

Subsistence at Lake Kopiago, Southern Highlands Province, During and Following the 1997–98 Drought

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Abstract

At Kopiago in the Southern Highlands Province of PNG, the massive drought of 1997–98 drastically affected subsistence agriculture. The drought followed a particularly wet period and garden production was greatly reduced. Large numbers of pigs died. Fires ravaged forests, depleting famine resources and destroying gardens and houses. People relied heavily on traditional ‘famine foods’ but some introduced crops were also significant ‘famine’ crops. The drought and the recovery marked a time of innovation and intensification: people experimented with new methods in order to maintain food and fodder supplies during the drought, and later intensified production in order to rebuild their pig herds. The wetlands of Kopiago played a key role in people’s survival strategies, some areas providing a small supply of sweet potato during the drought and many areas providing planting stock for drylands during the recovery period.

THE highlands of PNG do not bring to mind scenes of drought and fire—the western portion of the highlands does not even experience a significant regular wet or dry season. When drought occurs it can have major impacts upon people’s subsistence livelihoods—upon their ability to maintain gardens to feed themselves and their herds of pigs for the duration of the drought. It is likely that periodic climatic fluctuations, which result in excessive wet or dry periods, have affected the development and processes of traditional agriculture in the highlands (see also Golson 1997 for a considerable period of prehistory).

This paper discusses the impacts of the 1997 drought in the area around Lake Kopiago gardened by Duna-speaking people. It begins by describing the onset of the drought, then goes on to discuss its imme-

diated effects—the fires, the dying gardens, the loss of livestock, disease and so on, and lastly goes on to discuss the recovery period.¹

The vast majority of production at Kopiago is for household use (including fodder for large numbers of pigs)², with a little for the local market. Gardens, mainly made up of sweet potato, are located both within the wetlands, where extensive drainage ditches are made, and within the drylands, usually cleared from old secondary or younger woody regrowth. During and following the drought, wetlands were a key resource not only for families who were resident within the basin but also for people from other valleys who needed to find planting material when the rains finally recommenced.

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1. Most of the material here is based on research conducted between 1995 and 1998 (Robinson 1999).
2. The pig to person ratio in the Kopiago basin is between 1.78 and 2.15 (Robinson 1999).

Onset of Drought

The impacts of the 1997–98 El Niño drought upon the subsistence activities of Kopiago people were immense. At Kopiago, periodic droughts like that experienced during 1997–98 are often preceded by a series of destructive floods—a pattern apparently common to El Niño Southern Oscillation (ENSO) events—and frequently followed by food shortages (Brookfield and Allen 1989; Bourke 1988; 1989). In the region, the preceding years had seen reliable pandanus harvests, normally triggered by dry spells (Rose 1982 cited in Haberle 1993), become irregular and unpredictable. Floods destroyed many cultivated crops in the wetland gardens and so, as the weather became increasingly dry, people took the opportunity to clear new bush gardens. As the drought took hold, these dryland gardens withered and died or were burnt out by fire. People tried various strategies to buffer themselves against the worst effects of the drought. Their subsistence actions before, during and after the drought demonstrate how they intensified their activities because of extreme and unusual, though not wholly unprecedented, environmental stress. The period illustrates the potential that the high value placed upon pigs still has for agricultural intensification in parts of PNG, despite certain environmental extremes.

In the past, regional environmental crises, particularly drought, coincided with ritual activities that occurred across a large area well beyond the Kopiago Valley (Haley 1995; Strathern 1998; Robinson 1999; Sturzenhofecker 1995). These events were infrequent but periodic. Intensification and innovation, mainly to quickly renew pig stocks (lost directly to drought and, in the past, killed as ritual offerings), followed. Duna horticulture is now based upon sweet potato that, by genealogical reckoning, people have cultivated in the drylands for more than 300 years, and in the wetlands for approximately 250 years. The connections between periodic agricultural changes and pig foddering, as were witnessed during and following the 1997 drought, are likely to be a reflection of processes that have recurred repeatedly in the past, perhaps for the last 300 years.

Allen and Bourke (1997) observed that the 1997–98 El Niño drought was ‘at least as severe as the major droughts of the late 1890s, mid-1910s and early 1940s’ and, although El Niño may occur every 8 to 13 years ‘severe drought events such as 1997 possibly occur only once in a century’. Certainly, the impacts of the drought at Kopiago were said by locals to be the worst

in living memory and worse than extensive Duna oral history had recorded. The drought placed immense pressures upon the subsistence strategies of the resident population, for whom outside support was very late in coming.

