BANANA PRODUCTION BY KUBO PEOPLE OF THE INTERIOR LOWLANDS OF PAPUA NEW GUINEA

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ABSTRACT

A 15 month study of subsistence agriculture was undertaken at the small Kubo community of Gwaimasi, on the Strickland River, NNW of Nomad, Western Province, Papua New Guinea. Bananas and flour from sago palms were the primary carbohydrate foods of the people. The former were grown at small gardens cut into 15-20 year old secondary forest on river- or stream-side levee banks. Planting density was 1382 plants/hectare. Preparatory work (clearing, collection and transport of suckers, planting and felling trees) occupied 850-900 person-hours/hectare. The gardens were not fenced and 42 percent of the work was in collection and transport of suckers. Males did somewhat more work than females. Bananas were available for eating between 8 and 20 months after planting and the yield was 1313 bunches/hectare (4494 kg edible/hectare). At Gwaimasi village, with a monthly average of 25 residents through a 14 month period, banana production was sufficient to provide at least 50 percent of people's energy needs. Production was variable in time with people shifting between virtual independence of, and full dependence on, bananas. There is no evidence that these shifts were seasonally determined.

Key words: Subsistence agriculture; bananas; tropical lowlands; Kubo; Papua New Guinea

INTRODUCTION

Among the cultivated plant species of Papua New Guinea, McArthur (1972) ranked bananas fourth, after sweet potato, taro and yams, in terms of annual production. Walters (1963; in King *et al.* 1989) considered that the area under bananas was second only to sweet potato and that, nationally, the crop yielded 1 kg/person per day. In the lowlands, bananas are recognised as a primary carbohydrate food in areas where annual rainfall is 1000-2500 mm and a pronounced dry season occurs (Lea 1972; McArthur 1972); they can be also important where annual rainfall is 4000-8000 mm (M. Bourke personal communication).

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There have been few studies of the ecology of banana subsistence within Papua New Guinea. The most detailed recent work concerns the Amele (Madang Province) and Vanapa River-Kabadi (Central Province) areas though, in both these cases, banana production was tied to local market economies (King *et al.* 1989).

In the interior lowlands of the Western Province bananas have been reported as the major carbohydrate food of Betamuni, Gebusi and Samo people (Knauft 1985; Beek 1987; Shaw 1990). In this paper we describe the ecology of banana production by Kubo people whose territory lies to the north and northwest of these three groups (Dwyer *et al.* in press). In 1986-87, Kubo subsistence practices were not influenced by market economies. We report areas under cultivation, planting regimes, work associated with banana gardening and yield patterns and estimate that bananas provided at least half the energy needs of the people.

ENVIRONMENT AND SUBSISTENCE

The Kubo village of Gwaimasi was on the west bank of the Strickland River, 48 km NNW from the District Headquarters at Nomad, Western Province, at an altitude of about 80 m (lat. 5°54'S, 142°6'E). We lived at Gwaimasi from August 1986 to November 1987 and had visited the area in late January 1986. The village was established in February 1986. Thirtyone individuals were classed as residents during all or part of the 450 days we lived at Gwaimasi, with from 24 to 26 residents in any month. Thirteen males older than 14 years accounted for 4782 person-days of residency, 10 females older than 12 years for 3688 person-days, four children between three and 11 years (two males and two females) for 1800 person-days and four nursing infants (three males and one female) for 934 person-days. With nursing infants excluded these values are equivalent to 22.8 full-time residents (i.e. 10270/450) of whom 18.8 are classed as people who worked in gardens.

To satisfy subsistence needs the people used an area of about 50 km^2. This area included forested foothills to the north and east, extensive backswamps to the south and west and levee banks either side of the Strickland River and along major streams. Rainfall was high with 6580 mm recorded from September 1986 to October 1987 and monthly totals varying from 306 to 776 mm (Table 1). Lower rainfall and, particularly, longer runs of days without rain may be usual from September to November though year to year variation is probably high. Monthly mean minimum temperatures varied from 22.6 to 24.0°C and monthly mean maxima from 29.0 to 33.1°C (Table 1). The decline in mean maxima from February to July corresponded to increasing spells of day-long cloud cover and drizzling rain.

Carbohydrate staples were bananas and sago flour, the latter from both wild and planted palms *(Metroxylon sagu).* Primary protein foods were wild pigs, cassowaries and many fish though other animals, including insect larvae reared in felled sago palms, were also important (Dwyer and Minnegal 1991). Some domestic pigs were kept

Table 1. **Rainfall and temperature records from Gwaimasi village (lat.5°54'S, 142°6'E), Western Province, September 1986 to October 1987.**

	Months													
	S	O	N	D	J	F	M	A	M	J	J	A	S	O
Rainfall														
mm	343	329	343	371	776	523	707	635	346	512	306	437	586	366
Temperature (°C)														
min	23.3	23.7	23.4	23.2	23.5	23.2	23.7	23.6	23.7	23.7	22.6	22.9	23.5	24.0
max	33.1	33.0	32.7	33.1	32.1	32.6	32.3	32.1	31.5	30.1	29.0	29.4	31.1	33.0

(maximum population = 13) but these were usually killed and eaten on special occasions only.

Gardens were made on levee banks, usually near the river, sometimes adjoining major streams and, occasionally (one of 39 gardens), on minor rises within the backswamps. Bananas were the dominant crop in larger gardens where they were usually interspersed, at varying densities, with taro *(Colocasia esculenta)*, highland pitpit *(Setaria palmifolia)*, aibika *(Abelmoschus manihot)*, occasional pineapples *(Ananas comosus)* and new plantings of *Pandanus conoideus, Terminalia* and *Artocarpus altilis* (breadfruit). Saplings of *tulip (Gnetum gnemon)* were often left to supply leaves. Most sugar cane, lowland pitpit *(Saccharum edule)* and cassava were planted near the perimeter of banana gardens. In some parts of the gardens, tubers (taro, yams and sweet potato) and a mix of greens, beans and corn were concentrated and there were other small gardens where these crops predominated and bananas were few. Kubo people named 40 varieties of banana plants, all of which appeared to be diploids and some of which were very recent introductions. The collective name for bananas was *e*.

TECHNIQUES

The areas of all gardens that yielded bananas during the time we lived at Gwaimasi, and of all gardens made in this period, were measured using compass and tape. Perimeter zones, from 5-20 m wide, where trees were felled but crops were not planted, were excluded. Mapping was done, where possible, about one month after trees were felled; this facilitated movement around the garden. Nine of the gardens were planted and felled before August 1986; we saw two of these in January 1986 soon after they had been felled and estimated planting times at the others. Gardens are identified consecutively from Garden 1 planted in about January 1985 to Garden 39 planted in November 1987. Garden 9 comprised the area under crops at the village itself; this area altered in size and precise location through time as different families and individuals harvested or planted crops.

