6 Hunter-Gatherers and Early Agriculture

Before the development of agriculture and formal crop culture, wild plants and animals in the natural ecosystem were the only food for humans. How much wild plant and animal biomass is available for food, and how much land do hunter-gatherers need to meet their food needs?

The total annual production of plant biomass in the temperate region averages about 2400 kg (dry)/hectare. Under favorable conditions, this quantity of plant biomass might support an animal and microbe biomass of about 200 kg/ha (dry)/year. The proportions of the total 200 kg that comprise microbes, earthworms, arthropods, mammals, birds, and other animals are indicated in Figure 6.1.

Let us assume that a hunter-gatherer required 2500 kcal/day to meet his or her energy needs. By harvesting 0.1% of the available animal biomass from 40 ha, he or she would be able to consume 88 kcal/day (32,000 kcal/year) in the form of animal protein. The remaining 2412 kcal/day (880,500 kcal/year) of needed food energy would come from other sources, including seeds, nuts, fruits, roots, and other plant foods. Assuming that 1 kg of digestible plant material yields 3000 kcal, the hunter-gatherer would have to harvest about 300 kg of plant material from 40 ha (7.5 kg/ha/year) to meet calorie needs. Although obtaining this amount of plant material suitable for food might not be possible in a heavily wooded habitat, it likely would be possible on land containing a mixture of wood, shrubs, and herbs, as well as a productive stream.

If the plant food gathered contained an average of 5% protein, then a total of 12.2 kg of protein could be harvested per year, or about 34 g of plant protein per day. Combining the 34 g of plant protein and the 22 g of animal protein, the hunter-gatherer's diet would include a total of 56 g of protein per day under optimal conditions. The remaining calories would come from plant carbohydrates. Note that the consumption of fat was omitted from these calculations. Fats yielding 9 kcal/g would add substantially more calories to the daily intake. Except for animal flesh and such plant foods as nuts, the fat content of this diet would undoubtedly be lower than that of most diets consumed in the world today. Based on the preceding calculations, a family of five would require an estimated 200 ha of habitat from which to gather animal and plant food.

This estimate is based on an ideal ecosystem, one containing those wild plants and animals that are most suitable for human consumption. Researchers report that, in fact, modern-day hunter-gatherers need much more than 40 ha per person. For instance, Clark and Haswell (1970) estimate that at least 150 ha of favorable habitat per person is needed to secure an adequate food supply. In a moderately favorable

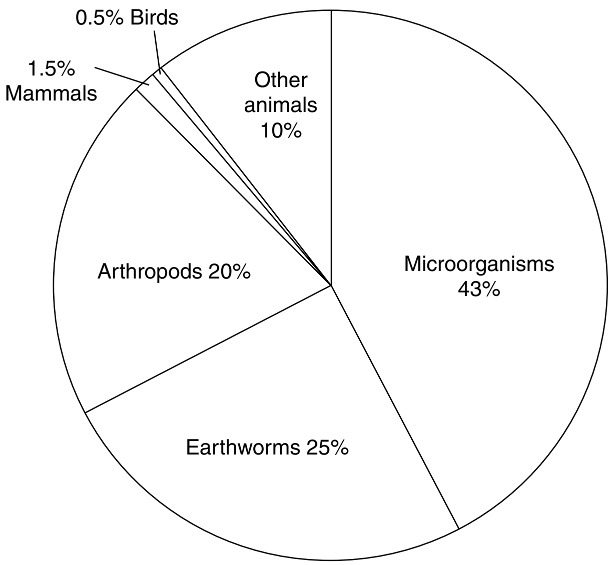

FIGURE 6.1 The proportion of the total biomass of 200 kg (dry) present in 1 ha that is made up of total animals and microorganisms biomass present in 1 ha.

habitat, these scientists estimate that 250 ha per person would be required. These estimates are four to six times greater than those in the model presented earlier.

