resistance to lodging.

Yields from all experiments reported in Table 51 ranged from 75 to 100 g/m^2. This level is an acceptable yield supporting the conclusion that sesame can be grown successfully in the climate of the research area. This observation does not support the conclusion in the literature (Yermanos, 1964) stating the crop is not adapted to rain forest conditions.

Sorghum heads were harvested and weighed. Freshly cut heads were weighed (1406 g), dried, and threshed. The 1134 g dry seed represented 80.7 percent of the fresh weight. The fresh head yield in PEOB2 was 335 g/m^2. The MUCOB yield from four sample plots produced a mean of

Table 49. Yields from two rice trials, RITRI and NIRI, brought into the study to supply yield information of local and green revoluation rice cultivars for the linear program.

Experiment	Cultivar	Yield	Planted	No. Reps. or Size
		g/m^2	date	
RITRI	Local	108[†]	Nov. 13, 1969	.03 Ha
NIRI	INIAP	263[‡]	Feb. 24, 1972	4
NIRI	INIAP	374[‡]	Feb. 24, 1972	4
NIRI	INIAP	331[‡]	Feb. 24, 1972	4

[†] Figure used in linear program to determine the amount of land required to produce one kilo of local rice.

[‡] Mean = 323 g/m^2 which represents the yield of the green revolution rice varieties.

Table 50. Yuca yields observed from two experiments using the local variety.

Row Title	Fresh Weight	Planted	Samples
	g/m^2	date	
SMADA	2292	Dec. 20, 1976	7
YUFER	1550	July 1970	30
$\overline{X}$	1921 †		
S	525		

† Figure used in the linear program to determine the amount of land required.

Table 51. Sesame yields and plant populations with statistics.

Row Title	VACO				BEGRA		MUCOA	MUCOB		MUCOX		DUEX	
	30 cm rows		60 cm rows										
	plants	seed	plants	seed	plants	seed	Seed	plants	seed	plants	seed	plants	seed
	no/m^2	g/m^2	no/m^2	g/m^2	no/m^2	g/m^2	g/m^2	no/m^2	g/m^2	no/m^2	g/m^2	no/m^2	g/m^2
I	19	59	11	74	9	95	88	8	92	3	60	13	67
II	20	47	10	82	6	109	61	12	109	6	73	17	93
III	17	54	10	80				8	96	3	69	14	77
IV										5	95		
$\overline{x}$	19	53	10	79†	8	102 †	75 †	33	99†	4	74 †	15	79 †
$s_{\overline{x}}$	0.9	3.5	0.3	2.4	1.5	7.0	13.5	23.4	5.1	0.8	7.4	1.2	7.6
95% C.I.		38-68		68-89		13-191	0-246		77-121		51-98		46-112

† Mean of these figures = 85 g/m^2 used in the linear program.

366 g/m^2 with a standard error of the mean of 18.5 g/m^2. The average of these two means multiplied by 80.7 percent produced a dry grain yield figure of 283 g/m^2.

In PEOB2 the birds indicated a clear preference for Gravis leaving very little to be harvested. Rico sustained very little damage. The ratoon crop of sorghum was observed to grow above the grass weeds very quickly. This bird resistance is a good feature which should be kept in mind. The literature review showed very clearly that maize is preferred above sorghum by people. Therefore, since maize grows so well, sorghum was not considered in the linear program.

Sunflower yields on a dry weight basis were quite low as shown in Table 52. The seed should be separated from the head soon after collecting. One harvest of heads molded before it dried completely. The mean yield of dry grain calculated as described in the materials and methods section indicated the cultivar used was not sufficiently productive to recommend an introduction of this crop.

The weeds developing in a harvested area were studied when VACO was terminated. Approximately 90 percent of the weeds were _Digitaria sanguinalis_ [(L.) Scop.]. The other weeds present were _Sida_ spp., _Amaranthus spinosa_ (L.), _Eleusine indica_ [(L.) Gaetn], _Heliconia_ spp., _Indigofera_ spp., _Euphorbia hirta_ (L.), _Setaria geniculata_ [(Lam.) Beauv.], and _Physalis angulata_ (L.).

Table 53 indicates that pigeonpea, wingbeans, yard long beans, and lima beans produced very low yields. These crops were planted once. The yields were so low these crops were not considered in further research. Due to the international interest in wingbean perhaps further research should be conducted before final removal from further consideration.

Table 52. Sunflower yield in VACO. Total area = 96 m^2.

Harvest	Heads--Fresh Weight		Harvest June 1977
	total[†]	per head[‡]	
no.	g/m^2	g/head	date
1	1942	38	1
2	2194	67	9
3	4662	88	14
4	1886	126	20
Total	10690[§]		

[†] Harvest area 3 m x 32 m.

[‡] Mean plant population of 10 samples = 4.7 plants/m^2.

[§] Divided by 96 m^2 x 38.3% of fresh weight = 42.5 g/m^2 dry grain yield.

Table 53. Crop kinds represented by the cultivars on hand which did not successfully adapt to the climate.

Kind	Cultivar	Experiment Name	Seed Yield
Pigeonpea	Normal	BEPESO	26 g/plant[†]
Pigeonpea	Coast of Ecuador	BEGRA2	None
Wingbean	3 Selections	BEGRA2	None
Bean	Yard Long	BEGRA2	11 g/m^2
Bean	Lima	BEGRA2	11 g/m^2

[†] Last measured harvest 201 days after planting.

Tribal Demonstration Plots

The yields shown in Table 54 from the QUIEX experiment were very low. Yuca was not ready when the research terminated so it was impossible to measure yield. Sunflower and maize production was not sufficiently high to record. One of the sesame plots was lost as a result of lodging. None of the treatments in the experiment improved upon yields previously recorded for traditional agriculture. One factor explaining the low yields was the intense shade. The plot dimensions were 36 x 26 m surrounded on all four sides by forest.

The cowpea cultivar selected by the cooperator was Supercream perhaps desiring the larger seed size. Previous experience showed this cultivar discolors rapidly when ripening in rainy weather. The P-R-V-71-10R-58 cultivar is more resistant to water damage and is numbered among the larger seeded cultivars. It cannot be associated with maize because the vine is too heavy and profuse.

A seed packet of promising cowpea cultivars was formed to distribute to the Indians. Table 55 presents the names and descriptions of the cultivars selected. A yellow local cultivar was included as a standard.

Table 56 presents SANEX data showing 6442 produced a high yield. Two men in the tribe independently indicated a preference for this cultivar from the five available. One man indicated the least amount of vininess attainable was desired. The yield advantage of Chenise was considered less of an advantage than the proper seed size. Tumbes cowpeas were unacceptable due to the excessive vine size and low yields. The maize associated with this cultivar offered no competition. It was

Table 54. QUIEX yields of cowpeas and peanuts with crops associated.

Crop	Cultivar	Yield	Associated Crops
		g/m^2	
Cowpea	Supercream	16	Maize, yuca, peanut
	Supercream	21	Maize, peanut
	P-R-V-71-10R-58	32	Maize
	Chenise Red	35	Maize
Peanuts	Tarapoto	19	Maize, yuca
	Tarapoto	27	Maize, cowpea
Sesame	Portoviejo2	26	Monoculture

Table 55. Promising bean cultivars planted in the Tena area throught to improve yields from Quichua agriculture.

Crop	Cultivar	Days to 1st Harvest	Vine Characteristics	Seed color	Seed size	Seed yield
					g/100	g/m^2
Cowpea	10R58	87	Heavy[†]	Red	13	99
Cowpea	Chenise Red	72	Small[‡]	Red	8	180
Cowpea	Supercream	87	Medium	White	17	82
Cowpea	Sin 8512	72	Medium	Brown	13	198
Common Bean	Yellow Local	48	Small	Orange[§]	20	15

[†] Vine is too profuse and heavy to be associated with maize. Considered a possibility as a monocrop.

[‡] Vine type is ideal for association with maize. Yield is good but seed is smaller than desired.

[§] Yellow color turns to orange when old.

Table 56. SANEX crop yields.

Crop	Cultivar	Association	Vine	Seed	Plants	Yield	2 Reps.
				g/100	no.	g/m^2	$s_{\overline{x}}$
Cowpea	5424	Mono	Medium	10	20	44	15
Cowpea	6442	Mono	Light	12	20	73	18
Cowpea	8520	Mono	Medium	14	20	40	4
Cowpea	Chenise	Sunflower	Light	8	16	94	22
Cowpea	Tumbes	Maize	Heavy		20	7	1
Peanut	Tarapoto	Mono			9	234	30
Peanut	Sarayacu Stripe	Mono			14	347	18
Sesame	Portoviejo	Mono				106	

completely dominated by Tumbes. Sunflower associated with Chenise did not grow so had no influence on yields.

A soil sample was taken in the area before the experiment was planted. The result of the analysis is present on the SANEX line of Table 4. Many of the elements were present at low levels. Table 57 presents data from sesame and peanuts grown in the demonstration plot planted in Dureno. Yields were average but high enough to be acceptable. A general understanding of the inherent fertility of the soil can be observed in the results of the soil test presented in Table 4. The row identified with the code DUEX represents soil in the demonstration plot.

Indigenous Systems

A study of indigenous agriculture was necessary to develop information for comparison with research results. The potential of new crops or practices can be judged on this base. The capacity to improve present agriculture or provide adequate supplies of protein to substitute for wild meat can be evaluated.

Crops

The survey of the indigenous systems within the research area revealed yuca and cooking bananas supplemented with a few eating bananas were the main crops of interest to most people. These crops provide carbohydrates in the diet. Common beans and peanuts were the primary protein rich crops grown by the Quichuas and in small quantities by the Aucas, Secoyas, and Cofans. Rodent damage to peanuts is frequently so extensive none can be harvested or yields are severely reduced. Common bean yields are extremely low partly due to the fact this crop is highly susceptible to fungal diseases.

Table 57. DUEX demonstration plot data.

Crop	Cultivar	Plants	Yield	Reps.	Deviation
		no/m^2	g/m^2	no.	$s_{\overline{x}}$
Sesame	Portoviejo2	14	79	3	8
Peanuts	Tarapoto	5	178	4	27
Peanuts	Commissary	8	213	4	32

The common Quichua planting pattern is to place the eating and cooking bananas on the perimeter of the field. This practice locates the long term crops around an area reserved for many plantings of crops requiring less time to complete their vegetative cycle.

Frequently maize seed is broadcast on the top of ground cleared of underbrush. The trees form debris above the maize seed. The practice produces a crop while waiting for the decaying process to reduce the amount of additional clearing required for subsequent crops. Maize is not eaten but is produced for chicken feed or cash.

Upon harvest of the maize the common practice is to remove all debris that can be moved by hand. Yuca is the crop frequently planted. Occasionally rice and yuca are planted. In this arrangement rice is harvested and the longer growing yuca is allowed to produce a crop to be harvested 9 to 12 months after planting. A mix of staked common beans and peanuts or either genera as a monocrop is also an option following the clearing crop. The most complex crop arrangement planned by the Quichuas is an association of yuca, common beans, peanuts, and maize.

Figure 4 presents the size of a typical indigenous maize field. This field was an area being claimed from the rain forest. Two sample plots were located and the planting pattern mapped. Table 58 data indicates that plant populations between the mapped plots varied greatly. These plots were chosen to represent the two densities most prevalent in the field. There were some areas where no maize could grow through the thick brush. The mean plant populations reported would overestimate the average density of the entire field. One seed per hill was planted. Table 58 shows the average plant density was 3.8 plants/m^2.