Rainfall records³ of the period 1985–95 (and the first nine months of 1996) show the Kopiago basin to be relatively aseasonal—but with great variation in the amount of rainfall in any given month or year (see Figures 1 and 2). Rainfall records are not available for Kopiago for the whole of the 1997 and 1998. Instead, I rely upon my own observations and the observations and impressions Duna people recounted to me of the worsening situation.

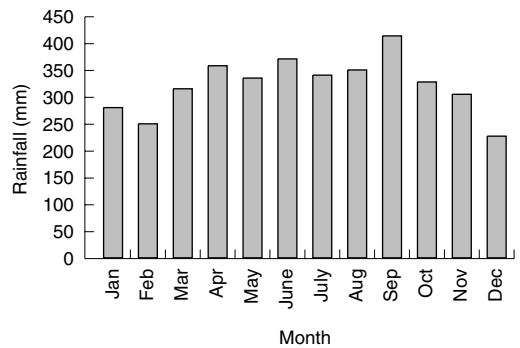


Figure 1. Average monthly rainfall, Kopiago, Eastern Highlands Province, 1985–96.

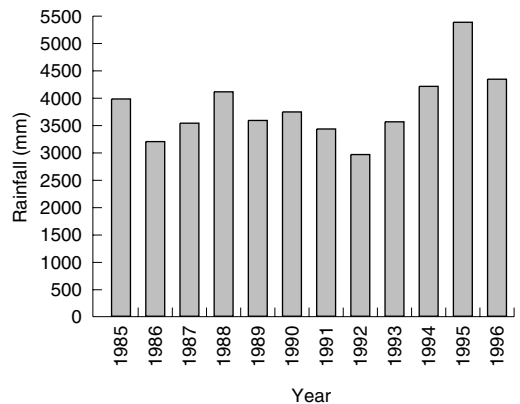


Figure 2. Total annual rainfall, Kopiago, Eastern Highlands Province, 1985–96.

³ Records kept at the Kopiago Catholic Mission.

Drought at Kopiago

Drought began at Kopiago with relatively lengthy periods without rain between April and July of 1997. Between July and November virtually no rain fell at all. At Kopiago, for the first time in oral historical records, the lake bed could be traversed on foot. As the lake levels fell, people fished intensively. While the lake was full, people were free to fish from any part of the lake. However, once the water receded and fish resources became scarce and localised in small remnant ponds,⁴ boundary and access disputes arose, to the extent that people erected posts through the middle of the lake bed to mark parish boundaries.

From August onwards, wild fires swept the region. Most fires (*rindi karia kirayea*: 'mountain fire') were accidentally started by people burning off new garden sites or lighting grass fires for hunting in places such as the Strickland Gorge, or from unguarded hearth fires. However, due to the unusually dry conditions, the fires took off unchecked through grasslands and rainforests alike. Massive fires burned through most of the Strickland Gorge, on many of the major mountain ridges and throughout Duna territory further east and beyond.

It is likely that for some time to come the fires will have a significant impact on the entire Kopiago catchment area, as well as on surrounding regions. Forest cover was destroyed and even the roots binding the soil together were burned so completely that, once rains recommenced, landslides became more common and even more forest cover was lost. The basin floods that also followed the drought were probably worsened by increased quantities of water reaching catchment creeks and rivers without being absorbed by the usual cover of vegetation.

The fires threatened, damaged and destroyed not only places of subsistence value (hunting grounds, forest crops and gardens) but also places of immense traditional sacred value (past ritual sites, secondary burials in caves and overhangs, the upper primary forest).⁵ During the peak period of the fires, between September and October 1997, the landscape was

obscured by smoke, and mountains, invisible by day, were only indicated at night by the lines of fire along the fire fronts. The sun was an eerie pink circle in the haze above, giving everything a strange orange half-light glow.