In marginal environments, such as the cold northwestern Canadian region, each person needs about 14,000 ha to harvest about 912,500 kcal of food energy per year (Clark and Haswell, 1970). The land area may range as high as 50,000 ha per person in subarctic lands, and in these cold regions meat and animal products are the predominant foods in the diet. In fact, animal flesh and fat may constitute up to two-thirds of the food calories consumed.

Plant productivity in such marginal habitats may average only 10–200 kg/ha/year (Whittaker and Likens, 1975), and animal production may average only 1–4 kg/ha/year. The annual yield of meat for humans may average 5–10 g/ha of protein.

Assuming that two-thirds of human calorie intake in such a habitat comes from animal matter, humans could easily consume 77 g of animal protein per day. The plant products consumed might add another 35 g of protein, bringing the total protein intake per day to about 112 g. This is a high-protein diet, but it is not out of the range of population groups that eat high-protein diets today.

HUNTERS AND GATHERERS OF FOOD

Hunter-gatherers probably expend 60–80% of their energy intake in securing food. In fact, obtaining food and collecting firewood for its preparation usually dominate the activities of these societies.

As so much human energy is expended in searching for, collecting, and transporting food, let us consider the energy required by humans for these various

TABLE 6.1
Energy Requirements for Various Activities (kcal/h)

Light Work	kcal/h	Moderate Work	kcal/h
Sitting	19	Shoemaking	80–115
Writing	20	Sweeping	85–110
Standing relaxed	20	Dusting	110
Typing	16–40	Washing	125–215
Typing quickly	55	Charring	80–160
Sewing	30–90	Metal working	120–140
Dressing & undressing	33	Carpentering	150–190
Drawing	40–50	House painting	145–160
Lithography	40–50	Walking	130–240
Violin playing	40–50		
Tailoring	50–85		
Washing dishes	60		
Ironing	60		
Book binding	45–90		
Hard Work	**kcal/h**	**Very Hard Work**	**kcal/h**
Polishing	175	Stonemasonry	350
Joiner work	195	Sawing wood	420
Blacksmithing	275–350	Coal mining (average for shift)	800–1000
Riveting	275	Running	800–1000
Marching	280–400	Climbing	400–900
Cycling	180–600	Walking very quickly	570
Rowing	120–600	Rowing very quickly	1240
Swimming	200–700	Running very quickly	1240
		Walking upstairs	1000

Source: Pyke, M., *Man and Food*, McGraw-Hill, New York, 1970.

activities. The energy expended is above that used for daily basal metabolism, which is about 45 kcal/h or 1080 kcal/day (Pyke, 1970). Walking at a rate of about 4 km (2.5 miles) per hour uses an average of 180 kcal/h (Table 6.1). If the individual carries a load weighing from 9 to 23 kg while walking, the energy expended nearly doubles to about 340 kcal/h. Running at 11–13 km (7–8 miles) per hour uses 800 to 1000 kcal/h. If the hunter-gatherer has to walk or run several kilometers in pursuit of food, the energy expended in food procurement can be relatively large.

Some hunter-gatherer communities exist at a density of 1 person per 15,800 to 31,600 ha (Sahlins, 1972). If only two-thirds of such a population actively hunts and gathers, then each person must search up to 47,900 ha (185 square miles) per year for food. The remaining third of the population, consisting of young children and elderly, usually does little or no hunting and gathering.

If hunter-gatherers were to search 47,900 ha for food, covering 58 meter-wide swaths, then they would have to travel 8316 km per year to cover the entire area. This would require that a person walk 4 km/h for 40 h/week for 52 weeks/year. Obviously, this pace would test the endurance of the hardiest individual; early hunter-gatherers could not work at such a rate, nor can their present-day counterparts.

Hunter-gatherers do not have to search the total area for food. Because they know their territory well, they know approximately where to find food, greatly reducing the distances they have to travel in search of food. However, distant food locations, even if known, would require a long trip. For example, a journey from one side to the other of the hypothetical 47,900 ha area would cover about 22 km. A round trip across this area would require an expenditure of about 1980 kcal.

