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Estimates of Food Crop Production in Papua New Guinea

R.M. Bourke and V. Vlassak

THE AUSTRALIAN NATIONAL UNIVERSITY

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Cover photo captions

Front cover

Top. Edible corms of swamp taro and coconut in a carry basket on a canoe, Mortlock Island, Bougainville Province. Swamp taro is a very minor crop in PNG. The main type of taro grown in PNG (*Colocasia* taro) was formerly more important, but production has not expanded as the population has grown. The various types of taro account for eight per cent of the food energy from the staple food crops. Coconut is widely grown and eaten in the PNG lowlands. It accounts for three per cent of the food energy from the staple food crops.

Middle. Sweet potato at different stages of growth planted in composted mounds, Tari Basin, Southern Highlands. Sweet potato is by far the most important food crop grown in PNG and accounts for 63 per cent of the food energy from the staple food crops grown in PNG. Both production and the relative importance of sweet potato have increased greatly over the past 40 years.

Bottom. A woman pounds the pith of a split sago palm log to extract its starch, Buka Island, Bougainville Province. Sago is an important staple food in a number of locations where there are extensive wetlands, particularly in East Sepik, Sandaun, Western and Gulf provinces. Sago accounts for seven per cent of the food energy from the staple food crops.

Back cover

Top. Yams in a storehouse, Milne Bay Province. Yams are the only root or tuber crop which can be stored successfully for more than a few days after harvest in PNG. The various types of yam account for five per cent of the food energy from the staple food crops.

Middle. Banana fruit being transported by canoe down the Tauri River, Gulf Province. Banana is grown in many locations in PNG and is an important staple food in some locations. Banana accounts for seven per cent of the food energy from the staple food crops.

Bottom. Fresh food market, West New Britain. Foods in this image include sweet potato and Chinese taro, both important foods in this area. Marketing fresh food is an important economic activity for many people in PNG and about 75 per cent of the rural population live in a household where income is derived from selling fresh food.

All photos by Mike Bourke except for the aerial view of sweet potato mounds, which was taken by Bryant Allen.

Summary

Estimates of the quantity of food produced in Papua New Guinea (PNG) are important for planning and research. Information contained in the Mapping Agricultural Systems of PNG database of the proportion of land devoted to various food crops allows new estimates to be made. To calculate annual production for each staple crop, estimates of the proportion of garden area devoted to each crop for each agricultural system were combined with census data on the rural population in 2000 (4.3 million rural villagers), mean garden area planted per person per year and mean crop yield for that environment. These data allow estimates to be made for banana, cassava, coconut, potato, Queensland arrowroot, rice, sago, sweet potato, and various taro and yam species. Total annual staple crop production is estimated as 4.5 million tonnes (1050 kg/person/year), with an energy value of 4.3×10^{12} kilocalories (2770 kcal/person/day). It would require an additional 1.2 million tonnes per year of imported rice to replace the energy value of these staple foods, with a retail value of K2850 million.

Sweet potato accounts for almost two-thirds (64%) of production of staple food crops by weight and 63% by food energy. No other staple in PNG contributes more than 10% by weight or food energy. The contribution by weight for the more important foods is: banana (9.7%), cassava (6.0%), yam (6.0%), Chinese taro (*Xanthosoma*) (5.0%), *Colocasia* taro (5.0%), coconut (2.2%) and sago (1.8%). The proportions of food energy produced by these crops are similar to their values for weight. Sago, coconut and rice are exceptions; their proportions of food energy are greater than their contribution by weight. The significance of the various staples varies between provinces in the lowlands, but sweet potato dominates production in the highlands.

An independent check of the production figures is made by calculating the energy in the food grown in representative agricultural systems and for all provinces. The energy needs from staple foods of the human population are compared with the available energy. Estimates of production and human needs are very similar for lowland agricultural systems and for provinces where most systems are in the lowlands. For highland provinces, production is 47% greater on average than the estimated human requirements. This is expected and consistent with the large domestic pig populations which are fed significant amounts of sweet potato. These figures suggest that about one third of all sweet potato tubers are fed to pigs in the central highland valleys, or about one quarter of all sweet potato production in PNG. Average sweet potato production per person for all PNG is 670 kg/year, with about 500 kg of this produced for people and the remainder for pig consumption.

The figures generated here are compared with estimates made as part of the Survey of Indigenous Agriculture conducted in 1961–1962, with data generated from the 1996 PNG Household Survey, and with figures published annually by the Food and Agriculture Organization of the United Nations. The most important difference between the surveys is that the new estimate for sweet potato production is more than twice that made in the first two surveys. A major change over the past 40 years has been the increased significance of crops of New World origin, that is, cassava, potato, sweet potato and Chinese taro. In contrast, production of staple crops of Asia-Pacific origin (banana, sago, taro and yam) has either decreased or is similar in magnitude to that of 40 years ago.

1. Introduction

Knowledge of the volume of crops grown in a country and where they are grown is basic information for development and research planning. This data can also be used to generate a better figure of the value of food for a country's Gross Domestic Product. Here we present estimates of production levels of staple foods grown in Papua New Guinea (PNG). Estimates of the value of all cash crops in PNG, including locally grown food, betel nut, fish and firewood, have previously been derived. These are based on extensive fieldwork conducted from 1990 to 1995 as part of the Mapping Agricultural Systems of PNG Project (MASP). A summary of the main findings is given by Allen et al. (2001).

It would be an extremely difficult and expensive task to actually record production for all staple food crops for representative sample locations in PNG. This is because the physical environment varies greatly, often over short distances, and hence crop yield and area planted per year also vary between locations. Such a survey would have to be conducted over an extended period because of the progressive planting and harvesting system used for most staple crops. This would increase the cost greatly and it is unlikely that sufficient human and financial resources could be found to conduct such a survey. However, it is possible to make estimates of production using some average values for crop yield and garden area; and with information on proportion of land devoted to each crop that is contained in the MASP database.

Two previous nationwide estimates of staple food crop production have been made in PNG. These were the Survey of Indigenous Agriculture in 1961–1962 (Walters 1963) and the Papua New Guinea Household Survey in 1996 (Gibson and Rozelle 1998; Gibson 2001a). Given the population growth and changes in the main crops grown over the past 40 years, it is anticipated that significant changes have occurred since the first estimates were made. The Food and Agriculture Organization of the United Nations also publishes production estimates for PNG every year (for example, FAO 2004), apparently based on an annual extrapolation from the 1961–1962 survey.

Over the six-year period 1990 to 1995, village agriculture was described in detail in the Mapping Agricultural Systems of PNG Project (Allen et al. 1995a; Allen et al. 1995b; Bourke et al. 1998). Field visits were made to all inhabited parts of PNG to develop this database. All land used for village agriculture in PNG was allocated to an agricultural system. An agricultural system was delineated to include land where six important aspects of agriculture were more-or-less homogeneous. The parameters used to define the 342 agricultural systems were: the most important food crops grown; type of fallow vegetation; the fallow period; the number of consecutive crops planted before land is fallowed; soil fertility maintenance techniques other than natural fallows; and garden and crop segregation. (In practice, the last-named parameter was rarely used to define a system. Sources of cash income were considered in borderline cases).

Some agricultural systems were divided into two or three subsystems where significant differences in the criteria to delineate systems existed, but the differences could not be mapped at the scale used (1:500,000). For each agricultural system in the MASP database, the staple crops were classed as dominant (33% or more of garden area), subdominant (10–32%), or present (2–9%).

Estimates of annual production for each staple crop for each agricultural system were generated by estimating the proportion of garden area devoted to each crop and combining

these figures with the 2000 population census data, mean garden area planted per person per year and mean crop yield for that environment. Each factor used in the equation contains potential errors. However, crosschecking of the method shows that the estimated total quantity of food produced in a number of agricultural systems is within ± 15% of an independent estimate of the energy requirements of the population for each system in the lowlands. For highlands locations, the estimates of food produced are generally greater than the human population's needs. This is consistent with the fact that a high proportion of all sweet potato production in the highlands is fed to domestic pigs (Hide 2003). This semi-independent crosscheck increases confidence in the validity of the final estimates and is discussed below.

The available data allows estimates to be made for banana, cassava, coconut, potato, Queensland arrowroot, rice, sago, sweet potato, and various taro and yam species. A number of other crops are moderately important food sources in PNG. These foods include sugar cane; peanuts; maize (corn); and various fruits and nuts, including breadfruit, Polynesian chestnut, *galip* nut, *karuka* nut, *okari* nut and *marita* pandanus fruit. It is not possible to estimate their production because the MASP database does not contain estimates of the area occupied by these crops. They are generally interplanted with root crops or cultivated outside fields.