Gardens were classed as banana or tuber gardens on the basis of predominant crops. (Two very small non-banana gardens included tubers but were, in fact, dominated by lowland pitpit.) Banana plants were counted at seven plots, amounting to 1.97 ha, within three banana gardens. These counts were made three to four months after planting. Thus, estimates of planting density ignore very early losses but attempts to count bananas soon after planting led to serious underestimation. The numbers of primary (or initial) plants per 100 m^2 were 5.54 (0.23 ha), 12.21 (0.25 ha), 13.18 (0.32 ha), 14.32 (0.74 ha), 15.86 (0.14 ha), 19.26 (0.25 ha) and 28.29 (0.04 ha) with an overall mean of 13.82 plants/100 m^2. The total of 2723 banana plants in these samples included 120 with multiple stems, increasing the total number of stems to 2858. The value of 13.82 plants/100m^2 was used to estimate the numbers of banana plants at other banana gardens; we are satisfied that the extreme values of density were exceptional. At tuber gardens all banana plants were counted.

Productivity data were obtained from eight gardens that were selected to represent different times of planting. At Garden 10 all 35 banana plants were monitored at each census. At other gardens, depending on size, details were recorded from between one and three 30 m transects. All banana plants within 2 m of the transect were included. We recorded diameter of primary stems 50 cm above ground, presence or absence of suckers and the condition of the plant (non-productive, flowering, early or late set, medium or advanced fruit, harvested, or lost through death or collapse). The stem of harvested plants was routinely cut and withered and rotted quite rapidly. At advanced gardens where weeds were well developed, plants that had been harvested months before were detected only on the basis of developing suckers; in a few cases we may have misinterpreted collapsed plants as being harvested.

We estimated labour input in two ways; as hours and as days per unit area. The former included rest periods and travel time on land but excluded travel time on water unless this entailed transport of banana suckers. Movement by dugout canoes to garden sites on the east bank of the Strickland River usually required that the canoe was first bailed and, when travelling upstream, necessitated an arduous haul along the bank against the current. Although the times recorded were all related to gardening they will overestimate actual hours of physical effort. Estimates of effort expressed as days/unit area take six or more hours (travel, work and rest included) as a full day, 4-6 hours as 0.75 days, 2-4 hours as 0.5 days and less than two hours as 0.25 days. Thus, these estimates index times when no other major activity could be undertaken and, in the Kubo context, may index effort more usefully than estimates of actual hours worked. In both sorts of estimates contributions from children less than 11 years old were ignored although very young children were encouraged to acquire skills, older children were expected to assist and young married females (perhaps 12 years of age) worked as adults did.

Table 2 records the distribution of hands of bananas/bunch and of fingers/hand from 58 bunches. Fortyseven of the bunches were sampled at gardens where we obtained productivity data. The criteria for selection were that the plant carrying the bunch was included within a transect, that the fruit were judged to be medium or advanced relative to expected harvesting time, and that the top of the bunch could be reached by hand; this last was usually accomplished by climbing logs that were strewn through the garden. Terminal hands without viable fingers (n = 18 bunches) or with a maximum of two viable fingers (n = 5 bunches) were excluded. The data show much variation in bunch characteristics. The average number of edible fingers/bunch was 49.6 (s = ± 22.3) for the 47 bunches sampled during standard productivity censuses; this value is used in later calculations.

Table 2. **The composition of banana bunches.**

Hands per bunch	Number of bunches	Fingers per hand	
		$\bar{x}$	±s
1	2	10.00	-
2	2	6.50	4.95
3	4	8.42	1.77
4	20	9.28	1.47
5	18	10.62	2.92
6	8	12.11	2.18
7	4	11.71	3.33

Table 3. **Weight (per finger) and proportion edible of 11 varieties of bananas.**

Variety	Type[a]	Sample[b]	Stem[c]	n	Total weight g	±s	Edible weight g	±s	Prop. edible	±s
ma	CS	A	P	18	42.1	18.3	29.8	13.4	0.71	0.03
		B	P	4	52.3	3.6	34.0	2.7	0.65	0.02
oiya	S	A	P	8	49.2	3.2	41.4	2.2	0.84	0.01
		B	P	12	54.4	3.7	45.5	2.7	0.84	0.02
		C	A	4	62.3	4.7	51.5	4.4	0.83	0.02
tisa	CS	A	P	14	48.3	12.3	34.4	7.8	0.72	0.04
		B	P	9	55.8	13.5	39.3	9.6	0.70	0.04
		mixed	P	15	74.2	24.9	53.7	19.7	0.71	0.06
mugua	CS	A	P	4	77.3	6.9	61.3	5.6	0.79	0.02
sosoi	CS	A	P	35	76.1	16.0	57.0	13.4	0.75	0.04
		B	P	8	92.1	7.4	69.9	4.6	0.76	0.04
		C	A	5	139.0	12.6	106.0	7.0	0.77	0.06
		C	P	6	139.8	13.5	104.3	10.0	0.75	0.05
gisio	CS	A	P	6	93.7	28.2	67.0	22.6	0.71	0.03
maiabu	CS	A	P	29	108.5	10.5	77.1	8.1	0.71	0.04
yimo e	CS	A	P	8	122.3	12.3	67.0	7.2	0.55	0.06
kogwai e	CS	A	P	8	127.9	10.3	80.9	7.0	0.63	0.01
tuguwa	CS	A	P	4	194.8	12.9	121.3	7.3	0.62	0.02
		mixed	P	15	195.5	38.7	137.1	27.9	0.69	0.03
		mixed	A	11	200.0	25.8	145.1	21.8	0.72	0.04
		B	P	10	227.4	18.7	154.6	10.9	0.68	0.02
saviti gwage	S	early	P	6	224.2	22.4	153.9	11.0	0.69	0.02
		late	P	5	200.2	16.2	149.3	11.4	0.75	0.01

a. C = cooking banana; S = sweet banana.

b. A, B and C denote seperate bunches, 'mixed' refers to a sample taken from more than one bunch and 'early' and 'late refer to samples taken from the same bunch at different stages of ripening.

c. P = stem of finger present; A = stem of finger absent.

Banana fingers were seldom badly damaged. Of 2362 potentially viable fingers on the 47 bunches referred to above only six were diseased and another 25 had been eaten by rats; our estimates of production accept this level of loss (0.01%). One exceptional case of damage is not included in the estimates of production. At two adjoining plots of Garden 16, 25 percent of potentially viable fingers (n = 425) from 11 bunches had been lost to disease or rats with most of the damage being to four bunches. The record was obtained late in the seventh month after planting. People said that the losses occurred because the garden had not been weeded. We did not see and were never told of damage caused by fruit bats *(Pteropus* and *Dobsonia* species) and presume this reflects the fact that most bananas were harvested for cooking while green and starchy rather than sugary. Fruit bats are recognised as major pests of bananas in other parts of Papua New Guinea and, in some areas, traps are made (e.g. Beek 1987) or ripening bunches are covered to reduce damage (Dwyer, personal observations; King *et al.* 1989).

Major differences in the energy content of bananas have been reported in the literature. King *et al.* (1989) obtained values of 137-180 kcal/100 g edible weight from 10 banana varieties from Madang Province, Papua New Guinea (overall mean 152 kcal/100 g edible). They compared their estimates with eight literature reports that varied from 87 to 128 kcal/100 g edible. An important component of this variation, though not noted by these workers, arises from changes during ripening. Osmotic effects cause water to move from the skin and stem of a banana finger into the pith (von Loesecke 1950). Von Loesecke reported that the edible proportion could increase from 0.62 to 0.74 during 26 days of cool storage from time of harvesting. In parallel with this increase the energy content, when standardized against weight, will decrease. King *et al.* (1989) purchased bananas at local markets and prepared fingers for analysis by peeling with a sharp knife. The bananas were unlikely to have been ripe. Combining von Loesecke's data with that of King *et al.* suggests that a banana finger that increased from 0.62 to 0.74 in edible proportion would drop from 152 to 127 kcal/100 g edible portion.