The !Kung bushmen, who presently inhabit the Dobe area of Botswana, Africa, illustrate the energy economy of a hunter-gatherer society (Lee, 1969; Lee and DeVore, 1976). The population studied consisted of 248 individuals and occupied an area of 2850 km^2. Each person required 10.4 km^2, or 1040 ha, for support. Note that this is much less land than the hunter-gatherers studied by Sahlins occupied—only 3% as much.

The habitat in which the !Kung bushmen live is relatively arid, with an annual rainfall of only 150–250 mm per year (Lee, 1969; Lee and DeVore, 1976; Marshall, 1976). Permanent watering holes, existing only in locations where the underlying limestone strata have been exposed, provide the only reliable supply of water. During the rainy season, water is also readily available at temporary water holes. A critical decision facing the bushmen is where to locate their camps. The location must allow them to obtain both food and water easily. Because water is the major limiting factor, the bushmen usually camp within easy reach of a reliable water source.

The food gathered by the bushmen consists, by weight, of 33% mongongo nuts, 37% meat, and 30% miscellaneous plant foods (Lee, 1969; Marshall, 1976). The nuts yield 1200 kcal/day, meat 768 kcal/day, and other plant foods 172 kcal/day, totaling a daily energy intake of 2140 kcal. This means that mongongo nuts contribute most (56%) of the daily calorie intake of the !Kung bushmen (Figure 6.2).

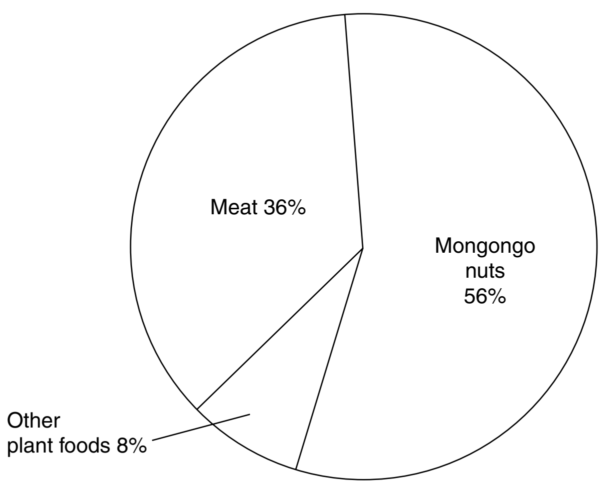

FIGURE 6.2 The percentage of various food types that make up the daily diet of the !Kung bushmen. (From Lee, R.B., *Environment and Cultural Behavior: Ecological Studies in Cultural Anthropology*, Natural History Press, New York, 1969.)

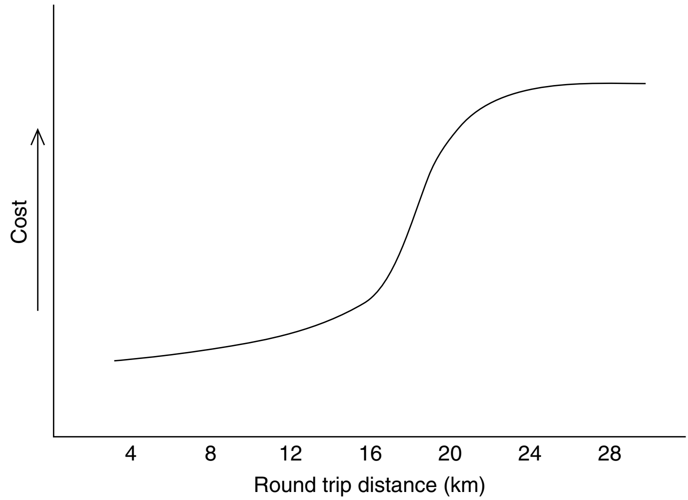

FIGURE 6.3 The energy cost of obtaining mongongo nuts at different distances. (After Lee, R.B., *Environment and Cultural Behavior: Ecological Studies in Cultural Anthropology*, Natural History Press, New York, 1969.)