The crop production estimates generated here include all food produced for both human and domestic animal consumption. The latter is mainly sweet potato grown for pigs in the central highlands. For most foods, only a very small proportion of production is intended for sale and this can be ignored as it is smaller than other potential errors. In some places, villagers obtain a significant proportion of their food needs through trade with people from nearby locations. In these situations, the calculations assume that the food was produced by the people who consumed it.

The current exercise was done by Mike Bourke, with database management by Veerle Vlassak. Laura Vallee set up the original database. Bryant Allen, Matthew Allen and John Gibson commented on a first draft of this paper. Tracy Harwood edited the final draft and prepared it for publication.

2. Methods

The estimated annual production was calculated using the following equation:

$$AP = Pop \times S \times A \times G \times Y$$

Where:

- AP = Annual production for each staple crop for each agricultural subsystem (tonnes/year)
- Pop = Rural population in 2000
- S = Subsystem extent
- A = Mean garden area planted (ha/person/year)
- G = Proportion of garden area planted with each staple crop
- Y = Mean crop yield for that environment (tonnes/ha)

Notes are now given on each of these factors.

Rural population. The rural population in 2000 was generated from the 2000 census figures. (See Table 1 for the rural population by province in PNG). Once the geo-referenced census points were made available in 2003, the Land Management Group allocated each census unit in the 2000 census to an agricultural system. This was not a simple task as there were a lot of changes in the names and locations of census units (village names) between the 1980, 1990 and 2000 censuses. In the 2000 census, the rural non-village census units (such as village schools and plantations) were not identified. We removed the population of census units which appeared to be for rural non-village locations from the total population of agricultural systems. The total village population in each agricultural system was then calculated. The rural village population in PNG in mid 2000 was 4,296,334 people (Table 1), which was 83% of the national population.

Subsystem extent. Where there is only one subsystem, it is allocated a value of 1. Where there are two or three subsystems, the proportion of the entire system occupied by a given subsystem is calculated, for example, 0.75.

Mean garden area planted. The mean garden area planted per person per year is a mean derived from selected published recordings of the area of food garden planted per person per year. Not all published figures are used, firstly because some of the earlier published figures are clearly inaccurate. For example, Schindler (1952) presents figures from which it is possible to calculate that people were planting a garden area of 2500 m^2/person/year for an Eastern Highlands village in the late 1940s. Working in the same village 30 years later, Bourke (1988) recorded the actual areas planted by members of ten households every month over a three and a half year period. His mean figure was 1065 m^2/person/year, which is similar to estimates or recordings from other highlands villages, and less than half Schindler's figure. The second reason why only selected published figures were used is that it is likely that the mean garden area per person has declined somewhat in recent decades as villagers can now depend on purchased food when there is a shortfall in their own production. Until the advent of cash cropping, they had to plant more garden area each year as insurance against a shortfall. Macewan (1978) gives a summary of previous studies on garden area planted per person until the mid 1970s.

In the absence of qualifying factors, the mean garden area planted is taken as 0.08 ha/person/year for the lowlands (up to 1200 m altitude) and 0.09 ha/person/year for locations above 1200 m altitude. For agricultural systems where a significant proportion of food is obtained from purchased imported food, a lower figure (such as 0.07 ha/person/year) was used. There is less reliable data for the lowlands, but the available figures indicate that the area planted per person tends to be less than in the highlands. This is probably because significant amounts of sweet potato are fed to domestic pigs in the highlands.

Proportion of garden area planted. The proportion of garden area planted with each staple crop is derived from the MASP database. In that database, staples were classed as dominant, that is, occupying 33% or more of garden area, subdominant (10–32%), or present (2–9%).

Rules were established so that numerical data could be generated from the class data. Initially, dummy values were assigned to each crop based on certain 'rules'. For example, 35% was assigned to a dominant staple where there were two dominant staples; and 15% where there were two subdominant staples. These values were adjusted up or down depending on additional information in the notes section of the database, the senior author's extensive field

observations in PNG, and other information on the relative importance of each staple crop. For each subsystem, the values were further adjusted so that the total was 100%.

Mean crop yield. The mean crop yield for each agricultural system is based on mean yields from village surveys (Table 2). These were assembled from published literature and unpublished records. There are numerous recordings for sweet potato; a limited number for banana, taro, yam and cassava; and none or very few for the minor crops.

For sweet potato in the highlands, 17 published estimates of village yield exist which appear to be reasonably reliable (Bourke 1985). The mean of these figures is 15 tonnes/ha. For the other root crops and banana, the figure used here is derived from all available published and unpublished village and experimental yields. The last-named were mostly made by staff of the Department of Agriculture and Livestock and the National Agricultural Research Institute. These yield recordings are located in many publications and files and the full sources are not listed here. For a few crops, many of the records have been assembled in one publication: in particular, for sweet potato by Bourke (1985), and for cassava in a workshop proceedings in which yields for most experiments are given (Grant et al. 2004).

Where there are no recordings of village yields, the estimate for village production was taken as 75% of mean experiment station yields. The figures for sweet potato and taro are probably reasonable estimates of village yield. The other figures are less reliable. The figures given are annual yield for perennials such as banana and Chinese taro. For the annual crops, figures are taken as yield per year, even though crop duration may be less than a year. This is because the total time for land preparation, crop growth and harvest for the root crops approximates to one year in PNG. The figures used (Table 2) are for total tuber or corm yield for the root crops and the bunch weight for banana.

The estimated mean yields in the literature are derived from the mixed cropping systems that are used in PNG. Thus the small depression in the yield per hectare for each individual crop in a mixed planting system is accounted for in these figures.

Sago production

Sago is not grown in food gardens, but planted or self-sown palms are felled to manufacture sago starch. A different formula was required to estimate annual sago production for human consumption, as follows:

$$AP = Pop \times S \times E \times Y$$

Where:

AP = Annual production for each agricultural subsystem (tonnes/year)
Pop = Rural population in 2000
S = Subsystem extent
E = Proportion of food energy derived from sago
Y = Mean production of sago (tonnes/person/year)

The proportion of food energy is derived from the MASP field estimate and is a surrogate for proportion of garden area, that is, dominant, subdominant or present.

The mean production was calculated as 0.232 tonnes/person/year. This is the estimated consumption/production of sago if the only energy source from staple crops was sago (as dry sago starch). Mean production was derived from the following equation:

$$Y = C \times E/S$$

Where:

Y = Mean production of sago (tonnes/person/year)
C = Mean energy consumption per year (2665 kcal/person/day × 365 days/year)
E = Proportion of energy derived from the staple foods (85%)
S = Energy value of sago starch (3570 kcal/kg)

The mean energy consumption of 2665 kilocalories per person per day in PNG follows Gibson (2001b), and is similar to the mean value of the recommended daily energy intake of 2600 kcal/day for moderately active 'reference' men and women (WHO 1979:30). The proportion of food energy derived from staple foods (85%) is the mean of ten values in the literature for locations where sweet potato is the dominant staple food (Bourke 1985:92). It is similar to recordings from sago-producing areas. For example, in Kukipi village in Malalua area of Gulf Province, Morauta (1982) calculated that staple food crops provided 90% of the energy derived from locally grown or gathered foods. The energy content of sago (3570 kcal/kg) and other crops follows Leung et al. (1972).

The formula described above generates a figure for production and consumption of sago for humans, but does not include the minor amount of sago starch that is fed to pigs. This is a minor discrepancy compared with other potential sources of error.

Coconut production

As with sago, coconut is not grown in food gardens and a different formula was required to estimate coconut consumption. Production for copra and unharvested nuts was not considered here. The following equation was used to estimate coconut production for fresh food:

$$AP = Pop \times S \times E \times Y$$

Where:

AP = Annual production for each agricultural subsystem (tonnes/year)
Pop = Rural population in 2000
S = Subsystem extent
E = Proportion of food energy derived from coconut
Y = Mean production of coconut (tonnes/person/year)

The proportion of food energy is derived from the MASP field estimate and is a surrogate for proportion of garden area, that is, dominant or subdominant. Where coconut was estimated to contribute less than 10% of energy consumption (classed as present only), no estimate was made for that agricultural system. The mean production for entire (unhusked) mature coconuts was calculated as 0.551 tonnes/person/year. Mean production was derived from the following equation:

$$Y = C \times E/S$$

Where:

Y = Mean production of coconut (tonnes/person/year)
C = Mean energy consumption per year (2665 kcal/person/day × 365 days/year)

E = Proportion of energy derived from the staple foods (85%)
S = Energy value of coconut (1500 kcal/kg)

3. Sources of error and limitations to use of estimates

There are a number of sources of error in the factors used to generate these estimates.