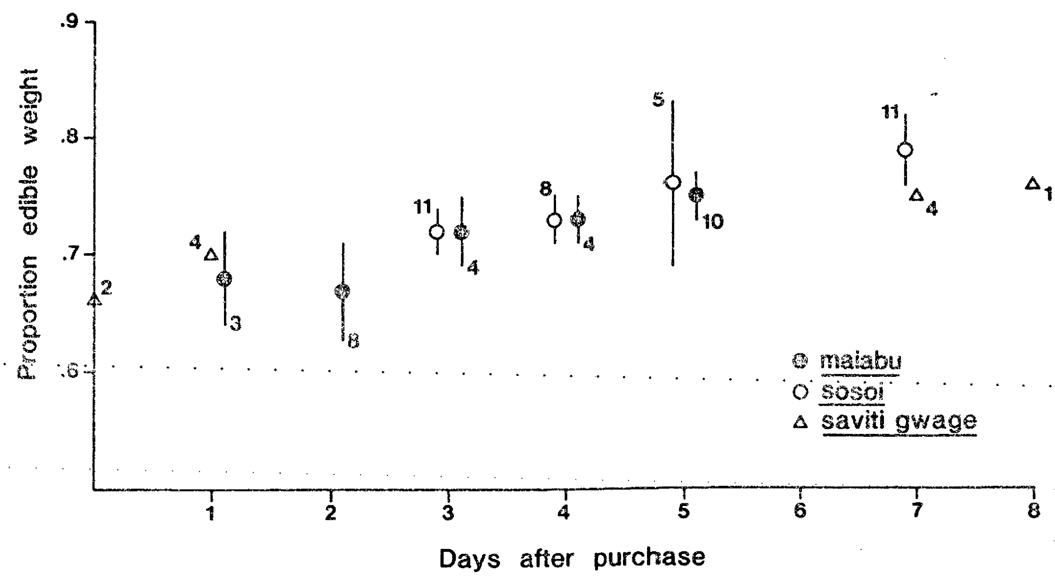

Figure 1. **Changes in the ratio of edible weight to total weight during ripening for fingers of three varieties of bananas.**

Table 3 summarizes data concerning total weight, edible weight and edible proportion of 244 fingers from 11 different Kubo varieties of bananas. These data were obtained from bananas that we purchased to eat. There is much variation in both weight and edible proportion. Edible proportions varied from 0.55 for the variety *yimo e* to 0.84 for the thin-skinned, sweet variety *oiya.* Data from two hands of the one bunch of *saviti gwage* (only one plant at Gwaimasi) and from single bunches of each of the varieties *sosoi* and *maiabu* showed substantial increases in edible proportion through time (Figure 1). Because we favoured ripe bananas and tended to be sold ripening fruit it is necessary to adjust for our behaviour before assigning energy ratings to bananas.

Based on the moisture-laden weight of 75.9 g edible/banana finger (Table 3) we use the range of 100-125 kcal/100 g edible for bananas at the time we ate them. The lower value is probably conservative, the upper value matches our reading of the estimate of King *et al.* (1989). Kubo people ate most bananas after cooking them when the fruit were not ripe and, therefore, before much starch was converted to sugars (cf. von Loesecke 1950). Figure 1 suggests a 10 per cent increment in edible proportion of a banana after five or six days in our larder. Using this value the average weight of a banana as eaten by Kubo would have approximated 69 g and the equivalent range of energy values would be 110-137.5 kcal/100 g edible. Von Loesecke (1950) reported values for total carbohydrate in the edible portion of five banana varieties between 21.51 and 33.02 percent. The highest value was from plantain and is equivalent to a minimum energy value of 130 kcal/100 g.

AREA AND NUMBER OF BANANAS PLANTED

Areas planted in crops are shown in Table 4 for each month from January 1986 to November 1987. Banana and tuber gardens are separated and estimates of the numbers of bananas planted are provided. We left Gwaimasi on November 18, 1987. The values for this month are from one garden where clearing but not planting was completed. Because preliminary clearing is time consuming, it is unlikely that more bananas were planted at new gardens in November.

In 23 months 6.98 ha were planted, 4.87 ha as banana gardens and 2.11 ha as tuber gardens. This is equivalent to 0.16 ha per full-time resident per year, 0.11 ha as banana gardens and 0.05 ha as tuber gardens (nursing infants excluded from the tally of residents). For banana gardens differences between years appear pronounced (0.14 ha and 0.08 ha per resident/year in 1986 and 1987 respectively, though the value from 1987 is based on records from only 11 months).

The 411 banana plants scattered through, or clustered within, tuber gardens would have occupied 0.30 ha if planted at conventional densities. Thus, the total commitment to bananas across 23 months was 7204 plants occupying an equivalent of 5.17 ha (316 plants and 0.23 ha per resident). Sixty percent of the bananas were planted in 1986. The pooled data from 1986 and 1987 reveal that 85 percent of bananas were planted in the months December to March and August.

The mean sizes of garden plots held by individuals or families, and of sets of contiguous plots that were made more or less synchronously, are given in Table 5. Average sizes were greater for banana than for tuber gardens; 2.86 times greater where comparison is based on plots and 4.44 times greater where comparison is based on entire gardens.

WORK AT BANANA GARDENS

The sequence of tasks at banana gardens was *(a)* initial clearing of undergrowth and small saplings, *(b)* collection of suckers from older gardens and their transport to the new site, *(c)* planting, *(d)* tree

Table 4. **Gardens areas (ha) and numbers of bananas planted from January 1986 to November 1987.**

	1986				1987			
Month	Banana garden		Tuber gardens		Banana gardens		Tuber gardens	
	ha	bananas	ha	bananas	ha	bananas	ha	bananas
Jan.	0.74	1021	-	-	-	-	0.05	2
Feb.	0.52[a]	722	-	-	0.62	992	-	-
Mar.	-	-	0.30[b]	34	0.51	736	0.07	26
Apr.	-	-	0.10[b]	17	-	-	0.29	181
May	-	-	-	-	-	-	0.29	52
June	-	-	0.21	35	-	-	0.09	50
July	-	-	-	-	0.18	242	0.10	-
Aug.	0.83	1253	0.08	-	0.28	387	0.02	-
Sept.	-	-	-	-	-	-	0.18	6
Oct.	0.19	263	0.19	6	-	-	-	-
Nov.	-	-	-	-	0.16	221	-	-
Dec.	0.84	956	0.14	2	no data	no data	no data	no data
Totals	3.12	4215	1.02	94	1.75	2578	1.09	317

a. Data from February 1986 exclude 0.30 ha and 419 bananas planted by a family that did not take up residence at Gwaimasi.

b. These areas were the first garden plots established at the village itself. Between August and October 1986 an additional 0.13 ha was planted but no bananas were included. Between November 1986 and November 1987 another 0.06 ha was cleared and planted and about one-third of the area that had been used earlier was replanted; again, no bananas were included. Areas used after mid-1986 are not included in the table; they are equivalent to approximately 0.36 ha of non-banana garden.