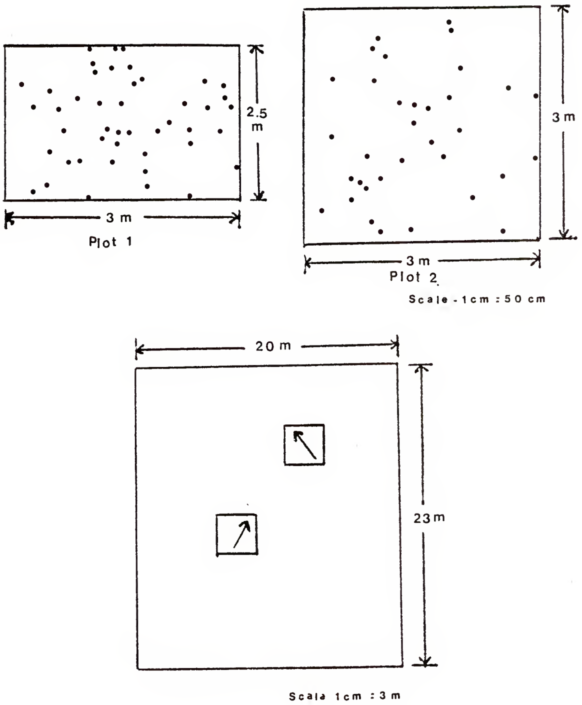


Fig. 4. SILOB maize observation under indigenous practice showing location of sample plots in maize field. The arrows in the plots point to the detail drawing to which it pertains. For further detail see Table 56.

Table 58. Maize production under indigenous conditions observed in SILOB. Plots 1 and 2 refer to plots in Fig. 4. Plots 3-7 present data from areas harvested in the same field, but not shown.

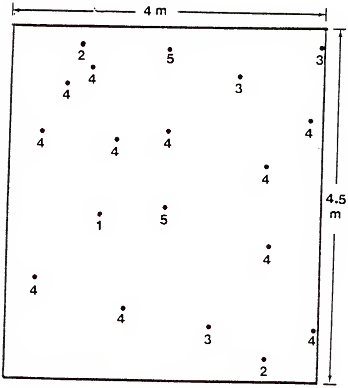
Plot	Size	Plants		Ear Weight	Shelling	Grain
no.	m^2	no.	no/m^2	g/ear	%	g/m^2
1	7.5	45	6.0			
2	9.0	32	3.6			
3	6.0	25	4.2	89	79	150
4	6.0	18	3.0	83	89	183
5	7.5	34	4.5	92	87	192
6	9.0	42	3.0	71	86	191
7	9.0	25	2.0	76	79	100
$\overline{x}$			3.8	82	84	163
$s_{\overline{x}}$			0.5	4	2.2	17.4

Yield of grain was 163 grams/m^2 on an 83 gram ear of which 84 percent was grain. The plant density in the SANOB maize was similar to the level reported in SILOB but resulted from almost four plants per hill spaced further apart. The map of the hill arrangement with the number of plants per hill is shown in Figure 5 with details presented in Table 59.

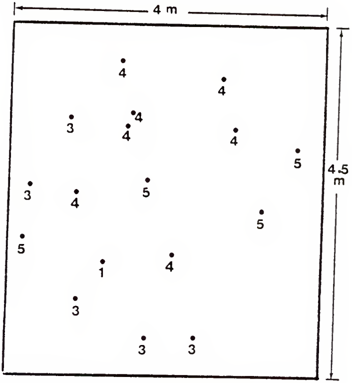
Maize planted on cleared ground to produce chicken feed was studied in VIOB. The size of the field and the location of sample plots is diagramed in Figure 5. Figure 7 displays the planting pattern and the number of plants per hill in selected plots. Table 60 lists the number of plants per site in this field. Maize hills/m^2 were similar in number as reported in SANOB. Grain yield was higher at 254 g/m^2 produced on a heavier ear of 147 grams and a smaller percentage of grain (71 percent).

The map of a rice field studied is presented in Figure 8. The plant counts and plot sizes are presented in Table 61. The yield of 70 g/m^2 was produced from 2 plants/m^2 of a local cultivar.

SILOB was a study of a bean monocrop. Figure 9 is a map of one plot showing the arrangement of sites identified by a number. The number of plants and pods per plant at each site are shown in Table 62. The population of 2.4 poles and 13 plants per m^2 produced slightly more than three pods per plant, a very low yield. Table 63 presents data from two other common bean fields showing a third to one-half the number of sites per m^2 were planted from which 40 to 60 g/m^2 yield of seed was measured. Shelling percent was 75. Table 64 describes the variety of colors present in many seed lots used for establishing a



Plot 1



Scale 1 cm = 50 cm

Plot 2

Fig. 5. SANOB maize planting pattern under indigenous practice in two sample plots representing plant population at each location. For more detail see Table 59.

Table 59. Maize production from indigenous practices observed in SANOB. Sample plot numbers refer to Fig. 5.

Plot	Size	Sites	Population	
no.	m^2	no/m^2	$plts/m^2$	plts/site
1	18	1.0	3.8	3.6
2	18	1.0	3.8	3.6

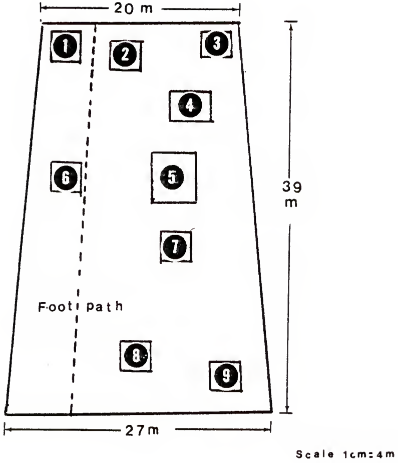


Fig. 6. Maize field of VIOB showing sample plot location and size of field. For more detail see Table 60.

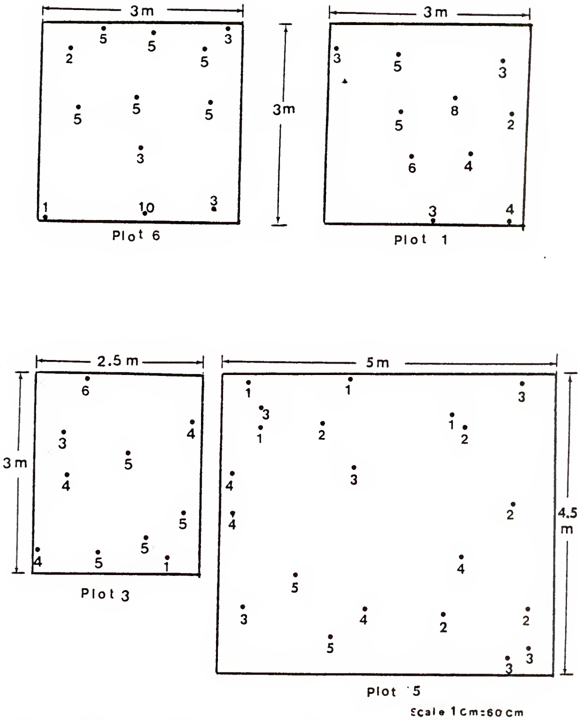
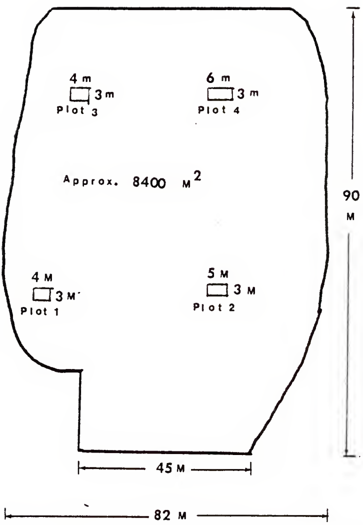


Fig. 7. Maize planting pattern in VIOB showing location of hills of maize with numbers representing plant population at each location. For more detail see Table 60.

Table 60. Indigenous maize planting patterns and yields observed in VIOB. Sample plot number refers to the numbers in Fig. 6 and 7.

Sample Plot		Populations			Yield Data		
ident.	size	sites	plants	plants	ear weight	shel-ling	grain
no.	m	no/m^2	no/m^2	no/site	g/ear	%	g/m^2
1	3x3	1.2	4.7	3.8	132	67	243
2	3x3	2.0					
3	3x2.5	1.5	6.0	4.1	137	72	184
4	4x3		2.4				
5	5x4.5	0.5	2.4	2.8	179	73	228
6	3x3	1.3	5.8	4.3	141	72	360
7	3x3		2.0				
8	3x3		2.3				
9	3x3		3.6				
$\bar{x}$		1.1	4.7	3.7	147	71	254
$s_{\bar{x}}$		0.2	0.5	0.4	110	1.5	38



Scale 1CM:10M

Fig. 8. Rice field in DANRI showing shape and size of the field from which yields were measured. Four sample plots were located to count rice plants to estimate plant population. See Table 61 for details.

Table 61. DANRI rice plant counts from four sample plots shown in Fig. 8.

Plot	Plot Size	Plants	
		Total	Population
no.	m^2	no.	plts/m^2
1	12	26	2.2
2	15	23	1.5
3	12	21	1.8
4	18	28	1.6
$\overline{x}$			1.8
$s_{\overline{x}}$			0.2

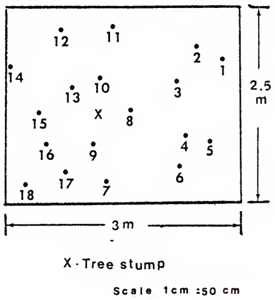


Fig. 9. Indigenous planting pattern of common beans observed in SILOB showing spacings resulting. The numbers identify the sites described in Table 62.

Table 62. Analysis of the planting pattern observed in SILOB. Details are presented of indigenous common bean planting practices in Fig. 9.

Site no.	Population plt/site	Pods no/plt	Site no.	Population plt/site	Pods no/plt
1	9	3.8	10	2	8.5
2	9	1.7	11	5	4.0
3	4	3.8	12	7	2.4
4	6	4.5	13	2	4.0
5	6	5.3	14	5	0.6
6	3	0.7	15	3	2.3
7	4	0	16	7	3.6
8	7	4.7	17	7	1.7
9	3	3.7	18	9	3.1

Means are as follows: Stake population = 2.4/m^2, plant population = 13 plants/m^2, plant/pole = 5.4, pods/plant = 3.4.

Table 63. Yield data of common beans observed in SILOB.

Field One				Field Two			
size	poles	grain	shelling	size	poles	grain	shelling
m^2	no/m^2	g/m^2	%	m^2	no/m^2	g/m^2	%
18	0.8	28	73	12	1.6	53	76
63	0.5	20	77	6	2.0	86	78
18	0.6	54	77	9	1.1	42	74
15	0.7	53	74				
$\bar{x}$	0.7	38.8	75.3		1.6	603	76.0
s	0.1	17.3	2.1		0.5	22.9	2.0

Table 64. Yield data of common beans observed in TRIOBA. Common bean seed yields per site from 13 locations are shown.