Rural population. We believe that the 2000 census provides reasonably accurate data on the population in mid 2000. The figures for the five highlands provinces, especially Southern Highlands Province, seem to be less accurate. This assessment is based on a comparison of intercensal growth rates with those for previous intercensal periods. Despite the apparent problems with the Southern Highlands Province figures, we are confident that the census data is fairly sound.

Mean garden area planted per year. The mean figures used for garden area planted are likely to be reasonably accurate estimates for the means for the lowlands and highlands. However, there is likely to be considerable variation about these means for individual locations. This would result in only minor errors in the provincial or national level figures, but larger errors at the agricultural system level. The recordings on which these figures are based were mostly done in the period 1960 to 1990. If pig numbers per person have declined in the highlands since then, the garden area per person is also likely to have decreased in the highlands.

Proportion of garden area planted. The estimates for the proportion of garden area planted with different crops are based on the MASP database. The fieldwork for this database was conducted from 1990 to 1995. Since then, a number of independent checks have been made in various locations on the accuracy of the data by members of the Land Management Group (other than the person who did the initial field survey) and staff of the PNG National Agricultural Research Institute. These checks have shown that the classification of crops grown is generally accurate and has not changed significantly over the 5–10 year period since the data were recorded.

Despite the conversion of class data to numerical values, the figures used for proportion of garden area planted are likely to be a good estimate of the actual proportions for each agricultural system, and to contain fewer errors than the figures for mean garden area per person and mean yield per hectare for each crop. Estimates of the proportions for the minor crops are less reliable than for the more important food crops.

Mean crop yield. The figures used here for mean crop yield are likely to be reasonably accurate estimates for the means for the lowlands and highlands for the major crops. There is considerable variation about these means for individual locations, but this is not likely to result in major errors for the provincial or national level figures. There are no available village yield recordings for the minor crops such as Queensland arrowroot and the minor taro and yam species, hence the yield figures are approximate only. Because production of these minor crops is negligible, this will not have any impact on the broader estimates.

Limitations to use of estimates. *It is important to note that the estimates of energy produced at the level of agricultural system or province can* **not** *be used to establish that food production in a particular location is deficient or particularly abundant.*

This is because mean yield and garden area figures were used for all locations in the highlands and lowlands, and the figures were not varied for particular places. In practice, it is known that people in some locations produce food surplus to their requirements while those in others have a minimum surplus and are consequently more vulnerable to variation in subsistence food supply. So for any given agricultural system, the food produced may be greater or less than the estimates at this level.

A semi-independent check (see page 12) establishes that, at both the agricultural system and provincial levels, the figures for food produced appear to be close to the expected food requirements of the human population. But it is not possible to conclude from these figures that production at a particular place is significantly greater or less than the human population energy requirements.

4. Production estimates

National-level production estimates and the food energy content of this production are given in Table 3 and Figures 1 and 2. Total staple crop production is estimated as 4.5 million tonnes/year, with a food energy of 4.3×10^{12} kilocalories (Table 3). This is equivalent to 1050 kg of staple food crops per person per year with food energy of 2770 kcal/person/day. Note that other foods such as meat, fish, fruit, vegetables, nuts, and imported food also provide some energy to villagers. A significant amount of sweet potato produced in the highlands is fed to domestic pigs. Thus this figure for energy production is not directly comparable with human energy needs.

The dominance of sweet potato in PNG food production is clear from the figures in Table 3. Sweet potato accounts for almost two-thirds (64%) of production of staple food crops by weight and 63% by food energy production (Table 3). These proportions are similar to the proportion of PNG rural villagers who grow sweet potato as their most important crop, either by itself or with one other crop (61%) (Allen et al. 2001). These results are consistent with those of the 1996 PNG Household Survey where sweet potato was found to contribute as much energy as the combined contribution of banana, sago, sugar cane and all other root and tuber crops for rural Papua New Guineans (Gibson 2001a).

Average sweet potato production for all rural villagers is calculated as 670 kg/person/year. Seventy-five per cent of sweet potato is grown in highlands locations (above 1200 m) and the remainder in the lowlands. A similar proportion of the total is grown within the administrative boundaries of the five highlands provinces of Southern Highlands, Enga, Western Highlands, Simbu and Eastern Highlands.

No other staple in PNG contributes more than 10% by weight or food energy. The contribution by weight for the more important foods is: banana (9.7%), cassava (6.0%), yam (6.0%), Chinese taro (5.0%), *Colocasia* taro (5.1%), coconut (2.2%) and sago (1.8%). A number of minor crops contribute a very small amount to production, with locally grown rice responsible for about 0.01 of total production of staple food crops in PNG (Table 3).

The proportions of food energy are similar to those for production by weight. However, the contribution to food energy is greater for sago (6.8% of energy produced from staples), coconut (3.5%) and rice (0.03%). This is because these foods have a higher energy value per unit weight than banana or the root crops (Table 3).

Estimates at the provincial level for banana, cassava, coconut, potato, Queensland arrowroot, rice, sago and sweet potato are given in Table 4, and for five species of taro and five species of yam in Table 5.

Banana is grown in all parts of PNG up to its altitudinal limit at about 2200 m.[1] Production is greatest in Morobe, East New Britain, Central and Madang provinces (Table 4).

Cassava is also grown in many locations in PNG, up to 1800 m. Production is greatest in Milne Bay Province, where it is commonly planted with sweet potato after taro and yam have been harvested, and in West New Britain Province.

Coconut is grown in all coastal locations and many inland locations up to about 1000 m altitude. The figures generated here are for nuts consumed by villagers only and do not include nuts consumed by pigs or for copra production. Significant quantities of coconut are fed to pigs (Hide 2003:58–61) or used to produce copra in some coastal locations. The highest consumption of coconut by people is in East Sepik, Madang, Milne Bay, Bougainville and East New Britain (Table 4).

Irish potato is grown for sale at altitudes above about 1500 m in the highlands, but is usually only significant as a subsistence food at higher altitudes (above 2000 m). The figures generated here are for subsistence consumption, but almost certainly include some produce that is sold in distant (mostly urban) markets. As well, some growers produce significant quantities of potato mainly for sale, but their production is not included here. Irish potato is the only staple food crop in PNG where a significant proportion of production is sold in food markets or in distant urban locations. Production is greatest at high altitude locations in Enga Province (Table 4). In early 2003 potato production in PNG was severely affected by Potato Late Blight disease, which is caused by a fungal infection. It is likely that potato production in 2004 is much less than the estimates here because of the impact of this disease.

Very small quantities of rice are grown for local consumption in a number of lowlands provinces. Only in Bougainville did production exceed a few hundred tonnes per year in the mid 1990s, although rice production on Bougainville had virtually ceased by late 2002 (Bourke and Betitis 2003). Plantings in PNG have increased since the early to mid 1990s when the observations on crops grown were made. It is likely that annual production is now somewhat greater than the figures presented here, but total production is still unlikely to exceed 0.03% of total staple production in PNG.

Sago (*Metroxylon sagu*) is grown and eaten in all provinces in PNG, except East New Britain, up to an altitude of 1200 m. The greatest production occurs in parts of East Sepik, Sandaun, Western and Gulf provinces (Table 4). A different species, *M. solomonense*, is grown and eaten on Bougainville.

Sweet potato is grown in almost every agricultural system in PNG, with some minor exceptions in East Sepik and Western provinces, and is the only staple food grown in all locations. Production is greatest in the five highlands provinces (Southern Highlands, Eastern Highlands, Western Highlands, Enga and Simbu), but significant production occurs in all lowlands provinces as well (Table 4).

[1] Information on crop altitudinal limits in PNG in this paper is from Bourke (1978).

Taro (*taro tru* or *Colocasia* taro) is grown in most locations in PNG, but often as only a minor crop. It was formerly the most important staple food in much of the lowlands, and probably was the most important food in the highlands before sweet potato was adopted about 300 years ago. Production is greatest in Madang, East Sepik and Morobe provinces (Table 5). Chinese taro (*Xanthosoma*) is most important in Morobe, Madang, East New Britain and West New Britain provinces (Table 5).