Table 5. **The sizes of gardens.**

	Banana gardens	Tuber gardens
Plots held by nuclear families and independent individuals:		
sample	23	16[a]
mean area (ha ±s)	0.20 ± 0.12	0.07 ± 0.05
range (ha)	0.03 - 0.52	0.01 - 0.21
Contiguous plots (pooled areas):		
sample	13	20
mean area (ha ±s)	0.40 ± 0.32	0.09 ± 0.06
range (ha)	0.07 - 1.13	0.01 - 0.21

a. **There were several cases where individual plots within tuber gardens were not identified; thus, sample size here is lower than for the pooled areas from contiguous plots.**

felling, *(e)* weeding and *(f)* harvesting and transport of the crop. Fences were not usually made at banana gardens; the only exceptions were two gardens that included yams and were contiguous with a tuber plot. Only once were banana plants damaged by pigs; this occurred when a domestic sow destroyed 20 of 25 bananas planted near a small house in the forest.

Estimates of labour input for all tasks except fencing and harvesting are summarized in Table 6. Both sets of values - hours and days per hectare - show that much effort was required in garden preparation. From 850 to 900 person-hours or, as opportunity costs, 110 to 120 person-days were occupied in clearing, obtaining and transporting suckers, planting and felling one hectare of garden. These values are equivalent to 120-130 hours or 15.5-17.0 days per worker allocated to the preparation of banana gardens in 12 months (based on 5.17 ha in 23 months and an equivalent of 19 full-time workers).

Clearing and planting occupied about one third of the time allocated to preparation of banana gardens; collection and transport of suckers and felling of trees occupied about two thirds. Clearing entailed fairly thorough removal of undergrowth and slashing of saplings. Most of the work was with machetes and, during this phase, some trees were felled, especially at the garden perimeter beyond the zone of planting. Sucker collection and transport was the most arduous preparatory task. Suckers were dug from gardens that had been planted a minimum of 10 months earlier (usually 12 or more months earlier) where weeds and regrowth might be tall and dense. They were prepared by paring the corm and cutting across the stem to leave a portion 8-12 cm in diameter and 20-30 cm long. Average weight was near one kilogram. A few suckers with intact leaves were nearly always included among those that were planted. Suckers were carried by foot or by canoe to the cleared garden site. Distances varied from a few hundred metres to more than 4 km with most suckers for larger gardens carried more than 1 km. Distances travelled to service one set of contiguous plots where 1727 bananas were planted summed to 89 km by foot unladen, 63 km by foot laden and 28 km by canoe. Use of canoes either on the river or by haulage in streams greatly reduced the work. Very

Table 6. **Labour inputs at banana gardens.**

	Sample			Sample		
Task	no. of plots	ha.	Days/ha[a]	no. of plots	ha.	Hours/ha[a]
Clearing	1	0.17	23.5	1	0.17	155.9
Suckers	3	1.47	40.6-41.7	2	0.34	374.0
Planting	3	0.45	18.3	3	0.45	106.6
Tree felling	6	1.05	34.5-35.5	6	1.05	229.9-238.2
All preparatory tasks[b]	3	1.47	110.8-119.0	1	0.17	851.9-902.9
Weeding	1	0.31	56.5	1	0.31	401.6

a. **A range of values is indicated for some estimates.**

b. **Data from these plots do not separate labour inputs as clearing, transporting suckers, planting and tree felling.**

often the suckers were obtained from other people's gardens.

Planting of banana suckers was relatively quick. There was no soil preparation. A digging stick, made on the site, was used to make and widen a hole in the ground and the sucker was thrust inside. Trees were usually felled immediately the bananas had been planted. Steel axes were used and larger, buttressed, trees were usually felled from flimsy frames that placed the axeman above the level of the buttresses. Because banana gardens were made in advanced second growth forest many trees were relatively large and the work was difficult. The 35.0 person-days (234.1 person-hours) needed to fell 1 ha of banana garden contrasts with an estimate of 21.3 person-days (124.7 person-hours; sample 0.20 ha) needed to fell 1 ha of tuber garden; the latter gardens were made in younger regrowth.

Ideally, portions of banana gardens where taro had been planted relatively densely were thoroughly weeded in about the fourth month after planting and areas where taro were absent or few were weeded in the sixth or seventh month after planting. Delays beyond these times seriously reduced taro yields and promoted the chance of damage by rats to fruiting bananas. Again, ideally, weeding of taro and bananas was maintained until about the twelfth month after planting by which time the taro harvest was effectively over and banana productivity was at a peak. A garden might be older than one year before much weeding - in fact, slash clearing - was done in fringe areas where sugar and lowland pitpit were concentrated. At Gwaimasi few people adhered to these ideals. Most people did weed taro in the fourth month after planting but many did little subsequent weeding; the cost to them was probably reduced yields in the later phase of the harvest period, after about 8 months. Some people did little or no weeding among banana plants, or delayed the task until the ninth month when the harvest was underway. Often they merely slashed back higher weeds to improve access and did not maintain the work. Again, the cost would be in the later phase of the harvest period, after about 15 months from planting.

The magnitude of differences among garden owners in their enthusiasm for weeding, combined with the intermittent nature of the work, meant we obtained few quantitative records. Details are available from a 0.31 ha garden that was very thoroughly weeded in the fifth month after planting (Table 6). The effort entailed was both considerable and exceptional. The work was done on behalf of a married couple who had been absent for one month awaiting the birth of their child and, with most village residents contributing to the task, the occasion was as much social as it was necessary. At Gwaimasi, few people made this sort of commitment and we doubt that the average for all weeding would match the value recorded from the one episode shown in Table 6.

One other maintenance activity was performed, with varying consistency, by banana gardeners. This was removal of the bell (or male bud) from the bunch after all bananas had set. (This act may increase final bunch weight; Johns and Stevenson 1979). The task was accomplished easily when people were weeding or harvesting and, hence, opportunity costs were probably negligible. Groups that weeded their bananas most thoroughly were also most likely to cut the bell from the bunch, doing so when the fruit were well established. The frequency with which the bell was cut was highest in the ninth month after planting (>50% of bunches with medium or advanced fruit) and was low after the twelfth month (<10% of bunches with medium or advanced fruit). Kubo do not eat the bell of banana bunches though, elsewhere in Papua New Guinea, it is sometimes cooked and eaten (cf. Womersley 1972; May 1984). Trashing was not done and propping stems was uncommon. Suckers were not thinned except as required for establishing new gardens. Because suckers were often obtained from gardens that had been planted about one year earlier, and from plants that had not yet produced, there was probably an incidental gain in weight to bunches carried by these mother plants (e.g. Heenan 1973).

We lack specific data concerning harvesting. A one hectare banana garden yields 1313 bunches of bananas (see below). At Gwaimasi most bunches were carried from the garden to the village for consumption either intact or, less often, as separated hands. Average bunch weight was about 5.5 kg and average round-trip distance was about 1.20 km. A minimum estimate, based on three bunches per load and 3 km per hour, would be 180 person-hours to harvest 1 ha but actual cost would have been higher because relatively few loads included three bunches.