Pole	Seed	Size	Shelling	Various Seed Colors [†]
no.	grams	g/100	%	
1	30	24	60	White, orange
2	38	21	69	Orange, white specks on orange
3	33	20	61	White kidney
4	5		33	
5	105	31	66	White kidney
6	88	30	73	White, red, orange
7	44	34	59	White kidney
8	14	22	78	Red, orange
9	84	36	71	White kidney, orange
10	150	37	77	White, orange, red
11	100	33	71	White, orange, red
12	184	41	67	Red, orange
13	69	25	69	
$\bar{x}$	78	30	66	
$s_{\bar{x}}$	14	2	3	

[†] Possible when many seeds of mixed colors are planted per site. Perhaps from Kentucky Wonder seed obtained from crop observation plots.

stand of common beans. A few cowpea plants were observed in some fields adding greater variety to the stand.

The Indians grow peanuts in monocultures or association with yuca. The data in Table 65 showed sample plot unshelled peanut yields in Dayuma's field averaged 404 g/m^2. The smaller seed size from Gaucamo's and Bishop's plots reflect the immaturity of the plants sampled. The low yield of peanuts in SMADA is explained by the fact the associated yuca competed heavily with the crop. Yields of 20 g/m^2 were considered too low for this association to be an improvement of production compared to a monocrop arrangement. The yuca yields from this association with peanuts are presented in Table 66. Approximately 2300 g/m^2 of 400 g tubers was recorded with an average of six tubers per plant from a population of one plant/m^2.

Multiple cropping, as predicted by the Quichuas, was observed under the titles of ELOB and SILOB. The map of plant locations and crop associations in two plots in ELOB is shown in Figure 10. Yields from one plot in SILOB are presented in Figure 11. Table 67 presents the plant populations observed resulting from the mixture of planting practices, germination, and weather conditions. Yuca was planted 1.5 plants/m^2 which is more dense than common. The other crops commonly were very sparsely planted.

Figure 12 presents the map of a planting in the SANOB observation. This planting received no fertilizer application. The map shows a planting arrangement of crops a farmer made on his own initiative. Such natural boundaries as logs and paths separate the crops and/or cultivars. This selection represents the selection by the farmer of seeds from those on hand which was produced from the SANEX demonstration

Table 65. Peanut production data observed in AUCA and SMADA grown under indigenous conditions either associated with yuca or monocropped as indicated.

Cooperator	Parameter	Pods	Population	Shelling	Size	Reps.	Area	Experiment
		g/m^2	plt/m^2	%	g/100	no.	m^2	
Dayuma	$\overline{x}$	404	11	42	76	3	8.4	AUCA †
Dayuma	$s_{\overline{x}}$	38	1	2	2			AUCA
Guacamo	$\overline{x}$			59	58	17		AUCA ‡
Guacamo	$s_{\overline{x}}$			2	3			AUCA
Bishop	$\overline{x}$	21	0.7	72	52	6	216	SMADA §
Bishop	$s_{\overline{x}}$	6	0.3	4				SMADA

† Yuca too young to compete.
‡ Monoculture.
§ Yuca competed heavily with peanuts.

Table 66. Yuca yields from SMADA. Associated peanut yields are reported in Table 65 on the lines starting with the name of Bishop. The plot size was 9 m^2.

Plot	- - Yield--Fresh Weight - - -			Population	Tubers
no.	g/m^2	g/plt	g/tuber	plt/m^2	no/plt
1	2681	2512	535	1.1	4.7
2	2909	3273	494	0.9	6.6
3	1644	2960	477	0.6	6.2
4	1794	1345	212	1.3	6.3
5	2887	2165	321	1.3	6.8
6	2911	2911	444	1.0	6.6
7	1105	1988	321	0.6	6.2
$\overline{x}$	2292	2451	400	1.0	6.2
$s_{\overline{x}}$	286	252	44	0.1	0.3

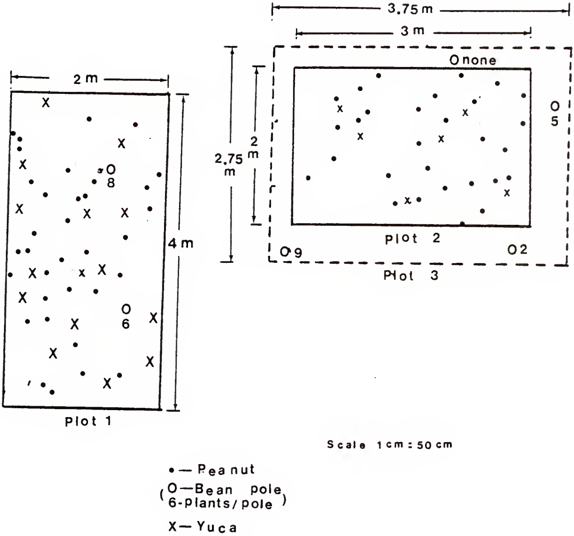
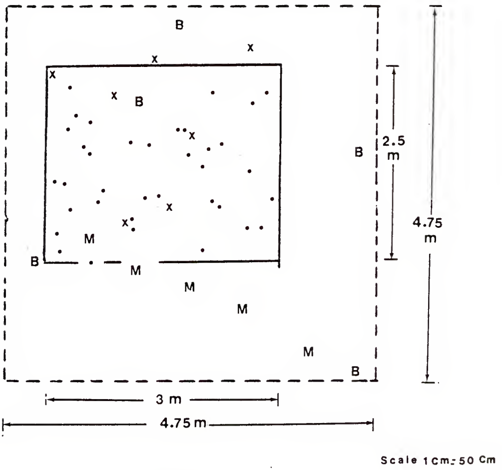


Fig. 10. ELOB Quichua planting pattern with associated yuca, peanut, and common bean. Plot boundary lines mark limits of mapping of yuca and peanut plant locations. Further information in Table 67.



•—Peanut
x—Yúca
M—Maize
B—Cooking banana

Fig. 11. SILOB multiple crop spacing practice of Quichua agriculture. The area enclosed by the inner box shows peanut and yuca planting pattern. The outer box measures the area evaluating populations of maize and banana. See Table 67 for more details.

Table 67. ELOB and SILOB associated crop populations. Plot numbers correspond with numbers in figures indicated.

Plot	Size	Yuca		Maize	Common Bean		Banana		Peanuts	
no.	m^2	no/plts	plt/m^2	plts/m^2	plt/pole	plt/m^2	no/plts	plt/m^2	no/plts	plt/m^2
ELOB (Fig. 10)										
1	8	14	1.8		7.0	1.8			34	4.3
2	6	6	1.0						28	4.7
3	9				4.0	1.8				
$\overline{x}$		10	1.4							4.5
SILOB (Fig. 11)										
1	8	5	0.7	0.2	5.0	0.2				4.7
2	23						5	0.2	35	4.7

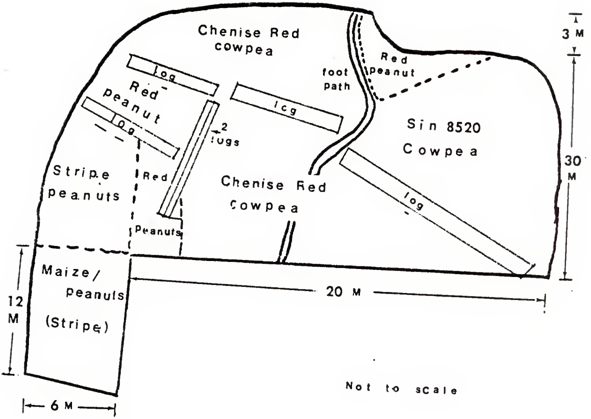


Fig. 12. SANOB indigenous planting pattern resulting from the farmer observing the demonstration plot and having seed from it to plant. The edges of the small areas of three cultivars of cowpeas, two of peanuts, and one association of corn and peanuts were bounded by log and path location.

plot. The farmer planted the peanuts in rows 70 cm wide and 50 cm between plants with two to four plants per hill duplicating the pattern in the demonstration plot. The maize was planted in 140 cm rows with a peanut row in the center. Two to three maize plants per hill were observed. The Chenise Red and cowpea cultivar 8520 were of particular interest to the farmer. Both yielded quite well and produced medium size vines that could associate with maize if this were selected.

The wife of the farmer who planted the field shown in Figure 12 expressed interest in Chenise Red cowpea. All beans, she reported, were customarily boiled with cooking bananas. This use of beans is an alternative to meat hunted in the forest. If meat is plentiful the beans are sold. Beans are not stored for long periods because insects will destroy them. The cowpea planting shown in Figure 11 was seeded in 60 cm rows with an average of three plants per site. There was a space of 30 cm between sites. During the visit on May 4, the cowpea leaves were very yellow indicating a possible mineral deficiency. A soil sample was taken from the area near the foot path in the Chenise cowpea planting where the symptoms were present. The soil was taken to Santa Catalina for analysis by INIAP. The pH was 6.1 and the elements present in low quantities were nitrogen, zinc, and copper. The elements present in medium quantities were phosphorus, potassium, and manganese. Calcium, magnesium, and iron were observed to be present at high levels. A very small crop of cowpeas were harvested from this area perhaps due to the fertility problem. The levels of elements present in this soil, as determined by analysis, is presented on the line marked SANOB in Table 4.

Peanuts began to peg on April 1, 1977. On May 4, the plants were growing vigorously. The striped peanut variety showed a greater susceptibility to leaf spot disease than the red cultivar. Harvest date was estimated to be one month later. Three plants of the red cultivar were observed to have four branches and an average of six pods.

When the plot was observed 20 days later rats had severely damaged the intercropped peanuts and a large number of the red cultivar. The peanuts near the foot path escaped damage. The production from samples of undamaged plants of both cultivars was 24 pods per plant. Not shown in the figure were a few sunflower plants produced from seed taken from the few plants in the SANEX plot.

The COFOB peanut planting was not very productive. In one plot leaf cutter ants appeared from their hill in the center of the plot and removed an excessive number of leaves. The plot was heavily shaded which also reduced yields. In a plot planted by Vendi extensive damage was caused by pigs and cut worms. The plants remaining had no more than two branches and some displayed main stems only. There were from one to three pods present per plant. Problems of this nature experienced here and in San Pablo hinder the wider use of peanuts.

The result of a soil sample taken near one of the peanut fields in Dureno by Jorge Caceres, INIAP soils scientist, showed nitrogen, phosphorus, zinc, and manganese to be low. Phosphorus was present in medium levels. Those present in abundant amounts were calcium, magnesium, copper, and iron. The laboratory analysis is presented in Table 4 on the line starting with the identification of LUCIANO-Dureno.

Chickens

The results of the QUIPI survey showed eggs from 11 of 17 flocks in the study were collected by women and five collections were made by children. Ten flock managers reported closing the chicken coop every night to protect the birds from such predators as oppossums, ocelots, and other animals in the rain forest. The supplemental feed nine families used was maize, often this was the only supplemental feed. Frequently these flocks could be classified with four others receiving no additional feed. Two families fed boiled yuca and cooking bananas. One family reported giving table scraps to their chickens. Only one flock was fed rough rice as a supplemental feed. Salt was very seldom given and water was obtained wherever the chickens could find it was reported for 11 flocks. Five families set their hens whenever one was ready. One man observed his hens did not become broody. Five people indicated they place from 12 to 15 eggs under a setting hen. One man stated he set 8-10, another 16, and a third person mentioned placing 20 eggs under a setter. One person observed his hens lay best during the Chonta (palm fruit) season when the rainfall decreases. Concerning the size of flock desired two people mentioned 20 to 50 birds was ideal for them. Four wanted somewhere between 100-150. One was interested in taking care of from 200-300. One man has for a long time desired to take care of 1,000 birds on a commercial basis.