Yam is grown in all provinces in PNG and is an important staple food in some locations. Five species are grown, but three of these are minor. The lesser Asian yam (*mami* or *taitu*) (*Dioscorea esculenta*) accounts for 66% of yam production, and the greater Asian yam (*D. alata*) for most of the rest. The greater Asian yam bears at up to 1900 m, whereas the lesser Asian yam is uncommon above about 900 m. The greatest production of yam, especially the lesser Asian yam, occurs in East Sepik Province. There is also significant yam production in Madang and Milne Bay provinces (Table 5).

5. Value of staple foods

The estimates in this paper allow a kina value to be allocated to staple food crops grown in PNG. This can be done by calculating the value of grain that would have to be imported to feed the population if all production of staple crops ceased.

Rice is the major grain imported. The brand 'Roots'[2] sold by Trukai Industries accounts for almost 90% of sales, and the 1 kg pack is the most popular packaging size. 'Roots' rice is made up of mixed quality grain, with a high proportion of broken grain that other markets will not accept. It was introduced into PNG in 1998 following the devaluation of the PNG currency and consequent marked increase in the price of 'Calrose' rice from Australia, marketed as 'Trukai' in PNG. Since 1998, sales of 'Roots' rice have expanded so that it is now the most significant rice brand in PNG. (The foregoing is mostly based on conversations with D. Ormsby and N. Whitecross, Trukai Industries, Port Moresby at various dates between 1997 and 2002).

The quantity of rice required to replace all PNG staple food crops can be calculated using the following equation:

$$RE = EV/EV_{rice}$$

Where:

RE = Quantity of rice equivalent in energy value to staple food crops (tonnes)
EV = Energy value of all staple food crops (4346.16×10^9 kcal)
EV_{rice} = Energy value of polished rice (3660×10^3 kcal/tonne)

This quantity of rice equivalent is 1,187,475 tonnes of rice. This is in addition to the existing rice imports, which averaged 149,000 tonnes for the three-year period 2001–2003 (Brett Schofield, pers. comm., April 2004). The retail price for 'Roots' rice in all centres was K2.40/kg in April 2004. Thus the rice needed to substitute for locally grown staple food crops has a retail value of K2850 million and a wholesale value of K2730 million. This confirms the

[2] The name 'Roots' is derived from 'grass-roots', that is, the ordinary people. This name was made famous by a popular cartoonist in the 1970s and 1980s.

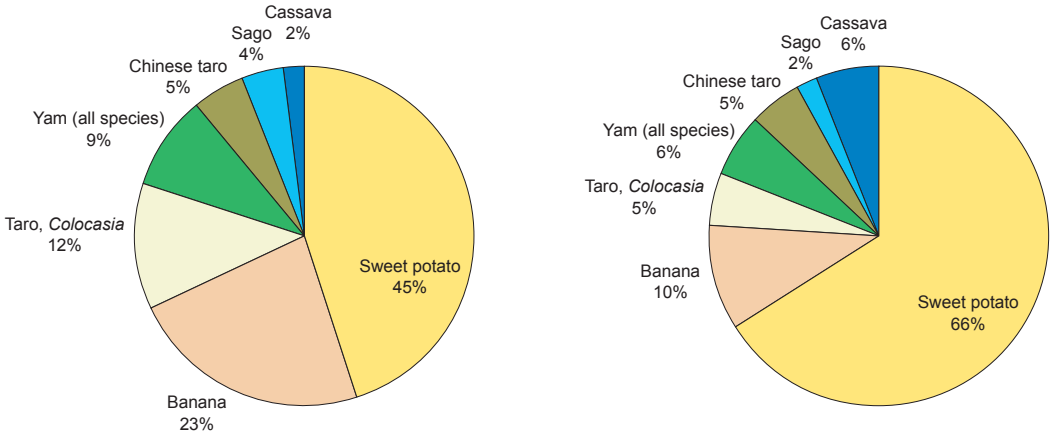

Figure 1. Estimated production by weight of staple food crops in PNG. **(a)** Survey of Indigenous Agriculture, 1961–1962 (after Walters 1963), **(b)** Mapping Agricultural Systems of PNG Project, 2000.

Note: Rice was estimated as 0.1% of production by weight of staple food crops in 1961–62; and as 0.01% in 2000. Coconut production was not estimated in 1961–62. Coconut contributed an estimated 2.2% of food produced in 2000, but has been excluded from these figures so that the two data sets can be compared.

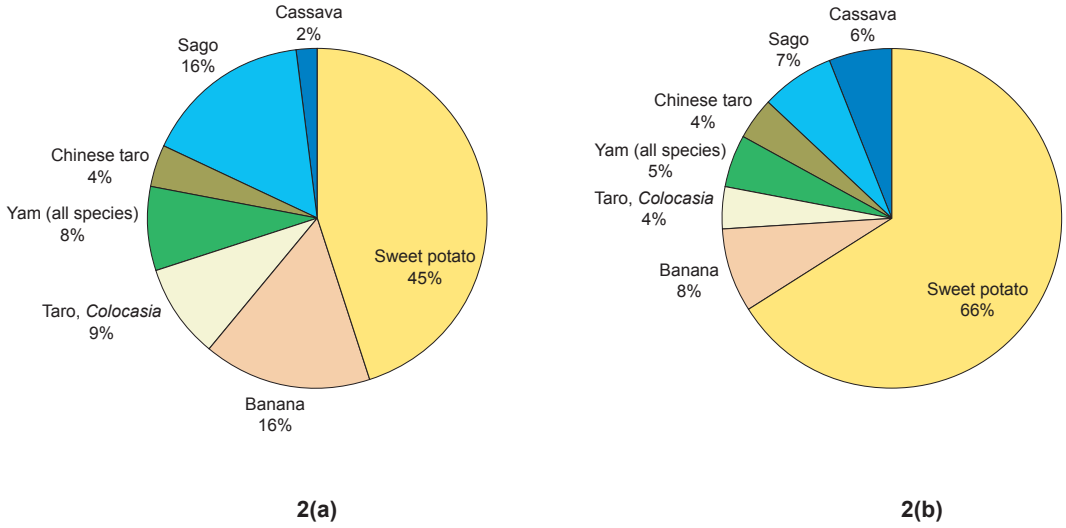

Figure 2. Estimated production of food energy of staple food crops in PNG. **(a)** Survey of Indigenous Agriculture, 1961–1962 (after Walters 1963), **(b)** Mapping Agricultural Systems of PNG Project, 2000.

Note: Rice was estimated as 0.4% of food energy of the staple food crops in 1961–62; and as 0.03% in 2000.

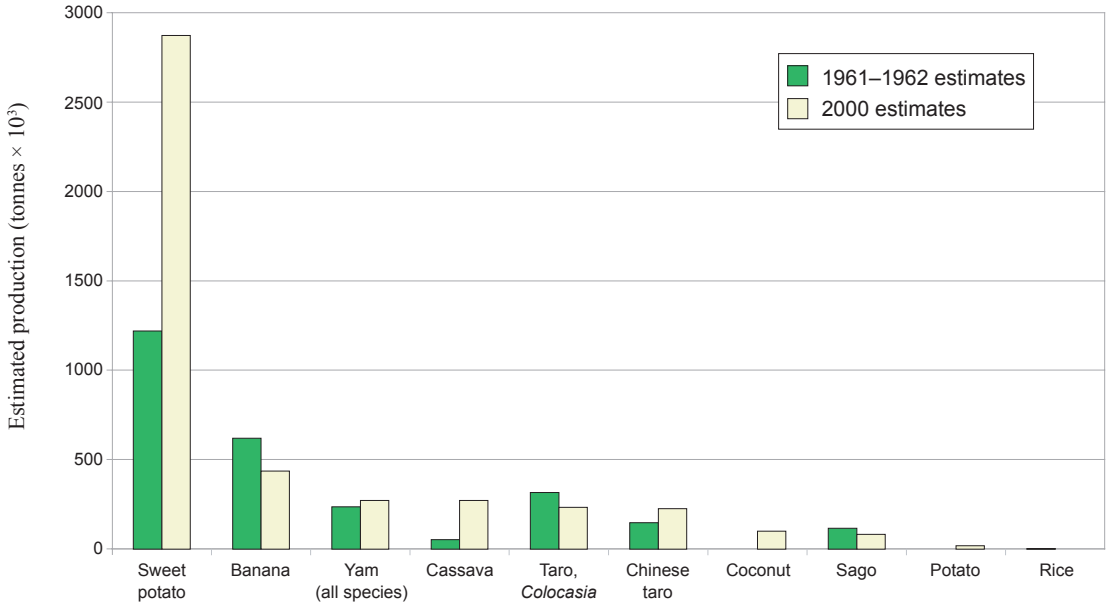

Figure 3. Comparison of the 1961–1962 and 2000 estimates of production by weight of ten staple food crops in PNG.