Males and females contributed in different ways to gardening tasks and, additionally, assistance with work at other people's gardens was common. Table 7 summarizes relevant data; these are from nine different sets of contiguous banana garden plots. On a per-person basis the estimates in this table, and in Table 8, slightly overstate the contribution of males because males comprised 56 percent of the available work force (4782 of 8470 person-days). An individual is classed as an 'owner' for work done at any plot within a contiguous set where he or she held a plot. Thus, the data overstate the contributions of true owners. In one exceptional case, true owners contributed only 1.5 person-days to the preparatory tasks at a 0.14 ha plot which, in total, required about 16 person-days effort. Note also that the ratio of visitors to residents at Gwaimasi (excluding absences by residents beyond the local subsistence area) was approximately 0.23:1.

Males did all tree felling in banana gardens and contributed more than females to the collection and, especially, transport of suckers; they did somewhat less clearing and much less planting and weeding than females. Assistance was most common with the labour-intensive tasks of transporting suckers

Table 7. **Gender roles and assistance at banana gardens.**

	Garden task				
	clearing	suckers	planting	felling	weeding
Sample: no. of person days	24.25	62.75	32.25	51.75	41.75
proportion by males	0.46	0.62	0.29	1.00	0.33
proportion by 'owners'	0.81	0.59	0.74	0.45	0.57
proportion by assistants:					
residents	0.19	0.41	0.26	0.47	0.40
visitors	-	-	-	0.08	0.03

and felling trees. Indeed, owners contributed less than assistants to felling trees and, with this task, visitors as well as residents were likely to help. Assistance with felling trees was sometimes actively solicited, even between communities. Most assistance with clearing and planting was from females (0.95 and 0.88 of 4.5 and 8 days respectively) and, with sucker transport, from males (0.64 of 25.5 days). The pooled data of Table 7 mask variation between gardens. Less assistance was forthcoming at small gardens than at larger ones, and when bachelors initiated gardens that were not part of a contiguous set of plots they were likely to do nearly all clearing and planting themselves.

The values of Table 7 and the estimates of labour input in Table 6 are combined in Table 8 to arrive at approximations of the total work done by males and females, owners and assistants. Males did more work than females in the preparatory phases of gardening but females contributed much more to weeding. Assistance at gardens amounted to a minimum of 40 percent of all work though little of this was with clearing or planting. One bachelor ratio-

Table 8. **Labour inputs at banana gardens (days/ha) by males and females, and by 'owners' and assistants.**

Task	Totaldays/ha	Males	Females	'Owners'	Assistants
Clearing	23.5	10.8	12.7	19.0	4.5
Suckers	41.1	25.5	15.6	24.2	16.9
Planting	18.3	5.3	13.0	13.5	4.8
Tree felling	35.0	35.0	-	15.8	19.2
Weeding	56.5	18.6	37.9	32.2	24.3
Totals	174.4	95.2	79.2	104.7	69.7

nalized the amount of weeding done by women by asserting that "women who have pigs should keep watch over gardens".

Most harvesting was done by owners or their appointed agents and the work was shared by males and females. Females contributed more than males to day to day harvesting needs but, if a large harvest was due, then males did most of the work.

Because females living near the Strickland River did not paddle canoes, all work at gardens east of the river required some male participation. It is probable that males contributed more to all tasks at

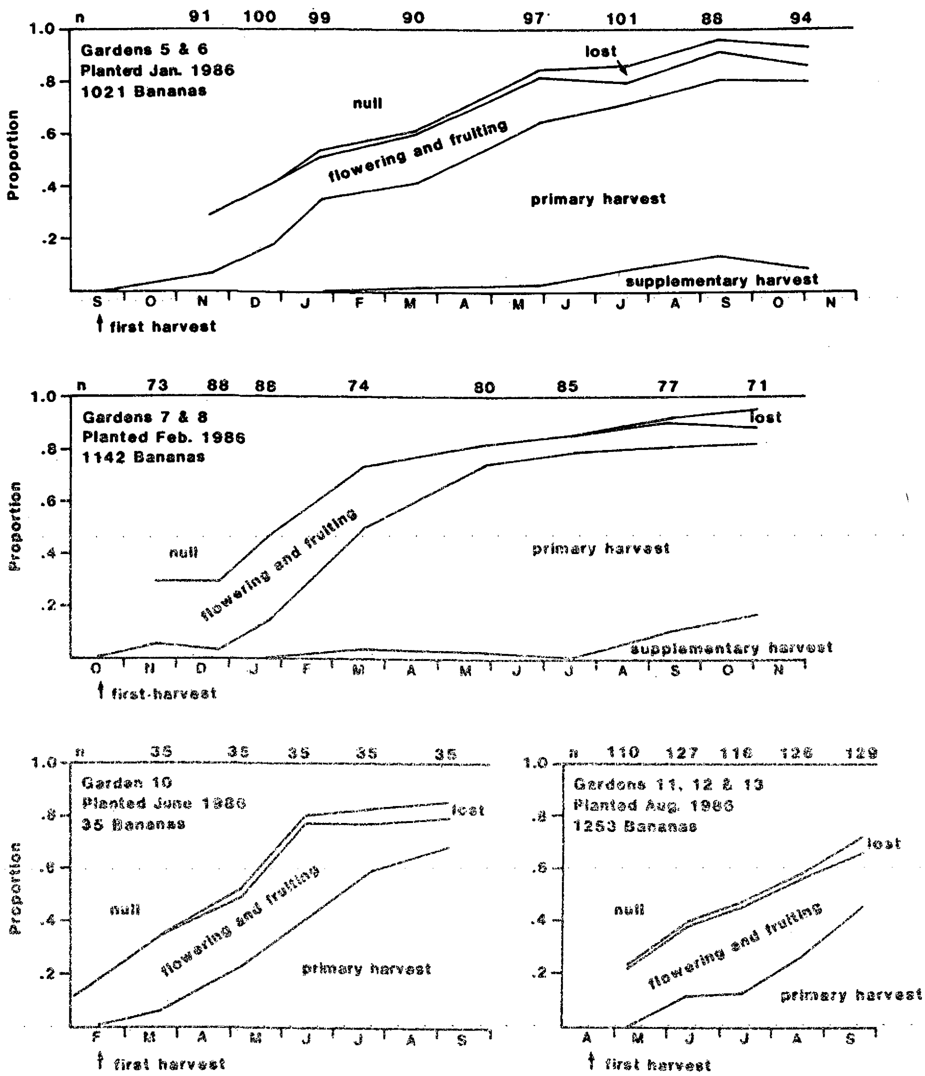

Figure 2. **Yield patterns of bananas from eight gardens. For each garden, or set of gardens, the figure records the month of planting, the number of bananas planted, sample sizes and the proportions of plants in these samples that were non-productive (i.e. null), collapsed or dead (i.e. lost), bore flowers or carried fruit (i.e. flowering and fruiting) or had been harvested. The 'supplementary harvest' is additional to the primary harvest and derived from multiple-stemmed plants and daughter suckers.**

these gardens than was the case for gardens west of the river. (Values in Tables 7 and 8 are biased by estimates from west-side gardens). East-side family gardens had not produced bananas by the time we left Gwaimasi but, unless the families concerned relocated to the east, the burden of harvesting would have fallen almost entirely to males. Larger banana harvests from west-bank gardens were often made by men using canoes.