Table 68 summarizes the production information gathered from the study. Average daily production varied from one to four eggs perhaps reflecting the number of eggs the family considers sufficient to meet their needs. Assuming this reflects the egg consumption of a family calculations show 15-30 eggs per week were ingested. Perhaps the mean

Table 68. QUIPI egg production data.

Flock	Hens	Days in Study	Total Egg Production	Lay	Eggs
no.	no.		no.	%	no/day
1	4	29	61	53	2
2	3	17	17	33	1
3	14	25	90	26	4
4	7	26	25	14	1
5	5	29	63	43	2
6	7	29	54	27	2
7	5	25	25	20	1
8	4	19	27	36	1
9	4	23	35	38	2
10	10	25	40	16	2
11	5	21	44	42	2
12	4	29	32	28	1
13	5	29	78	54	3
14	7	25	39	22	2
15	9	30	68	25	2
16	14	28	49	13	2
17	12	27	67	21	2

weekly egg consumption of one person would be two or three. At this rate one family of six would consume 15 to 24 kg during the semester.

The figures in Table 68 show rate of lay was below 55 percent. In a subsistence situation perhaps efficiencies above 20 percent would be considered acceptable. Further research is required to determine the efficiency level considered minimal.

One original purpose of the research was to identify the crops Indians could grow and feed to chickens enabling the owners to manage larger flocks. No conclusion could be made from this part of the research. The feeding experiments produced uncertain and highly variable data. Any real differences between treatments could not be identified.

Poultry Experiments

Table 69 lists the dates diets were prepared, quantities fed, and other data required for further calculations in Tables 70-72. The days between feed preparation were not always an accurate indication of days required to consume a diet. The lack of accuracy was true when feed remained on hand the day a formulation was prepared. The reported total feed consumed during the priod represented in the table is accurate.

A summary of feed consumption data in Table 69 is presented in Table 70. The mean feed consumption through May 7 was similar to 690 grams per Leghorn pullet reported by Scott et al. (1969). The 12.3 kg recorded through September 8 was considerably higher than the figure of 7.5 kg Scott et al. (1969) reported. Some of the difference could be explained by the weight difference between Rhode Island Red and Leghorn birds. Environment and feed efficiency differences could also be factors.

Table 69. Quantities of PORE diets consumed during the growing period from April 8 to September 8, 1976. The diet number is the same used in Table 17.

Date	Diet	Feed Mixed	Days Between Mixes	Birds in Flock	Bird Days to Next Count
	no.	kg	no.	no.	no.
April 8	1	50	11	299	3289
19	2	18	3	286	858
22	3	34	6	282	1692
28	4	22	2	275	550
30	4	27	4	272	1088
May 4	5	28	3	268	804
Subtotal†		180	29		8281
May 7	6	10	1	264	264
7	7	54	3	264	792
11	5	9	1	264	264
12	8	68	7	264	1848
19	9	23	1	264	264
20	10	560	27	264	7128
June 16	10	172	12	255	3060
28	11	204	10	221	2210
July 8	12	59	2	193	386
8	13	172	13	193	2509
23	13	884	32	186	5952
Aug. 24	14	480	15	186	2709
Totals		2875	153		35748

† Total from April 8-May 6.

Table 70. Summary of PORE feed consumption based on information in Table 69.

Date	Age	Bird Days	Birds	Feed Consumption		
				total	$\bar{x}$	$\bar{x}$
	days	no.	$\bar{x}$ no.	kg	g/brd	g/brd/day
May 7	29	8281	286	180	630	21.7
Sept. 8 †	153	35748	234	2875	12300	80.4

† Data in this row includes the entire period starting April 8.

Table 71. PORE live weight data.

Date Weighed	Sex	Age	Groups Weighed total	Groups Weighed range	Total Birds	Mean Weight
		weeks	no.	no/brds/g	no.	g/brd
April 8	Mix	0.5	1		299	43
May 7	Male	5.0	6	9-27	128	327
May 7	Female	5.0	5	13-37	136	268
Sept. 8	Male	23.0	21	1-3	52	2790
Sept. 8	Female	23.0	27	3-6	136	1890

Table 72. PORE feed efficiency figures supported by data in Tables 69-71.

Date	Age	Total	Feed Consumed	Live Weight When Weighed	Feed Efficiency[†]
		no/birds	g/bird	g/bird	
April 8	0.5	299		43	
May 7	5.0	264	630	297 [‡]	2.1
Sept. 8	23.0	188	12140	2140[‡]	5.7

[†] $\text{Ratio} = \frac{\text{Feed consumption to date}}{\text{Live weight}}$

[‡] Mean weight males and females. Data in Table 71 is not combined.

Table 71 presents live weight data observed when the chicks were one-half, five, and 23 weeks old. The chicks starting the research period could be considered to have a normal weight if 36 grams is considered to be the average weight of a normal, healthy five day old chick. At five weeks of age the Rhode Island Red chicks would be considered somewhat light (297 g) compared to the figure of 350 g given by Scott et al. (1969) for White Leghorn pullets. When 23 weeks old the experimental birds were considerably heavier (2140 g) than the 1500 gram White Leghorn pullets reported by Scott et al. (1969). The greater weight of the Rhode Island Reds would be expected.

Titus and Fritz (1971) presented a table indicating the amount of feed required to produce a stated body weight. Calculations indicate the average feed efficiency of a flock of New Hampshire birds, composed of equal parts male and female birds, was 1.8 kg of feed were required to produce one kilogram of live weight. This value was produced when the average bird weighed 225 grams. When this same flock reached an average weight of 2 kg the feed efficiency became 4.1 kg feed per kilogram live weight. These values compared to those presented in Table 72 indicate the diets presented in Table 17 were not sufficiently efficient.

Table 73 demonstrates egg production remained at 70 percent or better through May with one exception (April). The December drop in production could be explained by an inadequate diet for hens in total confinement. Excessive picking appeared in the flock November 23. When the hens were allowed to forage outside the pen during afternoons after December 12 the picking was no longer evident and egg production improved. This response would indicate diet 15 was not adequate for

Table 73. PORE monthly egg production.

Month	Total No. Eggs	No. Days in Period	No. Hens in Flock	% of Lay
Oct. 1976	940	9	136	77
Nov.	3230	30	134	80
Dec.	2821	31	130	70
Jan. 1977	2977	31	124	77
Feb.	2582	28	122	76
Mar.	1942 †	31	82 †	76
Apr.	2252	30	112	67
May	1400 ‡	31	63 ‡	72
June	1857	30	104	60 §
July	608	12	104	49

† Birds removed for the second KUPI experiment explains these lower numbers.

‡ Birds removed for the third KUPI experiment explains these low numbers.

§ On June 4, hens were 61 weeks old and had been laying 34 weeks since the date 50% production was first attained.

laying hens in total confinement. This diet with occasional minor changes was the production diet used in PORE.

The drop in production in April can be explained by the fact the 60 birds used in the second experiment of KUPI were returned to PORE April 2, 1977. A readjustment period was necessary to increase production from the depressed levels in the KUPI experiment. The fact production almost returned to the level recorded for May would indicate most of the birds returned to normal production.

Feed consumption of the RIR layers varied between 110 and 150 grams per bird day (Table 74). The feed given during the period sampled in this table was basically the same as diet 15. The metabolizable energy content of the diets was approximately 2800 calories, within the range specified by Scott et al. (1969). The 14.9 percent protein content provided 20 g of protein a day if 135 g is used as an average feed consumption figure. This consumption level compares to 18 g given by Scott et al. (1969) for Leghorn layers. Leghorn hens would require less protein because they are smaller than the Rhode Island hens used in this experiment.

Phase I began as predicted when the hens were 22 to 23 weeks old. The hens were 60 weeks old when production dropped below 65 percent indicating Phase II had ended according to the schedule given by Scott et al. (1969). This response would indicate the production diets had been adequate for hens allowed to forage during the afternoons. The diet and material found outside the pen provided sufficient nutrients to maintain sufficient vigor for egg production and recovery from adverse treatment effects in other experiments.

Table 74. PORE feed consumption during selected periods. All diets are approximately the same as number 15 in Table 17, which has an energy value of 2826 calories and 14.9% protein.

Period Ends	Days in Period	Birds in Flock	Feed Consumption		Protein [†]
			/flock	/bird	
	no.	no.	kg/day	g/brd/day	g/brd/day
Nov. 13, 1976	18	149	20	134	20
Nov. 30, 1976	17	149	22	148	22
Jan. 21, 1977	15	136	19	140	21
May 23, 1977	17	118	14	119	18
June 3, 1977	10	118	16	136	20
June 17, 1977	14	118	13	110	16

[†] Scott et al. (1969) recommended 18 g/bird/day during Phase I.

Egg production from this flock was higher than the production of flocks in the indigenous agricultural system. The major factor explaining this difference could be better feeding practices. Those practices followed in PORE were not reproducible because the major source of protein was fish meal which is not available to Indians. Acceptance by Indians of an improved poultry diet would be considerably better if an unextracted, high protein grain grown on the farm was successfully formulated in a diet not using fish meal.

The results from the first KUPI experiment was based on the response of five hens placed over a period of four days on pastures containing 5.6 m^2 area. The exact number of days that elapsed before the pasture was overgrazed is uncertain. If the number is three days then each hen required 2.6 m^2 of kudzu pasture each week. If four days was required the figure was reduced to 2.0 m^2. On a daily basis pasture was consumed at a rate of 0.371 m^2 (3 days) or 0.279 m^2 (4 days).

The first step to determine kudzu consumption was to estimate the amount available when the hens first entered the pasture. The sampling details were described on page 80. The mean production of fresh kudzu from the six 2 m^2 sample plots outside the poultry pastures was 3612 g/m^2 with a standard error of the mean = 253 g/m^2. After drying the material at the generator plant in Limoncocha the mean dry weight production was 933 g/m^2 and $S_{\bar{x}}$ = 120 g/m^2. Calculations show that the dry weight was 26 percent of the fresh weight. (Due to an error in calculation 27 percent became the figure used in the diet calculations.)

Three 2 m^2 plots were selected within the grazed area to determine the amount of inedible kudzu per m^2. The quantity of kudzu consumed by the hens was determined by subtracting the inedible kudzu values as determined in these plots from the total production measured in nearby plots across the fence.

The mean fresh weight of inedible kudzu was 2833 g/m^2 with an $s_{\bar{x}}$ of 290 g/m^2. The dry weight of these samples averaged 1133 g/m^2 with an $s_{\bar{x}}$ of 185 g/m^2 and a dry to fresh weight relationship of 40 percent. The fresh weight of ungrazed kudzu per m^2 subtracted from the g/m^2 total kudzu produced showed 779 g/m^2 fresh kudzu was consumed by the chickens. Multiplying this figure by 27 percent (the value should have been 26 percent as shown above) produced a dry weight kudzu consumption of 210 g/m^2.

Multiplying the square meters of pasture consumed per bird day (0.371 or 0.279 m^2) by the dry, edible kudzu production (210 g/m^2) the amount consumed per hen day ranged from 60 to 80 g.

Calculations based on total consumption of diet 15 fed to all birds in this first KUPI experiment showed a mean consumption of 80 g per bird day. This value added to the estimated kudzu consumption produces an estimated total intake of 140 to 160 g per bird day. These values compared favorably to the figure of 150 g per hen day reported (Scott et al., 1969) to be the consumption of heavy breeds of chickens. Estimations of the amount of feed consumed by the 135 bird flock in the linear program was based on consumption figures of 80 g formulated diet plus 80 g kudzu per adult bird day.