As one might expect, the bushmen prefer to collect the desirable foods that are closest to a water supply. They occupy a camp for a period of weeks and literally eat their way out of it. For example, they often camp in the nut forests and "exhaust the nuts within a 1.6 km (1 mile) radius during the first week of occupation, within a 3.2 km radius the second week, and within a 4.8 km radius the third week" (Lee, 1969).

The energy cost of obtaining mongongo nuts increases with their distance from camp. The cost curve rises gradually as the distance increases from 3 to 19 km (Figure 6.3). After 19 km, however, the cost curve rises sharply, because the gatherer must make a 2-day round trip. An overnight hike requires the gatherer to carry water and heavier loads during the entire trip.

An alternative to making longer food-gathering trips is to eat less desirable foods that can be found closer to the water holes. During the dry season, when there are fewer water holes, the bushmen use both strategies to maintain their food supplies. During these stress periods, "the older, less mobile members of camp stay close to home and collect the less desirable foods while the younger, more active members make the longer trips to the nut forests" (Lee, 1969).

During the rainy season, when there are many temporary pools of water, camps are located so that both nuts and water are relatively close. During these ideal periods, the gatherers seldom travel more than 9.7 km (6 mi) round trip to collect nuts. The total average energy expenditure for a day that includes nut collecting is about 2680 kcal. This energy expenditure can be broken down by activity, as shown in Table 6.2.

The energy expended to collect nuts gathered at an average distance of 4.8 km and the energy return from nut food can be calculated from the data of Lee (1969). Walking at 4 km/h, it takes about 1.2 h to reach the location of the nuts. Walking expends about 180 kcal/h (Table 6.1), and basal metabolism requires 45 kcal/h, for a

TABLE 6.2
Input/Output Analysis of !Kung Bushmen Gathering Mongongo Nuts at a Distance of 4.8 km from Their Camp

	h	kcal
Inputs		
Travel to location of nuts	1.2	270
Collecting nuts	3	675
Return trip to camp carrying 12.5 kg nuts	1.2	462
Subtotal		1407
Sleep	10.5	473
Other activities	8	800
Total	24	2680
Outputs		
Shelled nuts, 1.75 kg		10,500
Output/input ratio		3.9:1

Source: Based on Lee, R.B., *Environment and Cultural Behavior: Ecological Studies in Cultural Anthropology*, Natural History Press, New York, 1969.

total of 225 kcal/h. Over 1.2 h, the total energy expended is 270 kcal. Collecting nuts for an estimated 3 h at 225 kcal/h burns an estimated 675 kcal.

The return trip to camp at a distance of 4.8 km also takes about 1.2 h. However, carrying a 12.5 kg load of nuts while walking requires more calories—an estimated 385 kcal/h (340 kcal + 45 kcal basal metabolism)—than walking unencumbered does. For 1.2 h, this activity requires 462 kcal.

The bushmen rest and sleep 10.5 h/day, consuming 473 kcal (the basal rate). Postulate that other light activities are carried on for 8 h/day at 100 kcal/h (55 kcal + 45 kcal basal metabolism), or 800 kcal total. This brings the total energy expenditure per day to 2680 kcal.

The 12.5 kg load of nuts contains about 2500 nuts from which about 1.75 kg of nut meat is extracted for consumption. This volume of nut meat yields about 10,500 kcal.

With 2680 kcal expended to obtain 10,500 kcal of nuts, the basic output/input ratio is 3.9:1. Using similar assumptions but with the nuts 9.6 km distant, the output/input ratio declines only slightly, to 3.3:1 (Table 6.3).

These output/input ratios are based on data showing that women collect an average of 2.2 days/week (range 1.2 to 3.2 days) and obtain 23,100 kcal in nuts per week. This amount provides sufficient food calories for the gatherer (14,296) as well as a surplus of about 38%. The surplus is needed to help feed the children and elderly dependents who make up the third of the population that does not gather food.