By early October, the majority of people at Kopiago had come to rely upon bush or famine foods to augment and sometimes to wholly replace their remaining garden produce of small weevil-infested sweet potato (see Table 1). In dryland gardens and in many wetland gardens, sweet potato vines shrivelled up or were burned away by fire. In some areas of the wetlands, grass fires continued to burn slowly in the peaty soil, and in dryland gardens it was common to see burnt-out gardens where the composted sweet potato mounds continued to smoulder for days. Other important crops such as banana stopped producing edible fruit—some banana plants died, taro plants dried up and garden greens died away. For a time, people were able to salvage some *marita* pandanus by soaking the fruit before cooking—but soon the *marita* also ceased producing, and many of the trees were also killed by fires.⁶

In gardens everywhere pumpkin vines dried up but, when even minimal rains returned, they were quick to recover and bear fruit. The importance of the introduced crops, cassava and pumpkin, cannot be overstated; without the drought-hardy introduced crops, the effects of the drought upon the survival of people and their pigs would have been even greater.

From October, some people began making gardens in the deep swamp—near the main swamp river and around the southeastern edges of the dry lake. Those who could called upon kin ties with people who still had some sweet potato to spare to give them meals. Those living and gardening in the wetland margins around the parish of Tswaka on the northeastern side of the lake⁷ had more productive gardens than any other area, and provided food for a wide network of relations.

4. The introduction of carp, in conjunction with dichlorodiphenyltrichloroethane (DDT) sprayed to eradicate mosquitoes carrying malaria parasites, during the 1960s, and the postcontact use of canoes (increasing the use of the lake), are said to have dramatically altered the ecology of the lake. In the past people commonly caught small native fish, tadpoles, dragonfly nymphs, and waterbirds in the lake.

5. Compensation claims arising from fire damage led to a number of court cases in 1998.

6. Around Yokona, at the edge of the Strickland Gorge, fires that swept up from the grasslands are said to have burned most of the *marita* pandanus trees as well as tree crops such as pawpaw, highlands *kapiak* (*Ficus dammaropsis*) and *liki* (*Pangium edule*). Many of the gardens feeding close to 200 people (see Haley and Robinson 1998) were also destroyed as the fires continued on to burn the forests on Mount Komua at Yokona.

7. Significantly, the population of Tswaka is primarily Seventh Day Adventist (SDA), and therefore they do not keep pigs themselves. SDA members there still grow sweet potato, and even in normal times are able to profit from the sale of the smaller tubers to people who do keep pigs. People at Tswaka had fewer pigs to feed, and more productive gardens than many other residents.

Table 1. Principal Duna drought bush and famine foods utilised in 1997.

Local name	Common name	Scientific name
<i>Kao-ere</i>	Wild yam	<i>Dioscorea</i> sp.
<i>Anokua</i>	Wild yam (sour)	<i>Dioscorea</i> sp.
<i>Pema</i>	Taro	<i>Colocasia esculenta</i>
<i>Mbatia(tsiri la)</i>	Swamp taro	<i>Cyrtosperma chamissonis</i>
<i>Hii la</i>	Bush taro	<i>Colocasia esculenta</i>
<i>Waliwali</i>	Taro	<i>Colocasia esculenta</i>
<i>Hukia</i>	Kudzu	<i>Pueraria lobata</i>
<i>Kuango</i>	Ferns	na
<i>Yaki</i>	Ferns	na
<i>Kaiyuku</i>	Tree ferns	<i>Cyathea angiensis</i> , <i>Cyathea contaminans</i> , <i>Cyclosorus</i> sp.
<i>Poke</i>	<i>Kumu musong</i>	<i>Ficus copiosa</i>
<i>Riki</i>	Fig leaves	<i>Ficus pungens</i>
<i>Kane</i>	<i>Tulip</i> leaves	<i>Gnentum gnemon</i>
<i>Kutsi</i>	Climbing curcurbit	<i>Trichosanthes pulleana</i>
<i>Irapuya</i> ^a	Cassava	<i>Manihot esculenta</i>
<i>Mbawali</i> ^b	Pumpkin	<i>Cucurbita moschata</i>
<i>Riki</i>	Fig leaves	<i>Ficus pungens</i>

na = not available

^aIntroduced in the postcontact period

^bTwo of three varieties now cultivated were introduced in the last 40–50 years, and one, said to be an old variety, was adopted at a time prior to colonial administration in the region.

A number of Hewa people migrated from the north, to a parish named Dilini in the Kopiago basin, to live temporarily with distant Duna kin, relying upon their clan and historical connections.⁸ Hewa lands, if anything, were even more badly affected by the fires and drought than Duna lands. Duna people, on the other hand, did not migrate, as it was known that the situation was not any better anywhere else.