An estimation of the energy and protein content of the diet the chickens were consuming is presented in Table 75. The diet of a White Leghorn hen should contain metabolizable energy within the range of 2500 to 3300 calories and a protein content of 18 percent. These standards show the diet to be inadequate.

Table 75. KUPI diets (first experiment) selected by chickens on pasture. Two possible diets with different levels of kudzu intake determined by 3 or 4 days on pasture.

Feedstuff †	Consumed	Total Diet	Protein ‡	Energy §
	g/bird/day	%	grams	Cal ME
Kudzu	80	50.0	7.5	805
Diet 15	80	50.0	7.5	1413
Total	160	100.0	15.0	2218
Kudzu	60	42.9	6.4	691
Diet 15	80	57.1	8.4	1614
Total	140	100.0	14.9	2305

† Data from diet number 15 in Table 17.

‡ Kudzu data based on calculations Dr. J. Milligan in a study made in the Amazon jungle of Peru (Milligan, 1972).

§ Kudzu data based on alfalfa data.

The amount of kudzu and supplement consumed in the second KUPI experiment is presented in Table 76. The daily nutrient intake from each diet is shown in Table 77. The egg production resulting from the treatments appears in Table 78. The production before treatments were applied demonstrated that the egg production of all hens was similar. The first week of treatment was considered an adjustment period. The eggs produced were not included in the data measuring response to treatment.

The highest consumption of feed and greatest egg production were recorded in the fish meal supplementation treatment. The better than 50 percent production equals the results obtained by the better Indian farmers. The good production could be explained on the basis of adequate diet. The energy consumption was close to the 325 calories per hen day recommended (Scott et al., 1969). However, protein was overconsumed at great expense and this treatment could not be recommended to the Indians.

Egg production resulting from hens on pastures supplemented with maize was equal to the level expected from maize supplemented hens under indigenous conditions. Nutrient consumption data reveal that energy levels were slightly deficient but protein content was very low. The deficiency of protein suggests the production recorded was at some expense to the body reserves. The production life of the hen consuming this diet would be shortened.

Sesame supplementation produced egg production figures so variable any true response to the treatment could not be identified. The greater concentration of protein in the sesame improved the protein intake

Table 76. Feed consumption during the second KUPI experiment. The amount of feed consumed per bird day is calculated from the data presented. Supplement consumed was weighed. Kudzu pasture consumed was calculated from m^2 area grazed. Two reps. of each treatment.

Supplement Name	Supplement Consumed			Pasture Consumed	
	$\bar{X}$	$s_{\bar{X}}$	per bird †	grazed ‡	dry weight §
	g	g	g/bird/day	m^2/bird/day	g/bird/day
Maize	6908	268	69	0.20	42
Sesame	4368	122	44	0.22	46
Fish meal	9552	4	96	0.14	29
None				0.31	65

† Five birds 20 days = 100 bird days.

‡ Five birds 28 days = 140 bird days.

§ m^2 grazed times 210 g edible, dry kudzu produced/m^2.

Table 77. Daily nutrient consumption during the second KUPI experiment. Intake data from Table 76. Protein and energy content of feedstuffs same as those used in the linear program calculations.

Feedstuff	Intake	Protein †	Energy ‡	Diet
	g/bird/day	g	Cal ME	%
Maize	69	5.9	233	62.2
Kudzu	42	6.3	68	37.8
Total	111	12.2	301	
Sesame	44	7.7	206	48.9
Kudzu	46	6.9	74	51.1
Total	90	14.6	280	
Fish meal	96	58.6	275	76.8
Kudzu	29	4.4	47	23.2
Total	125	63.0	322	
Kudzu	65	9.8	105	100.0

† Phase I requirement 18 g/hen days (Scott et al., 1969).

‡ 325 calories per hen day recommended (Scott et al., 1969).

Table 78. Egg production pattern of the second KUPI experiment. Adjustment (Adj) period birds fed formulated diet. Remaining period on treatments.

Supplement	Production Periods				Treatment Summaries 2nd week + last period		
	adjust 5-6	1st week 7-13	2nd week 14-20	last 21-26	total	$s_{\bar{x}}$	lay †
	- - - - - -	- - - - - -	no. eggs	- - - - - -	- - - - - -	- - - - - -	%
Maize	8	19	12	12	23	1	35
Sesame	8	17	5	4	9	6	14
Fish meal	7	25	21	14	35	6	54
None	7	17	1	1	2	1	3

† Five hens x 13 days = 65 hen days.

over that reported for maize but the energy content, even with the oil present, could not equal the contribution made by maize.

Chickens on unsupplemented kudzu pasture responded with the lowest production of all treatments. Kudzu pasture is not an adequate feedstuff for egg production. Kudzu utilized as a dietary supplement added very little to the diets.

Table 79 presents feed intake and egg production data obtained from the third KUPI experiment. Production from the combination of maize and sesame supplementation was superior to pig weed or sunflower but egg production was not better than that obtained by the Indians.

Linear Program

Human Diets

Estimations of food consumption by a family of six in one semester was based on the information presented in the literature review. Calculations included the subtraction of 30 percent from the yuca consumption figures given by Waters (personal communication) to allow for waste. The consumption range became 1000 to 2275 kg. This range includes the yuca used to make a drink (chicha) consumed in large quantities. The six heads of plantains consumed each week indicates the average family is consuming 2000 kg in a half-year period. This value assumes 55 percent of the head is edible and weighs 23 kg. The egg consumption of two to three per person per week with the assumption 20 eggs are required to produce one kilo of edible product indicates the family is eating 15 to 24 kilos of eggs during a 26 week period. Assuming one bird produces 1.5 kilos of edible meat the poultry consumption in one-half year for the family would be from 15 to 45 kg if consumed at a

Table 79. Feed consumption and egg production during the third KUPI experiment. Three reps. were used.

Supplement Name	Supplement Consumption			Production Periods			Treatment Summaries		
	$\bar{x}$	$s_{\bar{x}}$	per bird †	April 29-4	May 5-10	May 11-15	total	S	lay ‡
	- - - - - g	- - - - - -	-	- - - - - - - -	no. eggs	- - - - - - - -	- -		%
Pig weed	471	35	5	14	1	0	1	2	2
Maize and	5351	435	56	16	11	4	15	3	27
Sesame	2962	113	31						
Sunflower	1833	167	31	16	2		2	2	7

† Five birds fed 19 days except sunflower fed 12 days = 95 or 60 hen days.

‡ Five birds laying 11 days except sunflower treatment which covered 6 days = 55 or 30 hen days.

rate of 10 to 30 birds during the period. Beans consumed at a rate of 0.9 kg a week calculated to be 24 kilos during a 26 week period. Food consumption of Quichuas in the Limoncocha area was estimated to range from 576 to 882 kg per person per semester. The Getulio Vargas Foundation (1970) reported semester family consumption to be 72 kg. The difference can be explained by the fact the Quichuas consume considerable quantities of manioc (yuca) and cooking bananas in the form of a drink.

The first human diet presented in Table 80 was designed to duplicate a typical diet. The yuca intake was calculated to be 2.5 kg per person day either in the form of boiled food or as a drink. Cowpeas were substituted for the common bean and placed in the diet at the rate of 0.9 kg per family week. Eggs were assumed to be consumed at a rate of three per person week. Chicken meat was used at a rate of 10 birds during the half-year period. When all calculations were made the diet contained adequate levels of most nutrients that could be calculated. The diet was very deficient in vitamin A. The addition of 100 kg of papaya for the week period solved this problem providing some surplus. This human diet along with others is shown in Tables 80 and 81.

Comparing the nutrients in this diet with the average recommended daily allowance (RDA) for the family of six the energy content is very high. An energy rich diet is expected in the humid tropics where carbohydrate is produced in abundance. The protein and amino acid needs are met with good quality protein (80 percent +). Most of the vitamin and mineral needs calculated were above levels listed in the standard. Riboflavin is above the level at which deficiency symptoms would occur.

Table 80. Human diets, numbers 1-5. Foods and amounts required to provide adequate nutrition for a family of six for 180 days are presented. Also presented are the nutrient levels in each diet on a daily intake basis along with the listing of the daily allowance (RDA).

Diet type:		Typical	Cowpea	Peanut Diets			Standards
Diet no:		1	2	3	4	5	
Yuca x 100 kg:		26	14-16	14-16	14-16	13	
Chicken-cons. no:		10	10	10	30	30	
Item	**Units**	For Family of 6 for 180 days					
Yuca	kg	2650	1500	1400	1400	1280	
Cowpea	kg	24	90				
Peanut	kg			96	68	96	
Papaya	kg	100	100	100	100	100	
Egg	kg	24	24	24	24	24	
Chickent	kg	15	15	15	45	45	
Amount eaten	kg	2763	1729	1635	1637	1545	
Land req.	ha	0.18	0.19	0.13	0.12	0.12	
Nutrient	**Units**	Ave. Consumption/Family for 180 Days					Ave. RDA †
Gross energy	kcal	3740	2405	2487	2409	2394	2357
Protein	g	41	43	45	43	48	39-44 ††
Amino A. sco. §	%	82	79	71	77	74	80-70
Meth-Cyst.	mg	1486	1331	1475	1505	1637	1193
Lysine	mg	2434	2699	2224	2397	2591	1299
Tryptophan	mg	599	553	594	572	630	299
Calcium	mg	858	555	521	506	487	683
Phosphorus	mg	932	894	830	784	852	683
Potassium	g	6	5	4	4	4	3
Manganese	mg	40	26	22	22	20	2.5

Continued next page

Table 80 - continued

Vitamin A	IU	1903	1980	1915	1927	1934	1852
Niacin	mg	17	11	24	22	26	15
Riboflavin	mg	0.9	0.7	0.6	0.6	0.6	0.6[¶]
Fat	g	174	10	51	44	56	93[#]
Fiber	g	27	19	16	15	15	25[#]

[†] Calculated from Table 19 except AA score and Riboflavin figures.

[‡] First figure is the requirement if protein has AA score of 80, second for 70.

[§] Calculated by adding together mg/g protein of methionine, cystine, lysine, and tryptophan. The total is divided by the content of the same AA in egg protein.

[¶] Level below which deficiency symptoms will appear (Pike and Brown, 1975).

[#] These levels are considered to be the maximum allowed. Lower values are desired.

The fat level is very high. Cholesterol problems might emerge among Indians consuming this diet, or one similar to it, for long periods of time. The fiber content might not be as high as indicated because no fiber content is taken in when yuca and cooking bananas are consumed as a drink. This diet will meet the nutritional needs of people who have no access to wild meat in the forest. This conslusion is possible because large intakes of carbohydrate rich foodstuffs provide other nutrients required by humans.

The experience realized from developing this first diet revealed some guidelines were required before other diets were formulated. One such guideline was the observation that the nutrient content of yuca and cooking bananas was sufficiently similar that they could be considered interchangeable in the diet. Human diets were constructed to indicate the amount of yuca required with the assumption cooking bananas could be substituted or any ratio of the two foodstuffs would be satisfactory.

Another guideline was required with yuca/cooking banana diets because tabular values of sodium, magnesium, zinc, panothenic acid, and choline were not available for yuca. The levels of these nutrients could not be determined in any diets containing large quantities of the crop. This particular list of nutrients was deleted from the tables presented in this section.