Note: Coconut production was not estimated in 1961–62. Estimated potato production in 1961–62 was negligible. Rice production was estimated as 3000 tonnes in 1961–62, and 409 tonnes in 2000. The 1961–62 figure for rice is unlikely to be accurate – see page 16.

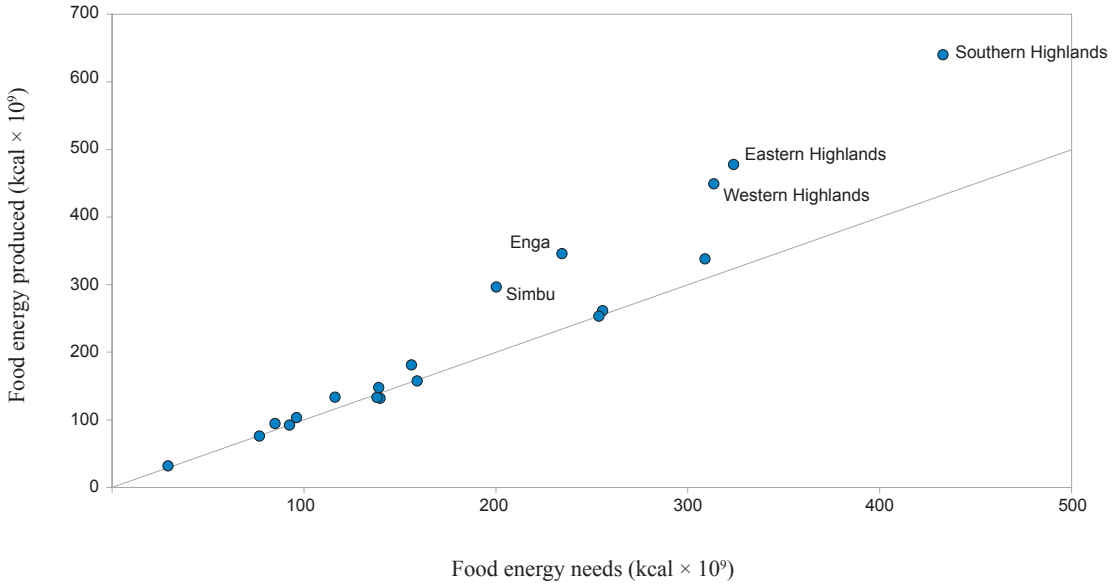

Figure 4. Estimated food energy produced from the staple food crops per province versus estimated food energy needs of the human population from staple food crops.

Note: The diagonal line represents points where food energy needs equals food energy produced.

findings of Gibson (2001a) that household production is undervalued in the PNG National Accounts. In 1996, the estimate for non-marketed production was about K750 million, much less than the estimates from the Household Survey or the estimates in this paper for staple crops only. Clearly, complete substitution of locally grown staples by imported grain is impractical and unlikely to happen, although failure of sweet potato production in the highlands would result in greatly increased food imports into PNG.

There are a number of conclusions from this exercise. Firstly, locally grown staple food is worth a lot to the PNG economy, even though most is consumed by the producing household. Secondly, it is important that the state and others invest in research and development of these foods given that they make such a contribution to the economy. This is particularly the case for sweet potato, as there are no other crops that can be readily substituted for sweet potato in the highlands, as can happen in most lowlands locations.

The 1996 PNG Household Survey valued annual household food production at K1299 million, with the staple food crops valued at K672 million (Gibson 2001a:Table 2). Given the devaluation of the kina between 1996 and 2004, the latter figure is now equivalent to around K1500 million. This is about half the estimate of K2850 million for the eighteen staple food crops included in this paper.

6. Semi-independent check of estimates

The methods used here rely on a number of assumptions and some of the figures used are average values for broad environments (highlands/lowlands). Hence it is important that the estimates generated are independently verified. The check is semi-independent because the same population figures are used. The check is done by calculating the energy available in the food grown in representative agricultural systems and also for all provinces. The energy needs of the human population are calculated for that area and estimates of the food energy produced and the food energy requirements of the human population are then compared.

The energy content of the foods produced is arrived at by summing the energy content of all foods produced, using the food values for ‘as purchased’ foods given by Leung et al. (1972). These authors give values for both ‘as purchased’ and ‘edible portion’ of foods, but it is the former which is required for this exercise. This is because the comparison is with the produce from the garden (such as an entire yam tuber), not just the edible portion of the produce (such as a peeled yam tuber). Other sources consulted, including Dignan et al. (1994) and WHO (1979), only give figures for the ‘edible portion’ of the food.

The energy needs of the human population from staple foods were calculated using the following equation:

$$EN = Pop \times C \times E$$

Where:

EN = Energy needs from staple foods of the human population (kcal/year)
Pop = Rural population in 2000
C = Mean energy consumption per year (2665 kcal/person/day × 365 days/year)
E = Proportion of energy derived from the staple foods (85%; see page 5)

Thus the figure derived for estimated energy needs is independent of the production estimates, with some exceptions. The first is that the same population figure is used for both calculations. Secondly, it is not possible to apply this independent check to production estimates for sago and coconut. This is because the estimates of sago and coconut production depend on some of the same figures used to calculate the food energy needs of the human population.

There are a number of other factors that could modify both types of estimates. The first is wastage of harvested garden produce and food that is not harvested. An estimate for this factor is not available, but is likely to be in the range 10–20%. This factor would reduce the amount of food available for human consumption. The second factor is energy obtained from food imported from outside PNG. (Food purchased or traded from local sources is accounted for in the estimates of production). Imported food contributes an estimated 15% of energy for rural Papua New Guineans (Gibson 2001a). Thus on average, rural people in PNG have a 15% lower requirement for locally grown food than if no imported food was available to them. This factor will reduce the energy needs from local foods of the human population by 15% on average. These two factors are similar in magnitude. Thus they will cancel each other out and are not considered further. A minor factor is food produced which is used as planting material. This only applies to yam and has been ignored for these purposes. Overall, it is a minor discrepancy, given the limited information on village yam yield.

A comparison between the energy produced and the energy requirements of the human population from staple food crops was conducted for ten selected agricultural systems in a number of different environments and with different staple foods. The check showed that in the central highlands about 50% more energy is produced than is required by the human population. This is consistent with the fact that the domestic pig population in the central highlands is similar to that of the human population. For highlands fringe locations, the estimate for production is typically about 30% greater than the human needs. Again, this is consistent with the need for more sweet potato to be produced to feed pig herds. On the highlands fringe, pig numbers are lower (Hide 2003) and the average ratio of pigs to people is 0.6:1.

For lowlands locations, the estimates for energy produced are generally lower than the human needs. Initially, a figure of 0.07 ha/person/year was used for garden area in the lowlands. There is a clear trend in the published figures for lowlands garden areas to be smaller than the recorded or estimated figures in the highlands. However, there is less reliable recent data on areas planted in the lowlands and the figure of 0.07 ha/person/year was chosen as this is about 80% of the highlands mean of 0.09 ha/person/year. As this resulted in production estimates which were consistently low for lowlands locations, a revised figure of 0.08 ha/person/year was used wherever most of the agricultural system was less than 1200 m in altitude.

Using the revised garden area for lowlands locations, estimates of energy produced and the energy needs of the human population from staple food crops were generated. A worked example of this exercise is given in Table 6 for one lowlands location and in Table 7 for one highlands location. Results at a provincial level are given in Table 8 and Figure 4.

Estimates of energy production and human energy needs were very similar for lowlands agricultural systems and for the 14 provinces where most systems are in the lowlands (Table 8, Figure 4).

For the five highlands provinces of Southern Highlands, Enga, Western Highlands, Simbu and Eastern Highlands, the energy production estimates were on average 47% greater than the estimated human requirements (Table 8, Figure 4). As previously mentioned, this is consistent with the feeding of significant amounts of sweet potato to the large domestic pig populations that live in the highlands. These estimates suggest that about one-third of all sweet potato tubers are fed to pigs in the central highlands valleys. The proportion is somewhat lower on the highlands fringe where the agricultural system tends to contain a greater range of other staple crops and pigs are less important.