YIELDS

Yield data from eight gardens are summarized on *Figure 2*. Data from gardens planted in the same month are pooled and, for each garden or set of gardens, the plots of Figure 2 commence in the eighth month after planting. It was in the latter half of this month that the first harvest of bananas could be expected. This was not confirmed at any of the gardens depicted on Figure 2 but was confirmed at two other gardens.

The depicted patterns are similar. About 5 percent of plants were lost because they died or were blown down. Flowering was underway as early as six and a half months after planting, and from the ninth to fourteenth months, between 20 and 30 percent of bananas were either flowering or carrying fruit. Thereafter, this proportion dropped rapidly to about 5 percent. Banana production was well underway by the eleventh month post-planting and continued at a high rate until the fifteenth month. After this time the rate of production from primary suckers was greatly reduced but a brief supplementary harvest, from multiple-stemmed and secondary suckers, commenced. (In the case of multiple-stemmed plants 'supplementary harvest' refers to second and subsequent bunches from the one set of stems.) After nineteen months the yield was effectively over. By the close of this month, 82 percent of initial plantings had produced a bunch of bananas and the supplementary harvest amounted to 13 percent of the number of suckers that had been planted. The average density of banana plants was equivalent to 1382 plants per hectare. Thus, the expected yield of bananas is 1133 bunches from primary suckers and an additional 180 bunches as supplementary harvest. This is equivalent to more than 7500 kg bunch weight or 4494 kg edible weight (at time of harvest) per hectare.

Little harvesting occurred at banana gardens beyond the twentieth month after planting. By this time the garden was difficult to traverse, walking tracks that once passed through it had been rerouted around it, and the banana plants were overgrown by a tangle of weeds, vines and regrowth and were often withered and dying. But we think that if maintenance had been sustained the yield would have persisted longer. People abandoned banana gardens because access became difficult and this happened because they ceased maintaining the gardens. At several very advanced gardens we saw bunches of ripening and of rotting fruit. Sometimes when people visited these sites for other purposes - to harvest lowland pitpit, obtain banana suckers, tend groves of fruit pandanus or fish nearby - they would eat bananas. Often they discarded most of the bunch because quality was poor and they did not carry these bananas to the village. Run-down gardens were fit for an occasional snack but were not visited with the expectation of a useful harvest.

For cases where data from two or three gardens were pooled in *Figure 2*, chi square comparisons within sample periods revealed differences in yield profiles in only one case; the harvested proportions recorded in samples from Gardens 7 and 8 were significantly different in January 1987. Further, there were no significant differences in yield profiles between gardens or sets of gardens of the same age since planting. Nor was there any difference between a yield profile obtained by pooling data from gardens planted in January and February (Gardens 5-8) with a profile from gardens planted in August (Gardens 11-13). In 1986-87 these times represented climatically distinct periods; they followed and preceded the months when rainfall was lowest.

Figure 3 combines data from all eight censused gardens to construct an ideal yield profile. The curve shows the cumulative yield from time of planting. Data after the twelfth month from planting have been bracketed as two-month blocks to smooth sample differences between Gardens 5 and 6 on the one hand and Gardens 7 and 8 on the other. The figure was used to construct a yield profile from all gardens (pooled) and it is this that is the basis of analyses of availability and consumption of bananas in the following sections.

AVAILABILITY OF BANANAS

Estimates of the numbers of bunches of bananas produced each month from January 1986 to December 1988 are given in *Figure 4.* These estimates are from all gardens made in the vicinity of Gwaimasi between January 1985 and November 1987. They are based on the ideal yield profile of Figure 3 with adjustments made for cases where bananas were known to be planted either early or late in a particular month. Gardens 1 to 4 were planted in 1985 and estimates of the numbers of bananas planted are approximations only.

The longhouse at Gwaimasi was built during February and March 1986. Before this time the residential base of the people who eventually lived at Gwaimasi was Sesanabi, 8 km northwest of Gwaimasi, and well outside the area used once Gwaimasi was established. By March or April 1986 Gwaimasi residents had effectively abandoned gardens associated with Sesanabi. From this time, until late 1986, when gardens planted in January and February 1986 were productive, the people were dependent upon sago starch. In December

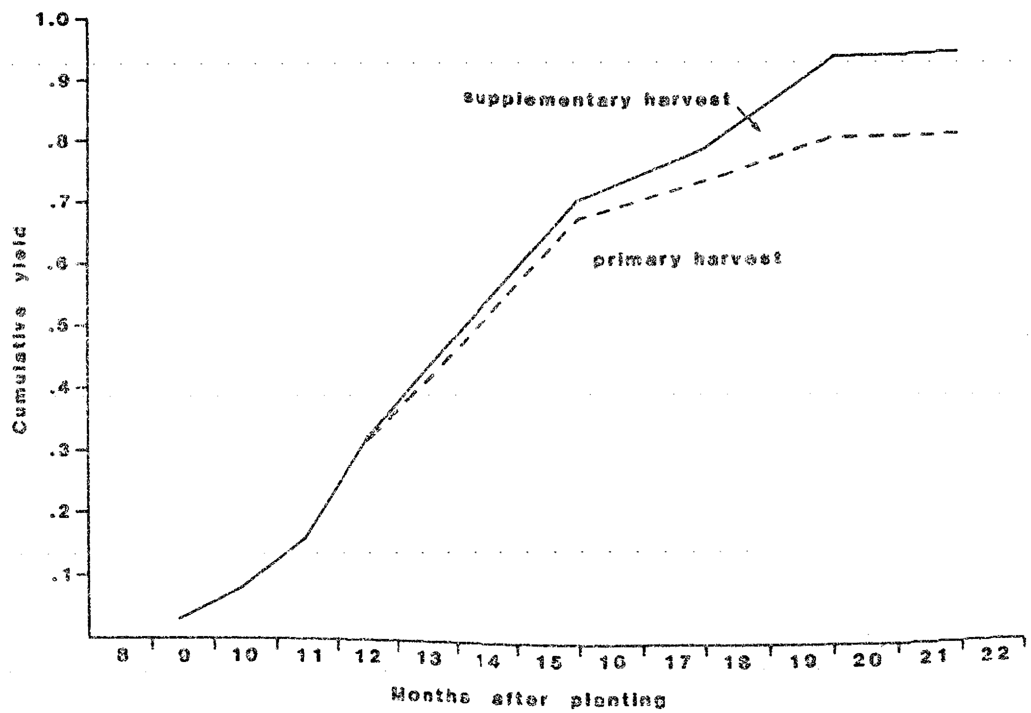

Figure 3. **An idealized yield profile for bananas. Yield is represented as a proportion of the number of bananas planted. The 'supplementary harvest' is derived from multiple-stemmed plants and daughter suckers.**