Providing diets which would introduce as few changes as possible was another principle guiding diet formulation. In all subsequent diets egg consumption was maintained at the customary rate of three per person week. Chicken mean consumption was restricted to the present intake level of 15 kg (10 birds) per family semester in many diets. Some diets were constructed to increase chicken meat consumption to one bird per family week (26 birds per family semester). The purpose was to decrease the amount of protein rich crops in the diets. This increase of chicken was considered so small it was assumed the change would be accepted by many Indians.

Papaya grows without cultivation providing large supplies of vitamin A rich fruit. The 100 kg per semester was a standard addition to all subsequent human diets.

All data upon which computer calculations are based are approximate. The linear program was observed to be a planning tool dealing with population needs rather than a consideration of individuals. The requirements of a family of six used in the program are designed to represent an average family in an indigenous society. The strength of linear programming is its capacity to determine if adequate nutrition is possible.

Protein deficiencies were supplemented with the addition of protein-rich crops. Many of them when in the uncooked state contain inhibitors of toxins which become harmless when heated. Boiling, toasting, or some other heat treatment was considered essential for the successful utilization of such crops.

The first deviation from foodstuffs commonly consumed by the Indians was to use cowpeas in the proposed diets in the place occupied by common beans. The substitution was made with the recognition cowpeas were more likely to be grown in the future. The chances this substitution would be accepted by the Indians were considered to be very good.

The remaining diets were constructed according to the above guidelines. Diet number 2 was designed and thought of as a cowpea diet. The use of 90 kg per semester reduced the size of the yuca by 43 percent. Use of cowpeas reduced the size of the yuca or cooking banana patch. More land was required to produce this diet, adding manpower hours to food production.

Compared to the first diet the protein quality in this one is only slightly reduced yet continues to be nutritionally adequate. Calcium is somewhat deficient but is well above the level of 400 mg per day required by people on a long term low calcium diet (Pike and Brown, 1975). Niacin is below the standard but somewhat above the level Pike and Brown (1975) reported of 4.4 milligrams per 1000 kilocalories of energy representing the level at which deficiency symptoms would begin to appear. In this diet the minimum safe level would be 10.5 milligrams intake of niacin per day.

The daily per capita consumption required by this diet drops to 1.6 kilos compared to 2.5 in the first diet. This level compares to 0.4 kilos daily per capita consumption in the Getulio Vargas (1970) study. The 3.2 to 5.0 kilos daily consumption of the Quichuas reported in the literature can be reduced if proper foodstuffs and amounts are selected.

The third diet substituted cowpeas with peanuts. This crop was considered more readily accepted because a desire for peanuts already exists and some of the tribesmen in the experimental area know how to produce them. The level of 96 kg of peanuts during a 180 day period allowed yuca production to be reduced by 100 kilos when compared to the cowpea diet. The amount of land required to produce the food was reduced considerably from that required for the first two diets. The protein quality of this diet was close to 70 percent indicating over

44 grams of protein would be required. Energy and protein needs along with the amino acids are met in this third diet. All other nutrient needs are met with the observation calcium is above deficiency levels as described in the second diet and niacin is marginal.

The question was asked what would happen to the peanut level if chicken meat consumption was increased to one bird per family per week, yet maintaining the other foodstuffs at the same levels. This thinking was behind the fourth diet using only 6 kilograms of peanuts. The quality of protein increased considerably with the increase in chicken meat. All other nutrients were more than met with calcium and niacin levels remaining essentially the same.

Recognizing peanuts are high in energy perhaps yuca/plantain consumption could be decreased if the family consumed more peanuts. Diet number 5 shows this was possible. Yuca consumption was reduced by 120 kilos to produce nutrient intakes similar to the other peanut diets. The amount of land required to produce foodstuffs for all the peanut diets was about the same.

If chicken consumption was maintained at one bird per week, how much swordbean or jackbean could be consumed and what level of yuca would be required? Swordbeans were considered because they produce very well with no apparent disease problems. The possibility this crop would be accepted was enhanced upon the realization one of the Quichuas at Limoncocha had introduced it on his own initiative.

Yuca was required at 1600 kg and jackbeans at 70 kg in diet number 6 presented in Table 81. This level of approximately 2.7 kg per family week was considered to be sufficiently larger than the 0.9 kg traditionally consumed. Doubt existed this higher level would be accepted.

Table 81. Human diets, numbers 6-10. Foods and amounts required to provide adequate nutrition for a family of six for 180 days are presented. Also presented are the nutrient levels in each diet on a daily intake basis along with the listing of the daily allowance (RDA).

Diet type:		Jackbean Diets		Jack-Pea.	Soybean	Velvet Bn.	Standards
Diet no:		6	7	8	9	10	
Yuca x 100 kg:		14-16	14-16	14-16	14-16	14-16	
Chicken-cons. no:		30	10	10	10	10	
Item	Units	For Family of 6 for 180 Days					
Yuca	kg	1600	1600	1600	1600	1600	
Soybean	kg				50		
Jackbean	kg	70	90	24			
Peanut	kg			61			
Velvet Bn.	kg					90	
Papaya	kg	100	100	100	100	100	
Egg	kg	24	24	24	24	24	
Chicken	kg	45	15	15	15	15	
Amount eaten	kg	1809	1829	1824	1789	1829	
Land req.	ha	0.11	0.11	0.13	0.12	0.36	
Nutrient	Units	Ave. Consumption/Family for 180 Days					Ave. RDA ‡
Gross energy	kcal	2537	2531	2647	2410	2515	2357
Protein	g	45	45	44	41	51	39-44 ‡
Amino A. sco.§	%	77	72	71	84	72	80-70
Meth-Cyst.	mg	1551	1455	1469	1431	1507	1193
Lysine	mg	2743	2550	2312	2656	3128	1299
Tryptophan	mg	415	358	531	605	358	299
Calcium	mg	586	601	581	617	745	683
Phosphorus	mg	594	538	758	816	838	683
Potassium	g	4	4	4	4	4	3
Manganese	mg	24	24	25	25	24	2.5

Continued next page

Table 81 - continued

Vitamin A	IU	1943	1934	1918	1961	1892	1852
Niacin	mg	14	12	20	11	10	15
Riboflavin	mg	0.7	0.7	0.7	0.7	0.6	0.6 ¶
Fat	g	16	11	37	18	14	93 #
Fiber	g	21	23	19	18	21	25 #

† Calculated from Table 19 except AA score and Riboflavin figures.

‡ First figure is the requirement if protein has AA score of 80, second for 70.

§ Calculated by adding together mg/g protein of methionine, cystine, lysine, and tryptophan. The total is divided by the content of the same AA in egg protein.

¶ Level below which deficiency symptoms will appear (Pike and Brown, 1975).

Those levels are considered to be the maximum allowed. Lower values are desired.

Assuming for the sake of discussion Indians would accept this diet their nutrient needs would be met. The same could be said for the seventh diet which was also a jackbean diet. This latter diet contains chicken meat at the typical level and a 20 kilo increase in jackbean intake. One weakness of this diet is perhaps the Indians will not want to eat this much jackbean during the semester.

Considering the possibility jackbean might not be consumed in very large quantities diet number 8 was constructed to limit jackbean intake to 0.9 kg per family week. The question was asked how much peanuts would be required to make the diet adequate consuming 10 chickens a semester. Diet number 8 shows 61 kg of peanuts are used which is close to the same level required in the peanut diet using 30 birds a semester. This diet would have a good chance of being accepted by the Indians because peanuts are desired by them. The nutritional data demonstrates the diet is adequate.

The protein quality of soybeans is quite high (82 percent). Research showed it grew well in the area being studied. Diet 9 was constructed to use this crop. Only 50 kg was required along with the other foodstuffs indicated to produce a nutritionally adequate diet. Much interest was shown years earlier by Quichuas. Some people asked for toasted, whole soybeans for eating out of hand. There is a possibility this crop could become a part of the human diet.

Velvetbeans are a good green manure crop for pasture land renovation. Perhaps the beans produced as a by-product could be utilized in a diet. Little is known about this crop by the Indians. An additional disadvantage is it contains toxins which are removed by boiling in repeated changes of water. This crop has been consumed by humans when under famine conditions. Diet 10 used this crop.

A considerable amount of land is required for this diet. When it is realized 0.26 hectares is required to produce the velvetbean, the actual land worked becomes comparable to all the other diets with the exception of those containing cowpeas. The land producing velvetbeans would be considered primarily in pasture improvement and the beans would be a by-product.

Poultry Diets

The poultry flock in the linear program was composed of 90 meat birds raised from hatching to 180 days of age. The flock also consisted of 45 mature chickens. Adequate diets were formulated for this flock and evaluated by the computer program.

As mentioned earlier the computer program was not sufficiently constrained to select either human or poultry diets Indians are likely to accept. The diets in the computer printout were evaluated by a program I designed for the Hewlett Packard HP 97 printing calculator. This program monitored the total levels of metabolizable energy, protein, methionine, cystine, and lysine. These nutrients were considered to be the most critical. It was assumed that if these nutrients are present in adequate quantities little or no further dietary changes would be required to meet the requirements of the remaining 15 nutrients considered in the rows of the linear program matrix.

The level of each of these five critical nutrients in a diet is not a sufficient measure of quality. Relationships and concentrations must be calculated and compared to standards. Energy density (calories of metabolizable energy/kg of diet) was one monitor of quality. If the HP 97 program showed this value was outside the range suggested by Scott et al. (1969) changes were made in ingredient levels until this standard was met. The same pattern was followed with such other quality measures as percent protein in the diet and the metabolizable energy:protein ratio.

Daily feed consumption was a quality measure and had two parts. One was the level of feed consumed per bird day if the entire proposed diet for the 180 day period was consumed. This figure was compared to standards recorded in the literature to determine if a chicken had sufficient capacity to consume that amount of feed. The second consumption parameter was predicted consumption based on energy needs. This consideration would be a practical measure of quality if chickens will generally eat only to satisfy energy needs, which was the position taken in this research. Therefore, if a diet is to contain the necessary quality, the daily predicted consumption should be very close to the actual consumption. If all quality measures were met it was assumed the diet was adequate providing the feedstuffs used contained the same nutrient levels as those used in the calculations.

The levels of each dietary component determined by the trial and error methods described and evaluated by the HP 97 program were placed in the linear program after all the quality monitors were optimized. The computer program was constrained to fix the levels of each feedstuff entered. The linear program of the computer then computed the levels of the five nutrients calculated by the Hewlett Packard plus printed the levels of the other 15 nutrients in the matrix and all other rows including the accounting rows giving an indication how the Indians were benefiting from the combination of all systems. In addition the computer program selected the amounts of vitamin and mineral supplements necessary to insure adequate levels of those nutrients. The amount of each nutrient present was compared to the standards and discussed in terms of how adequately it met the needs described in the literature.

The amount of feed consumed was calculated. The level of consumption determined the concentration of nutrients to be designed in each diet. Feed consumption of Rhode Island Red chicks in the PORE experiment was 80 g per bird day measured over a 22 week period (Table 69). Egg production began a week later.

Titus and Fritz (1971) reported Rhode Island Red chicks consumed 11.7 kg per bird during an unreported length of time. Assuming the time period was to egg production the intake would be 76 g per bird day and close to the Limoncocha figure.

The flock of 90 meat birds would consume 1100 kg of feed during the first 22 weeks of life if consumption averaged 80 g per bird day. The total consumption of these birds during 180 days is estimated to be 1550 kg. The assumption is consumption after 22 weeks of age was 177 g per bird day as reported for the last 15 days in Table 67.