Because of the sweet potato that is fed to pigs in the highlands, it is useful to make an estimate of the production of sweet potato for human consumption only. For all agricultural systems in the highlands (above 1200 m), the estimate for sweet potato only was multiplied by a factor of 0.675 to account for the fact that the estimate for sweet potato production in the highlands provinces was 47% greater than the estimated human needs. The figure for lowlands locations was not adjusted. This exercise indicated that 75% (2,171,000 tonnes) of all sweet potato produced in PNG is grown for human needs. The corresponding proportion for locations above 1200 m in altitude was 67%. If these assumptions and figures are accurate, it suggests that about a third of sweet potato tubers grown in highlands locations is fed to pigs. For all PNG, it suggests that about one-quarter of all sweet potato is fed to pigs.

Hide (2003:63–70) assembled data from a number of village studies on the quantity of sweet potato fed to pigs in the highlands. The proportion of sweet potato fed to pigs ranged from 23% to 70%, with many studies indicating that about half of all sweet potato produced was fed to pigs. Thus the estimate here that a third of all sweet potato produced at locations above an altitude of 1200 m is fed to pigs is consistent with Hide's village-level studies. Estimated average production of sweet potato for all PNG is 668 kg/person/year, with about 500 kg of this produced for people and the remainder for pig consumption.

7. Comparison with previous estimates

Three previous estimates of crop production have been undertaken for PNG. The first is part of the Survey of Indigenous Agriculture conducted in 1961–1962 (Walters 1963). This was designed to meet the requirements of the 1960 World Census of Agriculture. One hundred sample villages were selected and sample families surveyed within these villages. The sample villagers were taken from about 84% of the total population, excluding urban Port Moresby (the only town of any size then) and parts of the highlands that were still not under control of the Australian Administration. Three visits at six-monthly intervals were made to each of the sample villages. Data recorded included garden area and production of certain crops. Walters (1963) cautions that 'Many of the statistics are subject to high standard errors owing to the relatively small sample on which the estimates are based and the uneven geographical distribution of the item concerned'.

The Food and Agriculture Organization of the United Nations also publishes production (and other) estimates for PNG every year (for example, FAO 2004). The basis for the FAO estimates is unknown, but it is presumed to be an annual extrapolation from the 1961–1962 survey. The FAO gives the PNG Department of Agriculture and Livestock (DAL) Statistics Section as the source, but the DAL statistician states that his section has not provided figures and that no reliable estimates exist (M. Rahman, pers. comm., April 2002). The FAO estimates are likely to be much less reliable than the other two estimates or the new ones presented here.

In 1996, a nationwide consumption survey was conducted as part of a World Bank poverty assessment. This was the PNG Household Survey (Gibson and Rozelle 1998; Gibson 2001a). It included a random sample of 1200 households, stratified by sector (urban/rural), physical environment and the level of agricultural development. The survey interviewed households at least twice, about two weeks apart. The value of food consumed was estimated by asking respondents to put their garden produce into marked bags or by recording units such as 'bundles or heaps'. The units of measurement (such as a rice bag) were converted into kilograms using standard conversions. Note that this survey estimated consumption, rather than production. Gibson and Rozelle (1998:13) note that reliable measures of food production were the most difficult part of the food consumption equation to estimate.

The field basis for the current estimates is the Mapping Agricultural Systems Project. The database was generated after extensive fieldwork in all of PNG. Part of the information gathered included the relative importance of the staple food crops. More details are given in the Introduction.

The new estimates of food production made in this paper are compared with the previous ones in Table 9. In broad terms, the different estimates are of a similar magnitude, with some notable exceptions. The totals of the three previous estimates are similar (2.5–2.7 million tonnes), despite there being a 40-year period between the 1961–1962 survey and 2003 FAO estimates. The earlier estimates are much less than the current estimate of 4.5 million tonnes. The 1961–1962 total production is of the correct order of magnitude for a subsistence population of just under two million people. Total figures from the 1996 Household Survey and FAO are too low for a rural population of about four million people, given that most food is produced at a subsistence level and imported food contributed only 15% of energy in PNG in 1996 (Gibson 2001a).

The most important difference between the surveys is that the new estimate for sweet potato production is more than twice that made in the Survey of Indigenous Agriculture 40 years ago and in the 1996 Household Survey. The current estimate is about six times greater than the current FAO figure. Bourke (1985) provides a summary of food intake and area planted to sweet potato per person in PNG. Even very crude estimates based on calorie needs of people, or on average village yields, indicate that both the FAO and Household Survey figures are too low. For example, based on a highlands population of about 1.8 million people and production of about 2 kg of sweet potato per person per day, production for humans in the highlands alone is around 1.3 million tonnes of tuber per year. But sweet potato is widely grown almost everywhere in PNG and significant quantities are consumed by domestic pigs in the highlands. Thus production has to be very much greater than one million tonnes per year. Gibson (2001c:21) writing of the 1996 Household Survey sweet potato estimate notes that 'it can be presumed that much of the sweet potato that was destined for pigs was not measured by the survey'.

A major change over the past 40 years has been the increased significance of crops of New World origin. Sweet potato was almost certainly introduced into PNG and adopted in the highlands about 300 years ago. The other New World crops have been introduced and adopted over the past 130 years, since permanent European settlement in PNG. Most of the rise in significance has occurred since 1960. There have been large increases in the estimated production of the New World crops of cassava, potato, sweet potato and Chinese taro over the past 40 years. Potato was a very minor crop in the early 1960s with negligible production and it has now increased in importance because of the consumption of fried 'chips' in towns

(by both urban and rural people) and baked or boiled potato in villages. Cassava has also increased greatly in significance over the past 40 years. Sweet potato is now widely grown in the PNG lowlands. In the early 1960s, it was the staple food in the highlands, but the only lowlands location where it was the dominant staple food crop was Bougainville and parts of New Ireland. Chinese taro rose in importance during the 1960s and 1970s, but production has decreased over the past 20 years because of damage by a root rot. Nevertheless, these figures suggest a modest overall increase in Chinese taro production over the past 40 years.

In contrast, production of staple crops of Asia-Pacific origin has either decreased or is similar in magnitude to that of about 40 years ago. There is an apparent decrease in production of banana, sago and *Colocasia* taro, with yam production about the same in 2000 as it was in 1961–1962 (Figures 1, 3).

The current estimate for coconut consumption of 101,000 tonnes/year is about half the figure for coconut consumption in the 1996 Household Survey. Results of that survey give mean consumption as 42 kg/person/year (Gibson 2001a). This would provide about 290 kcal/person/day or 11% of all energy consumed (Gibson 2001a). These are high figures, given that only a little more than half of all rural villagers consume significant quantities of coconut. Coconut is not eaten or is a minor food item at locations above 500 m altitude. In coastal and lowlands locations, food intake studies typically indicate that coconut provides 10–15% of energy consumed, with very low or no contribution in locations above 500 m altitude. This information casts doubt on the estimated total consumption of 195,000 tonnes of coconut from the 1996 Household Survey.

Rice production has been consistently estimated as 300–700 tonnes per year, except for the 1961–1962 figure of 3000 tonnes (Table 9). However, the latter estimate cannot be accurate. The Australian Administration allocated significant resources to promote domestic rice production between the early 1950s and the mid 1970s, despite many recent assertions to the contrary. Production is known quite accurately, unlike that for the other food crops. For example, in 1962, domestic rice production in PNG was 311 tonnes (Hale 1978), a similar figure to the estimate of 409 tonnes for 2000 (Table 3). Production of rice has fluctuated somewhat over the past 50 years, depending on inputs and subsidies by the Australian Administration, the PNG government (since 1975) or overseas and local development agencies. Peak production occurred in 1971 when production exceeded 2000 tonnes for that year only (Hale 1978:Table 8). It has exceeded 1000 tonnes in only a few other years.

8. References

Allen, B.J., Bourke, R.M. and Hanson, L. (2001). Dimensions of Papua New Guinea village agriculture. In R.M. Bourke, M.G. Allen and J.G. Salisbury (eds). *Food Security for Papua New Guinea. Proceedings of the Papua New Guinea Food and Nutrition 2000 Conference*. ACIAR Proceedings No. 99. Australian Centre for International Agricultural Research, Canberra. pp. 529–553.

Allen, B.J., Bourke, R.M. and Hide, R.L. (1995a). Agricultural systems in Papua New Guinea project: approaches and methods. *PLEC News and Views* No 5:16–25. (Newsletter of the United Nations University Project of Collaborative Research on People, Land Management and Environmental Change).

Allen, B.J., Bourke, R.M. and Hide, R.L. (1995b). The sustainability of Papua New Guinea agricultural systems: the conceptual background. *Global Environmental Change* 5(4): 297–312.