If hunters and gatherers have to work an average of 2.2 days/week to obtain food, that leaves approximately 4.8 days for other activities. These include gathering

TABLE 6.3
Input/Output Analysis of !Kung Bushmen Gathering Mongongo Nuts at a Distance of 9.6 km from Their Camp

	h	kcal
Inputs		
Travel to location of nuts	2.4	540
Collecting nuts	3	675
Return trip to camp carrying 12.5 kg of nuts	2.4	924
Subtotal		2139
Sleep	10.5	473
Other activities	8	600
Total	24	3212
Outputs		
Nuts shelled, 1.75 kg		10,500
Output/input ratio		3.3:1

Source: Based on Lee, R.B., *Environment and Cultural Behavior: Ecological Studies in Cultural Anthropology*, Natural History Press, New York, 1969.

firewood, moving, constructing shelters and clothing, caring for children, and enjoying leisure time (Lee, 1969; Marshall, 1976). Observations indicate that bushmen value their leisure and enjoy dancing, visiting other camps, and engaging in other social activities.

EARLY AGRICULTURE

Although we have no written account of the evolution of agriculture, we can logically reconstruct what might have happened. No doubt early agriculture evolved slowly from less structured societies of food gatherers. We know that gatherers brought fruits, nuts, vegetables, and seeds, including grains, back to camp for consumption. As expected, some seeds were dropped on the soil in the clearing of the camp and had the opportunity to grow there. Upon returning to the same campsite some time later, the hunter-gatherers discovered a concentration of grains, vegetables, fruits, and nuts. Some of the more observant people probably associated seeds with plants and began to plant seeds themselves. The relative ease of harvesting such crops as opposed to randomly gathering food in nature would encourage more plantings. The trend toward food cultivation is thought to have been slow, with the percentage of the food supply produced from gardens gradually increasing over time.

One important step in the emergence of agriculture was the deliberate removal of existing natural vegetation, including shrubs and trees, which would interfere and compete with crop growth. Burning was the easiest and most common means of clearing the land. Thorough burning not only completely destroyed weeds but also added nutrients to the soil. Following burning, the plots were generally clear except for a few large trees and charred stumps.

Early farmers planted crops by poking holes in the soil with digging sticks and dropping the seeds into the holes. Placing seeds in the cleared ground speeded their germination and subsequent growth, so they could compete more successfully with other vegetation. After being planted, the early crops were given little or no care. A few months or even a year later, the farmers might return to harvest their crop, or what was left of it. Mammals, birds, insects, and disease organisms shared in the harvest, and weed competition reduced yields. Many of these same pest species still reduce crop yields today.

The next step in the development of agriculture was to expand the crop plantings sufficiently to produce most of the food supply. With time, the camps became relatively permanent because an ample food supply existed nearby; men and women no longer had to travel to find food. Living close to the plantings allowed a group to claim ownership and to protect the plantings from other humans as well as from mammals, birds, and other pests.

Early plots were planted and harvested for about 2 years, then abandoned because production declined as nutrients in the soil became depleted and other problems (such as pest outbreaks) developed. Interestingly, this "cut/burn," or "swidden," type of agriculture is still practiced today in many parts of the world (Ruthenberg, 1971). Swidden agriculture requires that farmed land lie fallow for 10 to 20 years before it can be cleared again and farmed. During the long fallow period, the soil gradually accumulates the nutrients needed for successful crop production.

Swidden agriculture can cause severe soil erosion problems, especially when practiced on slopes in large hectarages. Erosion, of course, is a major global problem with all crop production systems, but the damage is intensified when hilly cropland is left without vegetation. Also, if crop residues are harvested and burned, the soil is left unprotected and susceptible to erosion. Thus, there is reason to discourage the burning of crop residues.