Consumption of Rhode Island layers reported in Table 74 was approximately 135 g per bird day. New Hampshire layers were reported (Titus and Fritz, 1971) to consume feed at an average rate of 105 g per bird day. Using reported and experimental values as the lower and upper ranges of estimated feed consumption the flock of 45 mature chickens would require 850 to 1100 kg during the 180 days in the planning period. The total consumption of the entire flock of mature and meat birds is estimated to be from 2400 to 2650 kg per semester. The mean consumption of the flock is 100 to 110 g per bird day.

Energy requirements of the indigenous flock was one of the values used in the H. P. 97 program when determining predicted feed consumption. This energy value was calculated from information given in the literature.

Rhode Island Red hens in hot climates require 325 kilocalories (Kcal) of metabolizable energy (ME) per bird day (Scott et al., 1969). This value is near the 320 Kcal ME per bird day given as the highest value in the range of Leghorn energy requirements in cool climates (Scott et al., 1969). The assumption was made, based on the closeness of these two figures, the energy values reported by Scott et al. (1969) for Leghorns in cool climates would approximate the needs of Rhode Island Red chicks in the tropics.

The energy requirement of the 90 meat birds was estimated by calculations based on the above assumption and a table of Leghorn chick energy requirements at various ages (Scott et al., 1969). The mean energy requirement of the meat birds was 178 Kcal ME per bird day during the 180 day planning period.

The energy requirement of the flock (135 birds) was the mean of 178 Kcal ME of the meat bird flock and 325 Kcal ME reported requirement of Rhode Island Red birds in the tropics. The resultant figure was 252 Kcal ME per bird day.

This value of 252 Kcal ME cannot be compared to any value in the literature. The average bird described by this figure does not exist. Two-thirds of this value was produced by the needs of young birds while the rest represented mature chicken requirements.

Predicted feed consumption, one of the measures of diet quality, was calculated by dividing the estimated daily energy requirement of

252 Kcal by either 2600 or 3300 Kcal ME per kg of diet. These energy figures were considered to be the practical limits on the energy concentration of any diet for chicks or layers. The predicted daily feed consumption was calculated to range from 75 to 97 grams. There is a 20 percent difference between these values and those based on the observed consumption of 100 to 110 grams per bird day. The difference was maintained by constructing a predicted consumption range considered acceptable. The lowest value of 75 g per bird day was produced from calculations based on information in the literature. The upper value, considered slightly excessive (110 g per bird day), was based on observed data.

The minimal protein consumption of this flock was calculated to be 14 g per bird day. This value was based on 20 g per bird day required by mature birds and 6.6 g per bird day by chicks in the first 22 week development period. The chick data are a mean of values presented by Scott et al. (1969).

The percent protein in the proposed diet was an important monitor of quality. The calculation of these values was based on the minimal requirement of 14 g per bird day protein intake. This figure was divided by predicted feed intake levels calculated as previously described. The result of the calculations revealed the protein content range of an acceptable diet is 14 to 19 percent.

The ME-protein ratios were used to insure proper relationships between energy and protein levels in the diet. The range of ratios fitting the flock of 135 birds was calculated to be 175 to 185. These values were calculated by dividing 3300 and 2600 Kcal ME per kg of diet by the percent protein range of 19 and 14 percent, respectively. The order of protein figures was based on the fact chickens eat enough feed to satisfy their energy requirements. The higher the energy concentration the less feed will be consumed and the greater the protein concentration required to insure adequate protein intake.

The diets which come sufficiently close to the standards are presented in Tables 82 to 85. Tables 82 and 84 present the crops selected and the percent each is present. Also the supplements are shown along with the percent they are present. The exception is the vitamin mix which was 0.1 percent of the diet. This was listed as the number of grams used by the flock during the entire 180 days. The kilograms of diet required by the flock over the planning period is given to facilitate calculation of actual quantities of feedstuffs required during the entire semester. Daily and predicted consumption were presented in grams per bird day for reference. The land required to produce the feedstuffs for the period was based on the yield data presented elsewhere. Calculations reveal approximately three-fourths of a hectare is required to produce feed for a flock of 135 birds.

The nutrient concentrations of each diet and the figures used to determine quality are given in Tables 83 and 85. Soybeans are a high quality protein crop and can be grown in the Amazon, a factor considered in the selection of this grain in the first five diets. Experience has shown the soybeans can be dry toasted over a slow wood fire. How much this toasting requirement will be a hinderance to adoption of this crop as a poultry feedstuff remains to be observed. Diet three calls for the highest level of soybeans of 740 kg. This level requires the toasting of slightly less than 30 kg of soybeans each week during one or two toasting periods. The work to prepare this quantity of soybeans might hinder use of this diet.

Table 82. Poultry diets, 1-5 with soybeans.

Diet No: Crops Used:		1 Maize Soybean Sesame	2 Maize Soybean Sesame Kudzu	3 Maize Soybean	4 Maize Soybean Jackbean	5 Maize Soybean Sunflower	Standards
Carrier	Units						
Maize-reg.	%	50.8	33.2	54.4	49.1	49.2	
Soybean	%	32.5	22.5	38.5	33.3	33.4	
Jackbean	%				10.3		
Sesame	%	9.6	9.8			10.4	
Kudzu	%		29.3				
Min. salt	%	0.4	0.5	0.3	0.4	0.4	
Lime	%	4.3	2.8	4.4	4.2	4.4	
Bone meal	%	2.3	1.9	2.3	2.6	2.1	
Vit. mix	grams	1495	0	1413	1464	14.64	
Total cons.	kg	1870	2050	1922	1935	1930	1825-2675
Daily cons.	g/bdda	77	84	79	80	79	75-110
Predict. cons.	g/bdda	76	89	79	81	76	75-97
Land req.	ha	0.9	1.0	0.8	0.7	0.9	

Table 83. Nutrients in poultry diets 1-5 and quality measures along with standards used to identify diets with adequate nutrient levels.

Nutrient	Units	Diet Number					Standards
		1	2	3	4	5	
Met. energy	kcal/kg	3301	2838	3184	3098	3308	2600-3300
Protein	%	18.4	17.5	19.3	19.5	19.3	14-19
Protein cons.	g/bdda	14	15	15	16	15	14
ME/protein	ratio	179	162	165	159	172	175-185
Meth-Cyst.	%	0.64	0.58	0.62	0.61	0.60	0.60
Lysine	%	1.04	0.91	1.15	1.14	1.06	0.74
Tryptophan	%	0.25	0.23	0.25	0.22	0.24	0.20
Calcium	%	2.40	2.19	2.33	2.32	2.32	2.21
Phosphorus	%	0.69	0.63	0.67	0.67	0.67	0.65
Potassium	%	0.71	1.24	0.75	0.65	0.72	0.20
Sodium	%	0.21	0.19	0.21	0.21	0.21	0.20
Magnesium	mg/kg	1796	2118	1804	1612	1632	500
Vitamin A	IU/kg	5602	6337	5451	5414	5428	5675
Panothenic A	mg/kg	10	12	11	10	10	8
Choline	mg/kg	1177	1041	1365	1193	1196	995
Niacin	mg/kg	30	27	27	28	33	19
Riboflavin	mg/kg	3.8	4.8	3.6	3.6	3.6	2.7
Fat	%	12.8	10.9	9.0	8.0	10.6	15.0
Xanthophyll	mg/kg	8	180	8	7	7	11 †
Fiber	%	3.9	11.7	3.3	3.7	5.9	10.0

† Produces a light pigmentation in broiler skin and an approximate NEPA No. of 1.0 in the egg yolk (Titus and Fritz, 1971).

Table 84. Poultry diets, 6-10 with no soybeans.

Diet No: Crops Used:		6 Maize Jackbean	7 Maize Jackbean	8 Maize Jackbean Sunflower	9 Maize Velvetbean	10 Maize Velvetbean Sesame	Standards
Carrier	Units						
Maize-reg.	%	41.8	35.4	29.8	44.2	46.9	
Soybean	%						
Jackbean	%	51.6	51.7	50.6			
Sesame	%		6.2			9.1	
Sunflower				13.1			
Velvetbean	%				49.6	37.7	
Min. salt	%	0.8	0.8	0.8	0.8	0.8	
Lime	%	2.5	2.6	2.7	3.4	3.4	
Bone meal	%	3.2	3.3	3.0	1.9	1.9	
Vit. mix	grams	1532	1626	1642	1655	1644	
Total cons.	kg	2394	2263	2328	2264	2186	1825-2675
Daily cons.	g/bdda	99	93	96	93	90	75-110
Predict. cons.	g/bdda	91	88	86	92	85	75-97
Land req.	ha	0.7	0.8	0.8	3.8	3.1	

Table 85. Nutrients in poultry diets 6-10 and quality measures along with standards used to identify diets with adequate nutrient levels.

Nutrient	Units	Diet Number					Standards
		6	7	8	9	10	
Met. energy	kcal/kg	2776	2850	2945	2728	2951	2600-3300
Protein	%	16.7	17.3	18.3	20.1	18	14-19
Protein cons.	g/bdda	16	16	18	19	16	14
ME/protein	ratio	166	165	161	136	164	175-185
Meth-Cyst.	%	0.48	0.52	0.50	0.51	0.53	0.60
Lysine	%	0.80	0.82	0.82	1.12	0.94	0.74
Tryptophan	%	0.04	0.05	0.05	0.04	0.07	0.20
Calcium	%	1.87	1.98	1.93	1.98	2.05	2.21
Phosphorus	%	0.54	0.57	0.56	0.57	0.59	0.65
Potassium	%	0.13	0.15	0.18	0.14	0.21	0.20
Sodium	%	0.17	0.18	0.17	0.18	0.18	0.20
Magnesium	mg/kg	672	716	549	1762	1719	500
Vitamin A	IU/kg	4376	4629	4500	4627	4792	5675
Panothenic A	mg/kg	5	5	4	5	5	8
Choline	mg/kg	221	187	157	233	248	995
Niacin	mg/kg	26	28	34	17	21	19
Riboflavin	mg/kg	2.8	3.1	3.1	2.3	2.6	2.7
Fat	%	2.3	5.2	5.2	4.5	8.7	15.0
Xanthophyll	mg/kg	6	5	4	7	7	11 †
Fiber	%	5.3	5.8	8.7	4.3	4.5	10.0

† Produces a light pigmentation in broiler skin and an approximate NEPA No. 1.0 in the egg yolk (Titus and Fritz, 1971).

Sesame does not require toasting nor grinding. Diet one compared to diet three shows sesame reduces the amount of maize and soybeans required to balance the diet.

The value of pasture is seen when diet one and two are compared. The kudzu reduced the amount of maize and soybean required, and also it reduced the mineral supplements required. The need for a vitamin mix was eliminated. The fiber content of over 11 percent was not thought to be excessively high. Kudzu is not a good crop to use. The crop must be carefully managed or it will become a pest. The level of kudzu placed in diet two is that which was calculated to have been consumed by the chickens on the KUPI diets and represents pasture available on a free choice basis.

Diet four was designed to utilize jackbean. Less sesame is required when jackbean was used. Sunflower is yet another alternative. Diet five was formulated with the same levels of the three crops found in diet four.

Considering the nutrient concentration in these five diets the metabolizable energy is within the range suggested by Scott et al. (1969). The protein levels tend to be high bringing about overconsumption. If these levels were reduced the methionine and cystine content would be below recommended levels.