Bourke, R.M. (1978). Altitudinal limits of 230 economic crop species in Papua New Guinea. Unpublished paper, Department of Human Geography, Research School of Pacific Studies, The Australian National University, Canberra.

Bourke, R.M. (1985). Sweet potato (*Ipomoea batatas*) production and research in Papua New Guinea. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries* 33(3/4): 89–108.

Bourke, R.M. (1988). *Taim hangre*: variation in subsistence food supply in the Papua New Guinea highlands. Unpublished PhD thesis, The Australian National University, Canberra.

Bourke, R.M., Allen, B.J., Hobsbawn, P. and Conway, J. (1998). *Papua New Guinea: Text summaries*. Agricultural Systems of Papua New Guinea Working Paper No. 1. Two volumes. Land Management Group, Department of Human Geography, Research School of Pacific and Asian Studies, The Australian National University, Canberra.

Bourke, R.M. and Betitis, T. (2003). *Sustainability of Agriculture in Bougainville Province, Papua New Guinea*. Land Management Group, Department of Human Geography, Research School of Pacific and Asian Studies, The Australian National University, Canberra.

Dignan, C.A., Burlingame, B.A., Arthur, J.M., Quigley, R.J. and Milligan, G.C. (1994). *The Pacific Islands Food Composition Tables*. South Pacific Commission, Noumea.

FAO (2004). FAOSTAT. Agricultural data. Crop primary, 2003. Accessed 16 July 2004 at: <http://apps.fao.org/faostat/faoinfo>.

Gibson, J. (2001a). The economic and nutritional importance of household food production in PNG. In R.M. Bourke, M.G. Allen and J.G. Salisbury (eds). *Food Security for Papua New Guinea. Proceedings of the Papua New Guinea Food and Nutrition 2000 Conference*. ACIAR Proceedings No. 99. Australian Centre for International Agricultural Research, Canberra. pp. 37–44.

Gibson, J. (2001b). The nutritional status of Papua New Guinea's population. In R.M. Bourke, M.G. Allen and J.G. Salisbury (eds). *Food Security for Papua New Guinea. Proceedings of the Papua New Guinea Food and Nutrition 2000 Conference*. ACIAR Proceedings No. 99. Australian Centre for International Agricultural Research, Canberra. pp. 407–413.

Gibson, J. (2001c). *Food Security and Food Policy in Papua New Guinea*. Discussion Paper No. 83. Institute of National Affairs, Port Moresby.

Gibson, J. and Rozelle, S. (1998). Results of the household survey component of the 1996 poverty assessment for Papua New Guinea. Unpublished paper, Population and Human Resources Division, World Bank, Washington.

Grant, I.M., Allen, M.G., Wiles, G.C. and Laraki, J. (eds) (2004). *The Future of Cassava in Papua New Guinea. Proceedings of the NARI Cassava Workshop. NARI Proceedings Series No. 4*. National Agricultural Research Institute, Lae.

Hale, P.R. (1978). Rice. In B. Densley (ed.) *Agriculture in the Economy*. Department of Primary Industry, Port Moresby.

Hide, R.L. (2003). *Pig Husbandry in New Guinea: A Literature Review and Bibliography*. Australian Centre for International Agricultural Research, Canberra.

Leung, W-T.W., Butrum, R.R. and Chang, F.H. (1972). *Food Composition Table for Use in East Asia*. Food and Agriculture Organization of the United Nations and U.S. Department of Health, Education and Welfare, Bethesda, Maryland.

Macewan, J.M. (1978). Subsistence agriculture. In B. Densley (ed.) *Agriculture in the Economy*. Department of Primary Industry, Port Moresby.

Morauta, L. (1982). Sago for food in a changing economy. In *Sago Research in Papua New Guinea*. IASER Discussion Paper No. 44. Institute of Applied Social and Economic Research, Port Moresby. pp. 39–75.

Schindler, A.J. (1952). Land use by natives of Aiyura village, central highlands, New Guinea. *South Pacific* 6:302–307.

Walters, C.L. (1963). *Survey of Indigenous Agriculture and Ancillary Surveys, 1961–1962*. Territory of Papua and New Guinea, Port Moresby.

WHO (1979). *The Health Aspects of Food and Nutrition*. World Health Organization, Manila.

Table 1. Rural population in PNG in 2000

Province	2000 census rural population[1]
Western	111,994
Gulf	93,063
Central	168,996
Milne Bay	188,857
Oro	116,381
Southern Highlands	523,613
Enga	283,678
Western Highlands	379,245
Simbu	242,265
Eastern Highlands	391,720
Morobe	373,712
Madang	309,239
East Sepik	306,917
Sandaun	167,103
Manus	35,492
New Ireland	102,815
East New Britain	192,340
West New Britain	140,682
Bougainville	168,222
Total	4,296,334

[1] Population figures are for rural villagers only. Each census unit was checked and rural non-village census units, such as schools and plantations, were excluded.

Table 2. Mean crop yield used for calculating crop production (tonnes/hectare/year)

Crop	Lowlands	Highlands
Banana (*Musa* cvs)	12	9
Cassava (*Manihot esculenta*)	22	16
Potato (*Solanum tuberosum*)	-	14
Queensland arrowroot (*Canna edulis*)	10	-
Rice (*Oryza sativa*)	2	-
Sweet potato (*Ipomoea batatas*)	13	15
Taro (*Colocasia esculenta*)	8	10
Taro, Alocasia (*Alocasia macrorrhiza*)	8	-
Taro, Amorphophallus (*Amorphophallus paeoniifolius*)	6	-
Taro, Chinese (*Xanthosoma sagittifolium*)	14	11
Taro, swamp (*Cyrtosperma chamissonis*)	6	-
Yam, greater (*Dioscorea alata*)	13	11
Yam, aerial (*Dioscorea bulbifera*)	13	13
Yam, lesser (*Dioscorea esculenta*)	15	-
Yam (*Dioscorea nummularia*)	13	-
Yam (*Dioscorea pentaphylla*)	9	-

Notes

1. The lowlands yield is used where most of an agricultural system lies below an altitude of 1200 m; the highlands figure is used where most of the system is above 1200 m.

2. These figures are assembled from the published and unpublished recordings for village production. Where there are few or no village recordings, a figure of 75% of mean experimental yield was used. For some of the minor yam and taro species, yields were taken as the same as the better known species.

Table 3. Estimated production of 18 staple food crops in PNG (weight and energy produced)

Crop	Weight (tonnes)	Energy (kcal × 10^9)	Weight (%)	Energy (%)
Banana	436,496	301.18	9.66	6.93
Cassava	271,895	266.46	6.02	6.13
Coconut	100,930	151.40	2.23	3.48
Potato	18,760	13.32	0.42	0.31
Queensland arrowroot	1,431	1.12	0.03	0.03
Rice	409	1.39	0.01	0.03
Sago	82,962	296.17	1.84	6.82
Sweet Potato	2,871,850	2728.26	63.57	62.78
Taro (*Colocasia*)	229,088	178.69	5.07	4.11
Taro (*Alocasia*)	2,389	1.86	0.05	0.04
Taro (*Amorphophallus*)	1,216	0.95	0.03	0.02
Taro, Chinese (*Xanthosoma*)	226,534	176.70	5.01	4.07
Taro, swamp (*Cyrtosperma*)	822	0.64	0.02	0.01
Yam, greater (*Dioscorea alata*)	91,359	70.35	2.02	1.62
Yam, aerial (*D. bulbifera*)	468	0.36	0.01	0.01
Yam, lesser (*D. esculenta*)	180,371	156.92	3.99	3.61
Yam (*D. nummularia*)	478	0.37	0.01	0.01
Yam (*D. pentaphylla*)	37	0.03	0.00	0.00
Total	4,517,495	4346.16	100.00	100.00

Table 4. Estimated production of banana, cassava, coconut, potato, Queensland arrowroot, rice, sago and sweet potato in PNG by province (tonnes/year)