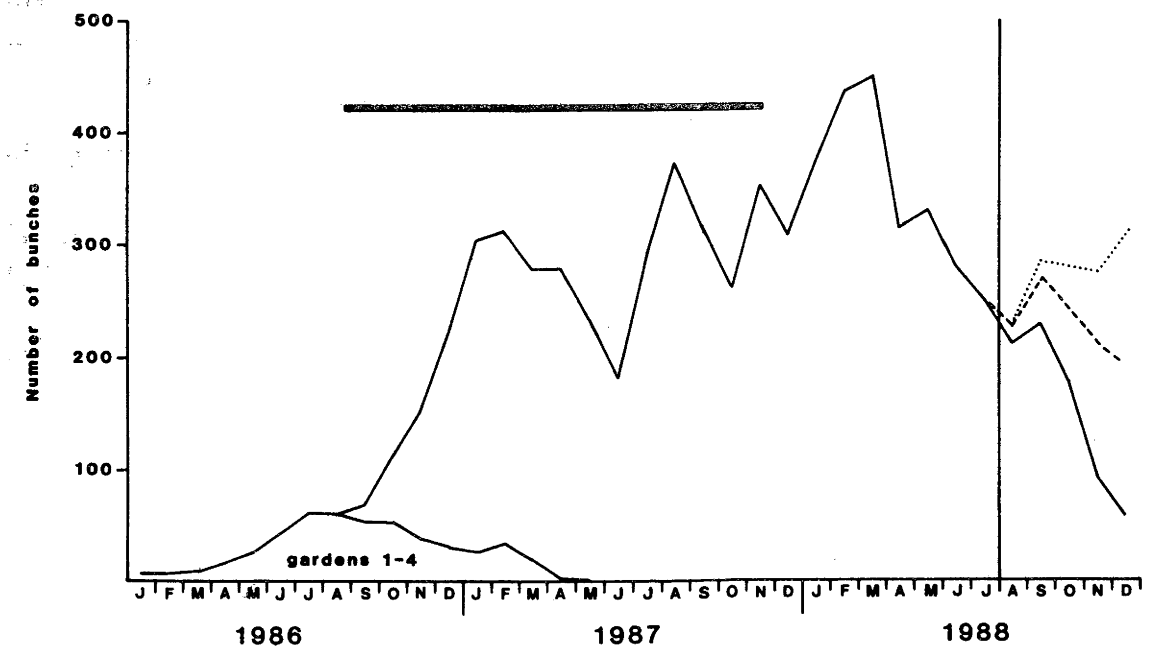

Figure 4. **Total production of bananas (bunches/month) at Gwaimasi from January 1986 to July 1988. Estimates from Gardens 1-4 are less reliable than those from gardens that were planted later. The study period is represented by a bar. Outcomes of planting (a) 1000 bananas in December 1987 (dashed line) and (b) 1000 bananas in each of December 1987 and January 1988 (dotted line) are indicated.**

1986 local gardens yielded 220 bunches of bananas and, thereafter, until July 1988, the yield fell below this level in only one month (June 1987). From mid-1986 until early 1988 the month to month yield oscillated but trended consistently upward to peak at an expected 450 bunches in March 1988. Thereafter, production from gardens we measured would fall dramatically. Until July 1988 (with an expected yield of 250 bunches) this fall could not be reversed but, if large scale planting occurred in December 1987, after we departed, further decline could have been avoided (i.e. gardens planted in December 1987 would produce bananas from August 1988). The figure records outcomes of planting (a) 1000 bananas in December 1987 and (b) 1000 bananas in both December 1987 and January 1988. Clearly, to maintain banana production at the 1987 level would have required much effort in the months immediately following our departure. Through the 29 months from March 1986 to July 1988 average production was 231 bunches per month (s = ±131 bunches) with a range from 8.5 to 450 bunches per month.

CONSUMPTION OF BANANAS

We did not directly investigate the consumption of bananas. The following analysis assumes that (a) Figure 4 represents month to month availability of banana bunches, (b) all harvested bananas were eaten and (c) sharing resulted in an even distribution of available bananas among actual consumers.

Table 9. **Monthly availability of bananas, September 1986 to October 1987.**

Month	Consumer-days (C)[a]			Bunches of bananas (B)			kcal/C[c]
	residents	visitors	total	total	adjusted[b]	B/C	
1986							
Sept.	616.2	67.1[d]	683.3	67.1	61.9	0.09	339-424
Oct.	584.4	173.8	758.2	110.8	103.2	0.14	527-659
Nov.	621.4	144.6	766.1	151.6	137.4	0.18	678-847
Dec.	545.8	71.7	617.5	219.8	191.6	0.31	1167-1459
1987							
Jan.	532.4	294.9	827.3	303.5	284.5	0.34	1280-1600
Feb.	492.4	23.6	516.0	312.8	288.5	0.56	2108-2635
Mar.	538.4	113.3	651.7	278.3	261.2	0.40	1506-1882
Apr.	542.6	88.4	631.0	279.6	265.3	0.42	1581-1976
May	532.8	132.7	665.5	235.1	218.4	0.33	1242-1553
June	474.2	221.1	695.3	182.1	165.6	0.24	904-1129
July	498.0	145.3	643.3	292.0	267.9	0.42	1581-1976
Aug.	601.0	131.2	732.2	370.3	339.2	0.46	1732-2165
Sept.	567.2	98.0	665.2	311.0	284.0	0.43	1619-2023
Oct.	580.8	71.8	652.6	261.6	240.4	0.37	1393-1741
	7727.6	1777.6	9505.2	3384.2	3109.1	0.33	1242-1553

a. Residency values for children under the age of approximately 12 years were weighted (see text).

b. Adjustments have been made for bananas eaten by domestic pigs and the authors.

c. Estimates of energy are based on mean values of 49.6 fingers per bunch of bananas and 75.9 g edible per ripe (moisture-laden) finger and a range from 100 to 125 kcal/100 g edible (see 'Techniques').

d. Minimum estimate.

In broad terms these assumptions fit our impressions. The number of actual consumers on any day was taken as all individuals (residents and visitors) who slept that night at Gwaimasi village or within the subsistence zone associated with Gwaimasi. Residency values for children were weighted such that one 2-4 year old was taken as 0.5 units, one 6-8 year old was taken as 0.7 units and two 9-11 year olds were each taken as 0.8 units. Nursing infants were excluded. (Comparable adjustments were made for visitors who were less than about 12 years old.)

Month to month estimates of banana bunches per consumer day and of calorific returns per consumer-day are summarized in Table 9 for the months September 1986 to October 1987. Through this period the mean return per day was equivalent to 0.33 bunches per adult consumer. A conservative estimate of the mean calorific return is 1242 kcal/day to each adult consumer but the value of 1553 kcal/day may be more realistic. Recommended daily intakes for males of Kubo stature (assuming a moderate activity regime) are of the order of 2500 kcal/day. At Gwaimasi, adult females, taken collectively, were either pregnant or lactating during 54 percent of their aggregated months of residency and, hence, average daily requirements for females may have approached those for males. Thus, even the conservative estimate of calorific returns from bananas suggests that from September 1986 to October 1987 people could have derived half their energy needs from bananas. Monthly variability in the availability of bananas to consumers was high with a range from 0.09 to 0.56 bunches per consumer-day. Thus, at a minimum, this food supplied from as little as 14 to as much as 85 percent of energy needs a month.