Women whose own gardens failed helped other more fortunate gardeners with their work in the hope that they would be given sweet potato at night to take back for their families and pigs. The women who did this felt a great sense of shame at their own inability to feed their families from their own gardens. During the height of the drought, on a number of occasions, different women were caught stealing sweet potato, and the garden owners sought compensation in the village

⁸ Dilini has land extending far north into Hewa lands, having been given the land when some of them fled their own territory and married women from the Wanakipa area of Hewa some generations before (Robinson and Haley 1998).

courts.⁹ The fact that the women stole sweet potato was a mark of the scale of the disaster. Under normal conditions, families suffering hardship (for example, if their crops are destroyed by flood or pigs) could call upon the hospitality of friends and relations with productive gardens to give them enough food to tide them over. To keep their crops alive, people experimented with various techniques, demonstrating that, in the face of the crisis, people were innovative rather than conservative. These techniques included:

- burning off *pitpit*, then putting out peat fires using containers of water;
- excavating ditches in deep swamp;
- planting some *mondo* in areas of the swamp without complete ditches;

⁹ The wider community felt so sorry for these women that the community, rather than just immediate kin, contributed to their compensation fines—recognising the terrible situation that had led them to steal food from other people's gardens.

Table 2. Pig fodder used during drought.

Local name of plant	Common name	Scientific name
<i>Kuango</i> (cooked)	Variety of fern	Not known
<i>Poke</i> (cooked)	Variety of fig leaves	<i>Ficus copiosa</i>
<i>Mbatia</i> (leaves cooked)	Swamp taro	<i>Cyrtosperma</i> sp.
<i>Hii la</i> (leaves cooked)	Bush taro	Not known
<i>Hinia rako, hinia kuapu</i> (cooked)	Sweet potato roots (not tubers)	<i>Ipomoea batatas</i>
<i>Hinia kei hini</i> (cooked)	Sweet potato leaves	<i>Ipomoea batatas</i>
<i>Ra tsapu</i> (cooked)	Wild <i>pitpit</i>	<i>Setaria</i> sp.
<i>Hii tsapu</i> (cooked)	Bush <i>pitpit</i>	<i>Setaria</i> sp.
<i>Tsola</i> (tips cooked)	Swamp <i>pitpit</i>	<i>Phragmites karka</i> and <i>Saccharum robustum</i>

- using a mulch cover of fern roots and grass (to maintain moisture) over newly planted sweet potato runners;
- watering casuarina trees and cordyline along ditch lines (to keep ditch walls from crumbling);
- watering sweet potato;
- watering banana plants; and
- irrigating sweet potato plots using bamboo feeder pipes from creek lines.

If they could afford to, people purchased rice from the small Kopiaigo trade stores, but the price of rice doubled as trade-store owners themselves tried to raise money for sweet potato, and as prices of rice in the towns rose.¹⁰ Biweekly markets began at first light, so that people who had enough money could buy sweet potato to feed their pigs as usual in the mornings in order to prevent them from becoming feral. Customers would rush to market to buy what they needed before it all sold out even though the price for a pile of sweet potato rose from 2 to 10 PGK.¹¹ More people than usual sold pig meat at market to raise money.¹² People did not sell live pigs, which would normally sell for a higher price than pork, because people would not buy new pigs that they could not feed.

¹⁰ The nearest town used to resupply trade stores at Kopiaigo is Tari, more than 80 kilometres away in Huli territory.

¹¹ In 1997, 1 PGK = approx. US\$0.70 (A\$0.94).

¹² They were usually able to sell only a small portion of the meat even at lower than predrought prices. This was because there was so much pork available for sale, because people had little money to spare on such a luxury item, and also because people had their own pork from animals that they too had been forced to kill (lest the animal starve to death).

Pigs were fed progressively less and less sweet potato. Instead they were fed cooked cassava, boiled wild taro leaves, and sweet potato rootlets and leaves, sometimes mixed with the chopped and cooked tips of swamp grasses (Table 2). Later they were also fed pumpkins grown in the recovering gardens. Great efforts were made to keep pigs alive, but still many pigs died from heat exhaustion and starvation (Table 3). With little prospect of a good feed of sweet potato from their owners in the mornings or evenings, some pigs went missing as they foraged for food without returning to pig-houses in the evenings. Owners were forced to kill some of their own valuable pigs, firstly, to raise money by selling pork (to buy food) and, secondly, because they could not feed all the pigs that they had. People had to kill their own pigs that were starving in case they should die first and be considered inedible. Occasionally people ate the pigs that had already died. Many people were unable to maintain their pig herds.