The percent figures of methionine-cystine, calcium, and vitamin A of some diets appear to indicate deficiencies exist. The greater quantity consumed of these diets insures adequate intakes of these nutrients. The fat content of the diets are all well below the maximum allowed as indicated in the standards column. The fiber content of the diet with kudzu is understandably high but the others are well below the 10 percent level listed in the dietary standards. Based solely on the diets outlined all but the one containing kudzu would produce meat and eggs very light in color. Since the tribesmen's chickens run freely during the day, sufficient grass likely will be consumed to improve the pigmentation of the eggs.

The levels of feedstuffs in diets six to ten are presented in Table 84. Diet six was formulated to take advantage of the easy production of both maize and jackbean. Adding sesame to these crops as shown in diet seven reduces the amount of maize and jackbean required which might be desirable. Diet eight shows sunflower substituted for maize. Morrison (1948) observed sunflower made a good substitute for the cereal grains. The addition of greater levels of sunflower than sesame to a maize-jackbean diet reduced the amount of maize required but the jackbean requirement remained the same. The remaining diets were designed to utilize velvetbean. By adding sesame, as in diet 10, the amount of velvetbean in the diet could be reduced.

Table 85 shows the energy levels of these diets tend to be toward the lower edge of the range yet protein intakes and concentrations are quite high. The same comment about the apparent deficiencies of methionine-cystine, calcium, and vitamin A in these diets could be made as written when describing this problem in diets one to five. Deficiencies of potassium, panothenic acid, and choline appear because no values could be found to describe the concentrations of these nutrients in these crops. Perhaps it can be safe to assume the nutrients in question are present in adequate levels. Manganese and zinc were not considered in any of the 10 diets because no values were available for the crops just discussed nor for sesame.

Nutrient Maximization

The crop selected by the computer to maximize nutrient production depended upon which objective function was being optimized. If energy was the selection, yuca was selected as being most efficient. All the land remaining after human and chicken needs were met was given to production of this crop. When protein production from the system was maximized jackbeans were the first choice. If this crop were taken out of the matrix soybeans appeared as the second choice (Table 86). Ten crops of principle interest were ranked according to production of energy or protein per m^2. Jackbean, peanuts, and soybeans are near the top of both lists. These crops appear to be the best choices to maximize nutrient production on the farm.

Three production systems have been discussed. Each diet within both the first two systems of food and feed production represent alternatives that could be selected by the tribesmen. Each diet was thought of as being a module. One question asked was, would it be possible for a farm family to produce most of their own food needs and those of their flock from the farm production with a minimum dependence on imports? Since 20 diets could be formulated using home-grown crops, the question can be answered affirmatively.

The third production system involved growing a commercial crop. Between one and two tenths of a hectare are required to produce food for the family of six. To feed chickens requires about three quarters of a hectare. Therefore, only one hectare is required to produce food and feed. The small amount of land is required for food or feed production would suggest that this farm family can produce food for other people and receive some income from their efforts.

Table 86. Energy and protein production/m^2 from various crops ranked and compared.

Energy			Protein		
rank	crop	yield	rank	crop	yield
		kcal/m^2			g/m^2
1	Yuca	2900	1	Jackbean	159
2	Jackbean	2069	2	Soybean	123
3	Peanuts	1446	3	Peanuts	67
4	Soybean	1081	4	Mungbean	27
5	Rice-HYV †	1074	5	Rice-HYV	26
6	Reg. maize	669	6	Sunflower	25
7	Sunflower	639	7	Yuca	24
8	Sesame	509	8	Cowpea	22
9	Mungbean	378	9	Reg. Maize	16
10	Cowpea	310	10	Sesame	15

† High yielding cultivar.

If the economy could support the production the income of the farmer from poultry could be considerable. The computer figures show if a chicken will sell for 80 sucres and an egg for two sucres the farmer could gross 9780 sucres from his 135 bird flock if a bird a week was being consumed in his diet. If human diets were selected calling for the consumption of chicken at the traditional level of 10 birds in 26 weeks the gross would be 11380 sucres. The conversion to dollars could be made by using around 22 sucres to the dollar. The cost of vitamin mix, lime, and mineralized salt depending upon which diet was selected to feed the flock would range from 670 to close to 1200 sucres. The income from any crops grown commercially would be extra according to the amount of land the farmer had available to use for that purpose.

SUMMARY AND CONCLUSIONS

The purpose of this research was to develop food production systems to provide adequate nutrition for a farm family of six people. Part of the protein intake of this family was to come from a flock of 45 mature chickens and 90 young meat birds. Development of feed systems was required to supply nutrients in sufficient quantities to support the flock.

Emphasis was placed on increasing protein production but some study was made of carbohydrate crops. The physical setting of the research was the continuously moist, humid tropics in Ecuador's North Amazon. The anthropological setting was within three tribal cultures as represented by the Indian tribes of Quichua, Cofan, and Secoya. The agricultural setting was that of indigenous, subsistence farming of small tracts of land.

Carbohydrates have been produced by indigenous agricultural practices, and yuca, maize, rice, and bananas were the major crops grown. Maize, past the roasting ear stage, was not used for human consumption. The main use for maize was to "tame" recently cleared ground; the crop is either sold or fed to the chickens.

Protein-rich foods were supplied from hunting-fishing activities. Peanuts were grown by many tribespeople. The quantities produced were small because predators caused heavy crop losses. Common bean yields were low because all cultivars tested lacked disease resistances. These two legume crops were used for protein production when wild meat was unavailable.

The common practice is to allow the chickens to consume anything they can find without the benefit of feedstuff supplementation. Maize, a carbohydrate rich feed, is often the crop fed if anything extra is given. Poultry flocks were small numbering under 15 birds. They were managed by women and children. Production seldom exceeded four eggs per day from the flock. The Indians desired to keep larger, higher producing flocks but were unable to identify the limitations to reaching this goal. I believe that increased poultry production was looked upon by the researcher as one means to increase the protein supply. One hindrance to expansion was the lack of an adequate feed supply to support a larger flock. The assumption was made that the food available free choice to the chickens was sufficient to support the size flocks presently being cared for by the families. Feed production on the farm must increase before flock sizes can be larger.

Crop observation experiments were the first to be conducted. Cultivar experiments were designed as the material available made this research possible. Tribal demonstration plots among the Quichuas, Cofans, and Secoyas provided opportunities to test promising crops, introduce new material to the tribesmen, and receive anthropological information concerning how the crop or practice fits the culture of the tribe.

Observations of tribal agriculture were made to develop a body of information to use when evaluating agricultural introductions. Both the tribal cropping and poultry management practices were described. Poultry experiments were designed to supplement tribal observations with the goal to increase egg and meat production, using practices Indians could duplicate.

I developed a column of linear equations with the coefficients arranged in rows and columns. One section of the columns provided crops as nutrient carriers to satisfy the nutritional needs of a family of six and their 135 bird Rhode Island Red chicken flock. Another section of the matrix selected a commercial crop to be grown that would maximize nutrient production from land remaining after food and feed needs had been met. The nutrients maximized were either gross energy or crude protein. Jackbeans, peanuts, and soybeans were observed to produce large quantities of both nutrients as shown by production data gathered during the research.

A section in the matrix was created to evaluate the combined effect of the systems a farmer might select. Gross and net income were one of the measures. Others were total protein and energy produced on the farm. The amount of land required to produce crops needed for chicken feed, human consumption, and commercialization was also distinguished. These data were based on information generated from many experiments.

Research confirmed common bean yields were low. Cowpea cultivars showed greater disease resistance and higher yield levels. Mungbean yields were acceptable but the seed was too small.

Soybean yields were high. Quichuas demonstrated a desire to eat unextracted, dry toasted soybeans. Toasting was possible by constant stirring in a container on a slow wood fire. The beans could also be used for chicken feed without cracking.

Jackbeans showed promise. A few plants were observed to be growing in the yard of a Quichua farmer. The crop demonstrated excellent disease resistance and high yields. Further research is required to determine how to prepare and utilize this crop as a food and feedstuff.

Peanut research demonstrated this crop was well adapted, was well known by the Indians, and was a desirable food. The greatest hindrance to wider use of this crop is the severe rodent damage occurring frequently. If rodents could be controlled peanuts would be grown in larger quantities. Local cultivars were very productive. Some new cultivars could be introduced if larger seed size was desired.

Sesame protein quality is very high exceeded only by soybeans. The quality results from greater concentrations of the amino acids methionine and cystine. Yields were at acceptable levels. The crop was considered useful for chicken feed. The pod splits open upon ripening, facilitating threshing. If harvest was made at the proper time the stalks could be stored under a roof in an area to which chickens have access. Feeding these small seeds would require inverting the stalks to allow the seeds to roll out for the chickens to consume. A limitation is the seeds tend to tie up dietary calcium.

Sunflower is commonly a component in bird seed mixture. The research with Mammoth, the eating variety, supported statements in the literature that this crop was not adapted to the climate of the research area. It is not known if there are other better adapted cultivars which might alter this conclusion. The crop has the added disadvantage that the seeds are high in fiber. Since there are other proven crops available to supply protein it would be well to eliminate sunflower from the crops to be grown in this area.

Wingbeans were observed to have many applications. If superior cultivars are not available this crop is of no value to the people living in the research area.

Sorghum produced acceptable yields. However, since yuca and maize were superior and better adapted, research with the crop was not continued.

Poultry research focused primarily on discovering ways Indians could use the promising crops to meet the nutritional needs of their flocks. Various combinations of crops and pasture were used as treatments. Calculations were made from the data developed to create information required for the linear program.

Much of the poultry data and cropping information was punched on computer cards. The linear programming capability of the computer was used to evaluate the various systems or modules making up the food and feed activities on the farm which was supplying the subsistence needs of the Indians. Ten humans and 10 chicken diets were formulated. All were designed to have a good chance of being accepted by the Indians. The inherent problems and strengths that could be foreseen were discussed. All diets were shown to supply adequate nutrition.

The conclusion of the research was one hectare will adequately feed a family of six and the flock of 45 mature chickens and 90 meat birds. Consequently, there is no need to depend on wild meat as a protein source. Each of the diets represented a feed or food production system or module. The way the farmer arranges these modules determines the total production from the farm. Some limited commercialization was available through the sale of eggs and chickens not used in the diets. If more than one hectare is available for crop production commercial crops can be produced to earn additional income.

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BIOGRAPHICAL SKETCH

The author was born in Franklin, N. J., on April 12, 1932. He grew up on a 100-cow, 450-acre dairy farm outside the town of Newton, N. J. He graduated from Newton High School in 1951, and received his Bachelor of Science degree in Dairy Science from Rutgers in 1955. He returned for one semester to Rutgers to complete an undergraduate major in Vocational Agricultural Education. He attended the graduate school of Columbia Bible College in Columbia, South Carolina, from 1957 to 1960. The Master of Science degree in Vegetable Crops was awarded at Cornell University in 1969.

In 1960 he became a member of the Summer Institute of Linguistics and Wycliffe Bible Translators. That fall he started work in Ecuador's Amazon jungle as an agricultural missionary. In 1973 he left Ecuador to take classwork toward a Ph.D. degree in Agronomy at the University of Florida until the summer of 1975. He returned to Ecuador to complete the field work for his dissertation. From the summer of 1977 to the fall of 1978 he was in Gainesville to complete the requirements for the degree. While at the University of Florida he has held an extension and later a teaching assistantship.

While at Rutgers he joined the Alpha Gamma Rho agricultural fraternity and was inducted into Alpha Zeta honorary fraternity. He is listed in the biographical listings of: Notable Americans of 1978-1979, Men of Achievement, and the Dictionary of International Biography. He is married and has four children.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Darell E. McCloud

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Professor of Agronomy

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