Between September 1986 and October 1987 the mean monthly total of consumer-days was 678.9; despite high mobility variance was not extreme (s = ± 75.8). Using this average value for March to August 1986 (before our arrival) and November 1987 to July 1988 (after our departure) gives mean values, respectively, of 0.05 and 0.51 bunches/consumer-day. If 678.9 consumers need 224 bunches (678.9 x 0.33) to meet half their energy needs, then from March to August 1986 bananas were of minor importance in the diet of Gwaimasi people (2-14% of monthly energy needs) and from November 1987 to July 1988 they were of major importance (56-100% of monthly energy needs; see Fig. 4). Pooling values for all 29 months (March 1986 to July 1988) and, again, using 678.9 consumer-days per month where data are missing, gives an overall mean of 0.33 bunches/consumer-day. All these values are, of course, crude approximations to what was possible. But they reveal that the people at Gwaimasi had the capacity to move back and forth between virtual independence of, and full dependence on, bananas as their primary carbohydrate source.

DISCUSSION

Kubo agriculture was non-intensive. Small gardens were cut into secondary forest that, in the case of banana gardens, had been fallowed for not less than 15 years. Different varieties of bananas and, usually, a mix of other crops were interplanted.

Bananas commenced yielding in the eighth month after planting and were most productive from 12 to 15 months. Planting densities averaged 1382 plants/hectare and the expected yield was 1313 bunches or 4494 kg edible (about 7500 kg as bunch weight) per hectare. All was available from eight to 20 months after planting and we estimated that from September 1986 to October 1987 bananas provided at least 50 percent of the energy requirements of the people. They contributed more to diet at Gwaimasi than they did in the seasonally dry environments at Kaiapit (Morobe Province, 30% by weight; Langley 1950) and Oriomo Plateau (Western Province, seasonal maximum 26% of energy; Ohtsuka 1983). At Gwaimasi people shifted between virtual independence of, and full dependence on, bananas but this variation in yield was not seasonal. In 1986-87, at Gwaimasi, most bananas were planted at intervals of roughly six months (Table 4). At nearby communities we knew of relatively large banana gardens that were planted in December-January, between late May and mid-July and in August. Shaw (1990) reported that among Samo, who live immediately south of Kubo, most bananas were planted from June to August. Though these records are few that suggest that in this region of Papua New Guinea the period from September to November may be least suited to planting bananas.

Relative to residents of Gwaimasi, people of the Amele area (Madang Province) ate about one third the quantity of bananas. King *et al.* (1989) estimated that in this area banana yields were about 5573 kg (bunch weight)/hectare. In South America the Bari (Columbian-Venezuelan border) produced about 4260 kg (bunch weight)/hectare per year (Beckerman 1983). These estimates were based on planting densities of 1030 and 770 bananas/hectare, respectively, and, thus, relative to planting density, match the Gwaimasi estimate. Compared to the wide range of values reported from Papua New Guinean sweet potato gardens these estimates of banana production are on the low side (Rappaport 1968; Waddell 1972; Hide 1981; Sillitoe 1983; Hide *et al.* 1984; Bourke 1985).

At Gwaimasi the work required to prepare a banana garden - clearing, sucker collection and transport, planting and felling trees - was 850-900 person-hours or 110-120 person-days per hectare. These gardens were not fenced and so this commitment appears high. For example, Clarke's (1971) estimate of the labour in preparatory tasks at the fenced tuber gardens of Bomagai-Angoiang Maring (Madang Province) was approximately 625 person-hours/hectare. Given that this value excluded travel and rest times it is probably similar to the Gwaimasi estimate. In the Bomagai-Angoiang case planting (36%) and fencing (34%) were the most demanding tasks; at Gwaimasi banana gardens the collection and transport of suckers occupied 42 percent of preparatory person-hours. Chagnon (1983) was also impressed by the work entailed in transporting banana (=plantain) suckers when Yanomamo (Venezuelan-Brazilian border) established new gardens at a distance.

Total commitment for all work at Gwaimasi banana gardens may have exceeded 185 person-days (or 1400 person-hours) per hectare. Using these values return for effort from banana gardening was 24.3 kg edible/person-day or 3.2 kg edible (3520-4400 kcal)/person-hour. Allowing that our estimates of hours worked included periods of rest, energetic efficiency may be in the range of 10-15:1, near the mode of the range of values reported from a variety of subsistence agricultural systems (e.g. Ellen 1982).

At Gwaimasi, banana gardens were virtually abandoned 20 months after planting. By this time weeds and early regrowth were well developed and remaining banana plants were in poor condition. Thus, the people obtained a single, staggered harvest and then shifted attention to another garden site. This behaviour has not been described among subsistence people who depend upon bananas as a staple food though it may be a correlate of growing bananas in regions of high, year-round rainfall. It is more usual that some weeding is maintained, that suckers are thinned and that daughter plants are promoted *in situ* or replanted within the same garden. In the Markham Valley of Papua New Guinea banana gardens, planted with dry-adapted triploid varieties, may continue producing for more than 10 years (King *et al.* 1989). Among the Yanomamo, Hames (1983) reported that plantain gardens were maintained until a third harvest after which the yield dropped. There was a small increment in yield from the first to the third harvest that resulted from a "near-doubling of plants" after each harvest combined with a substantial decrease in the size of bunches from suckers that had been separated from the mother plant. Hames' report implied that Yanomamo banana gardens exhibited discrete harvest periods. Chagnon (1983), however, wrote that "there is no peak harvest period, for plantains, if planted in the proper fashion, are ripening all year long". Oriomo Papuans (Western Province) also continued to harvest bananas from gardens that had been planted three or four years earlier (Ohtsuka 1983).

When the life of a banana garden can be extended, felling of trees and transport of suckers are needed less often and, presumably, efficiency may be increased. The abandonment of gardens by tropical agriculturalists is commonly discussed in terms of costs arising from increased growth of weeds, decreased soil nutrients, or both (e.g. Chagnon 1983; Hames 1983). In North Queensland (Australia), where rainfall is high but seasonal, commercial banana growers plant on alluvial flats and maintain the gardens for only three to five years (Cull 1987; E. Gall, personal communication). This contrasts with the 10-15 year life of commercial banana gardens in southeastern Queensland. The relatively brief lifespan of the northern gardens is, in large part, a consequence of reduced productivity in response to increased infestations of root and corm nematodes (E. Gall, personal communication). Depletion rates for both nitrogen and potassium are also high. The long fallow period accepted as necessary by Kubo implies that restoration of soil nutrients was needed before a site could be reused. It may be that the combination of high temperatures and very high rainfall characteristic of the region promoted both parasite load and excessive weed growth as it exacerbated nutrient loss. More detailed research is needed to enlarge understanding of both the successes of, and limits to, banana production in this region of year-round high rainfall.

ACKNOWLEDGEMENTS

P.D. thanks the University of Queensland for granting consecutive periods of leave, the Biology Department, University of Papua New Guinea, for affiliation and the Government of Papua New Guinea for permission to conduct the research. We were assisted in different ways by John and Celia Fletcher, Eric Gall, Jack Greenwood, Fay Marsack, Matt and Jeanne Minnegal, Su Solomon and Jeffrey Willmer. Michael Bourke and Robin Hide commented on the manuscript, Lynn Pryor prepared the figures and Jan Mehaffey did the typing. The people of Gwaimasi, both residents and visitors, were exuberant and exhausting in their care of us. We thank them all.

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