Province	Banana	Cassava	Coconut	Potato	Queensland arrowroot	Rice	Sago	Sweet potato
Western	15,167	9,141	4,312	0	0	0	12,940	6,863
Gulf	10,537	3,892	2,857	171	54	0	10,369	20,308
Central	43,014	19,379	5,142	1,305	787	47	588	49,267
Milne Bay	23,591	51,485	9,795	444	590	4	1,676	43,831
Oro	9,866	10,403	1,549	0	0	48	1,624	53,309
Southern Highlands	15,121	12,626	449	4,920	0	0	2,405	619,561
Enga	6,052	4,215	0	6,485	0	0	104	340,745
Western Highlands	30,989	10,412	0	1,725	0	0	7	425,964
Simbu	10,334	2,482	0	593	0	0	166	294,708
Eastern Highlands	17,038	6,134	0	0	0	0	3	469,939
Morobe	63,311	12,111	5,704	2,455	0	1	572	194,695
Madang	41,729	16,612	14,091	661	0	0	5,288	77,746
East Sepik	37,100	5,086	17,806	0	0	0	23,484	26,175
Sandaun	18,322	883	8,133	0	0	0	16,711	25,036
Manus	1,389	5,715	1,956	0	0	0	4,575	4,477
New Ireland	8,288	15,652	5,612	0	0	0	1,797	38,891
East New Britain	55,587	33,900	8,847	0	0	0	0	42,642
West New Britain	11,885	39,855	5,101	0	0	0	222	45,103
Bougainville	17,176	11,911	9,575	0	0	307	431	92,591
Total	436,496	271,895	100,930	18,760	1,431	409	82,962	2,871,850

Table 5. Estimated production of various taro and yam species in PNG by province (tonnes/year)

Province	Taro	Taro (*Alocasia*)	Taro (*Amorpho-phallus*)	Taro, Chinese	Taro, Swamp	Yam, greater (*D. alata*)	Yam, aerial (*D. bulbifera*)	Yam, lesser (*D. esculenta*)	Yam (*D. num-mularia*)	Yam (*D. penta-phylla*)
Western	5,066	0	108	2,165	0	1,910	0	7,794	0	0
Gulf	1,300	0	49	3,625	108	271	0	204	0	0
Central	5,796	310	504	6,715	0	7,109	197	10,462	0	0
Milne Bay	15,678	851	455	4,892	0	12,455	12	28,361	101	0
Oro	11,784	29	2	11,182	0	5,298	0	6,337	0	0
Southern Highlands	11,409	0	0	5,431	0	3,275	0	0	0	0
Enga	8,780	0	0	287	0	2,240	0	0	0	0
Western Highlands	9,212	0	0	1,586	0	3,143	0	567	0	0
Simbu	4,828	0	0	416	0	2,408	0	0	0	0
Eastern Highlands	11,160	0	0	15	0	5,792	0	6	0	0
Morobe	22,699	99	0	58,938	0	17,855	53	8,435	377	37
Madang	38,621	0	0	46,636	0	9,049	0	32,733	0	0
East Sepik	24,689	48	0	8,045	0	6,810	205	64,927	0	0
Sandaun	15,489	0	0	6,117	0	2,912	0	5,903	0	0
Manus	390	0	0	636	406	81	0	1,120	0	0
New Ireland	9,165	375	0	2,896	34	3,642	0	10,684	0	0
East New Britain	9,230	565	0	30,993	0	491	0	0	0	0
West New Britain	16,002	68	99	23,794	0	1,832	0	2,714	0	0
Bougainville	7,790	44	0	12,167	275	4,785	0	123	0	0
Total	229,088	2389	1216	226,534	822	91,359	468	180,371	478	37

Table 6. Example of estimates of food energy from staple food crops and energy required by the human population for a lowland agricultural system

System number = 1411
Location = Bongos area, East Sepik Province
Subsystem extent = 1.0
2000 population = 11,712
Area of food crop garden = 0.08 ha/person/year
Crop yields = Lowland default

Crop	Proportion of garden area	Mean yield (tonnes/ha/crop)	Estimated production (tonnes/year)	Calorie content (kcal/kg)	Energy produced (kcal/year × 10^6)
Banana	0.23	12.00	2,586	690	1784
Coconut	0.10	0.55	645	1500	969
Sago	0.15	0.23	408	3570	1457
Sweet potato	0.02	13.00	244	950	231
Taro	0.10	8.00	750	780	585
Chinese taro	0.02	14.00	262	780	205
Greater yam (*D. alata*)	0.03	13.00	365	770	281
Lesser yam (*D. esculenta*)	0.35	15.00	4,919	870	4280
Total			10,179		9792

The energy needs from staple foods of the human population were calculated using the following equation:

$$EN = Pop \times EC \times E$$

Where:

EN = Energy needs from staple foods of the human population (kcal/year)
Pop = Rural population in 2000
EC = Mean energy consumption per year (2665 kcal/person/day × 365 days/year)
E = Proportion of energy derived from staple foods (85%)

Thus the estimated energy needs for the human population are:

$$EN = 11{,}712 \times 2665 \times 365 \times 0.85$$
$$= 9683 \times 10^6 \text{ kcal/year}$$

The estimated energy produced from staple foods for this agricultural system is 9792×10^6 kcal/year. This is slightly more (1%) than the estimated energy requirements of the human population.

Table 7. Example of estimates for food energy from staple food crops and energy required by the human population for a highland agricultural system

System number = 0705
Location = Tari Basin, Southern Highlands Province
Subsystem extent = 1.0
2000 population = 61,652
Area of food crop garden = 0.09 ha/person/year
Crop yields = Highland default

Crop	Proportion of garden area	Mean yield (tonnes/ha/crop)	Estimated production (tonnes/year)	Calorie content (kcal/kg)	Energy produced (kcal/year × 10^6)
Banana	0.04	9	1,998	690	1,378
Sweet potato	0.94	15	78,236	950	74,325
Taro	0.02	10	1,110	780	866
Total			81,344		76,568

The energy needs from staple foods of the human population were calculated using the following equation:

$$EN = Pop \times EC \times E$$

Where:

EN = Energy needs from staple foods of the human population (kcal/year)
Pop = Rural population in 2000
EC = Mean energy consumption per year (2665 kcal/person/day × 365 days/year)
E = Proportion of energy derived from staple foods (85%)

Thus the estimated energy needs for the human population are:

$$EN = 61{,}652 \times 2665 \times 365 \times 0.85$$
$$= 50{,}975 \times 10^6 \text{ kcal/year}$$

The estimated energy produced from staple foods for this agricultural system is $76{,}568 \times 10^6$ kcal/year. This is 50% more than the estimated calorie requirements of the human population.

Table 8. Estimated energy available from staple food crops and energy required by human population from staple crops per province[1]

Province	Energy produced (kcal × 10^9)	Energy needed (kcal × 10^9)
Western	92.58	92.60
Gulf	76.19	76.95
Central	132.11	139.73
Milne Bay	181.25	156.15
Oro	103.46	96.23
Southern Highlands	639.80	432.93
Enga	345.79	234.55
Western Highlands	448.84	313.57
Simbu	296.49	200.31
Eastern Highlands	477.40	323.88
Morobe	338.06	308.99
Madang	261.36	255.68
East Sepik	253.45	253.76
Sandaun	133.38	138.16
Manus	32.23	29.35
New Ireland	94.66	85.01
East New Britain	157.55	159.03
West New Britain	133.49	116.32
Bougainville	148.04	139.09

[1] It is important to note that the estimates of energy produced at the level of agricultural system or province can *not* be used to establish that food production in a particular location is deficient or particularly abundant.

Table 9. Comparison with previous estimates of production for staples and other crops in PNG (tonnes $\times 10^3$)

Crops	Survey of Indigenous Agriculture 1961–1962[1]	Household Survey 1996[2]	FAO estimates 2003[3]	This paper 2000[4]
Staple crops				
Banana	620	413	870	436
Cassava	53	124	120	272
Coconut	-	195	570	101
Potato	0	10	0.8	19
Rice	3	0.6	0.8	0.4
Sago	117	95	-	83
Sweet potato	1220	1286	520	2872
Taro (*Colocasia)*	317	314[5]	250	233[6]
Chinese taro	148	-	-	227
Yam (all species)	237	143	280	273
Total for these crops	2715	2581	2612	4516
Other crops				
Aibika (*Abelmoschus manihot*)	-	40	-	-
Betel nut	-	49	-	-
Corn (maize)	62	-	6	-
Peanuts (groundnuts)	3	21	1	-
Pineapple	5	-	18	-
Sugar cane	312	190	442	-

[1] After Walters (1963).
[2] After Gibson (2001a).
[3] Estimates by the Food and Agriculture Organization (FAO 2004).
[4] These estimates are based on the MASP database (1990–1995 field surveys) and other data.
[5] The 1996 Poverty Assessment combined *Colocasia* and *Xanthosoma* taro.
[6] Taro and minor aroid species combined (swamp taro, *Amorphophallus* taro, *Alocasia* taro).

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