A study of a primitive agricultural society in New Guinea provides many insights into the energy inputs and outputs of a Swidden-type agricultural system (Rappaport, 1968, 1971). New Guinea has a tropical mountainous ecosystem with about 3910 mm of rainfall per year. The relatively steep slopes and heavy rainfall combine to make soil erosion a problem. These primitive agriculturalists, however, practice soil conservation by employing several of the conservation techniques previously mentioned.

When the New Guinea community was studied, the village numbered 204 inhabitants and occupied about 830 ha. Only about 364 ha of this land was suitable for cultivation. The village annually planted about 19 ha of crops, but because some crops required 2 years before they could be harvested, about 37 ha were cultivated at any one time. As a result, nearly 90% of the village croplands lay fallow each year.

The villagers' food was almost entirely (99%) of plant origin. The primary plants consumed (by weight) were taro, sweet potato, fruit, leaves, yams, and bananas (Figure 6.4). The animal protein came primarily from pigs raised by the villagers, who also hunted and ate marsupials, snakes, lizards, birds, and insect grubs.

The adult person's diet averaged about 2400 kcal/day and contained about 35 g of protein, mostly of plant origin (Rappaport, 1968). This protein intake is low by current Food and Agriculture Organization (FAO) standards, which recommend a daily intake of about 40 g of protein per day for an adult living under these conditions.

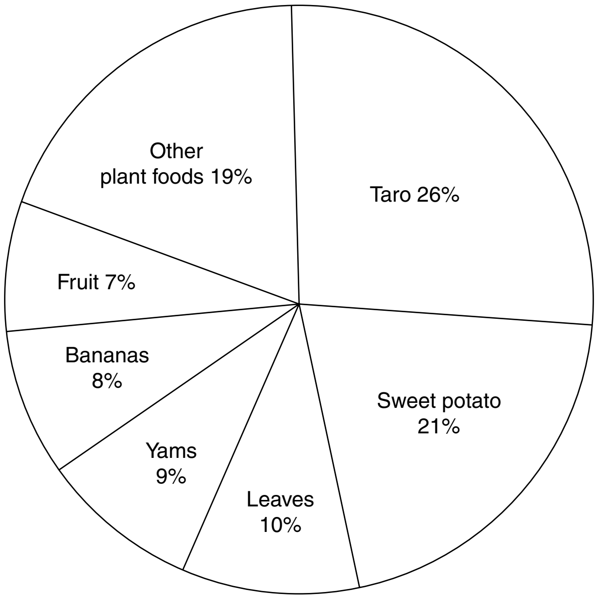

FIGURE 6.4 Percentage of the plant materials consumed by the villagers in New Guinea.

As expected, food production in swidden agriculture is labor intensive. The New Guinea villagers worked an estimated 1869 h/ha/year in crop production (Rappaport, 1968, 1971). About 42% of the labor input went into weeding, 15% into clearing trees and brush (Table 6.4). Another substantial labor input was for transporting the harvest from the garden plots to people's homes. This activity required about 277 h but was often viewed as a pleasure because the villagers took pride in harvesting their crops.

The total energy input to raise 1 ha of crops under the New Guinea agricultural system was about 739,160 kcal (Table 6.4). The crop yield averaged about 11.4 million kcal/ha, resulting in an output/input ratio of 15.4:1 (Rappaport, 1968, 1971).

If we assume an average daily per capita consumption of 2400 kcal, an individual would consume about 876,000 kcal/year. Hence, a 1-ha plot would provide sufficient food energy for 13 persons, and the 37 ha usually cultivated by the villagers would provide more than enough food for the inhabitants. However, the villagers consumed only 55% of the energy value of their crops and fed about 45% to their pigs. When this is taken into account, the ratio of people to land decreases; only 5.5 persons are sustained per hectare planted.

Rappaport (1971) reported that each pig required a total of 4.5 million kcal of feed over a 10-year period. If we assume that about 65 kcal of feed are required to produce 1 kcal of pork (Pimentel et al., 1975), the return from 4.5 million kcal of feed would be 69,230 kcal of pork. This represents only a 1.5% return on the food energy fed to the pigs.

From the 11.4 million kcal/ha harvested, as noted, 45% (5.1 million kcal/ha) was fed to the pigs. If 65 kcal were required to produce 1 kcal of pork, the yield would

TABLE 6.4
Output/Input Analysis of New Guinea Swidden Agriculture for 1 ha of Mixed Crops That Included Sweet Potato, Taro, Cassava, Yam, and Banana

	h/ha	kcal/h	kcal/ha
Inputs			
Clearing underbrush	175	400	70,000
Clearing trees	68	400	27,200
Fencing garden	84	500	42,000
Weeding and burning	78	300	23,400
Placing soil retainers	44	400	17,600
Planting and all weeding	742	300	222,600
Other maintenance	137	400	54,800
Harvesting	277	300	83,100
Cartage	264	400	145,600
Subtotal	1869		686,300
Axe, machete (0.8 kg)[a]			16,860
Seeds, etc. (10 kg)[a]			36,000
Total			739,160
Outputs			
Crop yield			11,384,462
Output/input ratio			15.4:1

[a] Estimated as additional inputs.

Source: After Rappaport, R.A., *Pigs for the Ancestors: Ritual in the Ecology of a New Guinea People*, Yale University Press, New Haven, 1968 and *Scientific American* 225, 116–132, 1971.

be only 78,461 kcal/ha. This 78,461 kcal, added to the 6.3 million kcal consumed directly by humans, provides a total yield of food energy of 6.4 million kcal/ha.

Rappaport (1968, 1971) mentions one advantage to pork production: Keeping pigs was a practical way to store some of the excess food during productive years. When crop harvests were poor, the villagers slaughtered some of the pigs to provide the needed food.

Another study of Swidden-type agriculture was conducted in a village in the Tepoztlan region of Mexico (Lewis, 1951). The manpower input for raising the staple food—corn—was 1144 h/ha, compared with 1869 h in New Guinea (Table 6.5).

Calculations for total energy output/input for this system are listed in Table 6.5. Basic activities directly related to corn production involved an expenditure of 344,800 kcal, with 64,350 kcal expended during rest and 85,800 kcal spent for miscellaneous activities. When the energy costs of the axe, hoe, and seeds are added, the total energy input to raise 1 ha of corn was 548,410 kcal. With a crop yield of 6.8 million kcal, the resulting output/input ratio was 12.6:1. This output/input ratio was only slightly lower than the New Guinea swidden agricultural system, which had a ratio of 15.4:1.

TABLE 6.5
Energy Inputs in Corn Production in Mexico Using Swidden Agriculture

	h/ha	kcal/h	kcal/ha
Inputs			
Clearing with machete and axe	320	400	128,000
Fencing with poles	96	400	38,400
Burning	64	300	19,200
Seeding	96	300	38,400
Reseeding	32	300	9600
Weeding	240	300	72,000
Transporting corn	80	400	3200
Shelling corn	120	300	36,000
Subtotal	1144		344,800
Rest	1430		64,350
Other activities	858		85,800
Axe and hoe (0.8 kg)[a]			16,860
Seeds, etc. (10.4 kg)[a]			36,600
Total			548,410
Outputs			
Crop yield	1944 kg		6,901,200
Output/input ratio			12.6:1

[a] Estimated as additional inputs.

Source: After Lewis, O., *Life in a Mexican Village: Tepostlan Restudied*, University of Illinois Press, Urbana, 1951.

Thus, even primitive societies vary in the energy efficiencies of their methods of securing or producing food. The early hunter-gatherers were probably much like the !Kung bushmen of today, who have an average output/input ratio of about 4:1 under ideal conditions. Somewhat more organized agricultural production systems like those of the villagers in New Guinea and Mexico have more favorable energy ratios of 12 to 15:1. In addition, less land per person is necessary in those systems where increased crop culture is practiced.

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