People had to travel further and further to collect drinking water. In some parishes, people spent up to six hours each day fetching water for their households (a task made more difficult for some after houses burned down and the water containers that were inside were destroyed). In November 1997 some rain began to fall again. The lake filled, and was quickly restocked with fish from small fishspawn ponds that people had maintained at the headwaters of tributary creeks.¹³ Drinking-water sources were renewed but, although green vegetables quickly became plentiful, reasonable quantities of sweet potato could not be har-

¹³ Fishspawn ponds—a postcontact technique—are stocked with introduced carp.

Table 3. Examples of pig losses during the 1997–98 drought, Kapiago, Eastern Highlands Province, PNG.

Informant(s)	Residence	Comments	Pigs lost	Reasons
Kipu Piero (female); Kenny Yuwi (male)	Hirane	Wetland garden at Kalitsanda (Hirane parish) dried up but kept runners alive. Dryland garden on Mbatuku dried up and runners died.	35 (of 42)	Died from starvation and disease; killed and eaten
Pariame Pora (female)	Aiyuguni	New gardens made at Konapia Kana beside Lake Kapiago (Yalia parish) during drought. Abandoned March 1998.	0	No pigs lost
Pokole Pora (female)	Aiyuguni	Wetland gardens at Auwi-Tsola (Mbara parish) continued producing some sweet potato.	0	No pigs lost
Hoiya Pora (female)	Mbara	Wetland gardens at Auwi-Tsola (Mbara parish) continued producing some sweet potato.	0	No pigs lost
Yemili Karali (female)	Yalia (Ndolowa)	Worked in other people's gardens to earn sweet potato for her family and pigs. Mainly fed her pigs famine foods.	0	No pigs lost
Urupu and Yapa Kareke (both male)	Yalia (Ndolowa)	New ditches made plus reuse of an area abandoned in 1960s at Kale Kana (Yalia parish). Abandoned in mid-1998.	6 <i>kurini</i>	Payment for sweet potato runners; killed and eaten before pigs starved; died from heat exhaustion
Goiya Yowe (male)	Yalia (Ndolowa)	Maintained one new wetland garden near Kale Kana (Yalia parish) throughout drought to feed his family and their five pigs. Thinking of abandoning garden in August 1998 (becoming too wet).	0	No pigs lost
Tsiwi Barako (male)	Mbatane	Attempted to make new wetland margin gardens during the drought because he thought he would run out of sweet potato, but the fences caught fire and the garden was ruined.	3 <i>kurini</i> ; 2 <i>range</i> ; 1 <i>rana</i>	Payment for land, food, sweet potato runners; killed and eaten before pigs starved; starvation; missing (found dead)
Kariape Pakalu (male)	Mbatane (councillor)	Had a dryland and a wetland margin garden at the beginning of the drought but both were burnt.	1 <i>warepu</i> ; 1 <i>range</i> ; 1 <i>rana</i> ; 5 <i>kurini</i> ; 3 <i>kupa tsiki</i>	Payment for land; missing (not found or found dead); sold; died

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Table 3 (cont'd). Examples of pig losses during the 1997–98 drought, Kopiago, Eastern Highlands Province, PNG.

Informant(s)	Residence	Comments	Pigs lost ^a	Reasons
Kepo Angora (female)	Mbatane	Worked in other women's gardens to earn sweet potato. Had three dryland gardens that all withered. Has since planted two wetland gardens.	Some <i>kipa isiki</i> ; 3 <i>kurini</i>	Payment for food; died from starvation
Kilimbi (male)	Hagimi	Lives outside the Kopiago Basin.	4 <i>kipa isiki</i> ; 2 <i>range</i> ; 2 <i>warepu</i> ; 4 <i>kurini</i>	Died; killed and eaten before pigs starved

^a *kurini* = medium-sized pig (either sex); *range* = sow; *rana* = young piglet (either sex); *warepu* = boar; *kipa isiki* = young pig (either sex)—the terms *rana* and *kipa isiki* are often used interchangeably

vested until March 1998 (about two weeks after food relief reached Kopiago). And, although there was plenty of food overall, even by August 1998 sweet potato production levels had not returned to normal.

The return of rains brought new problems; dried-up water sources had become contaminated and now became sources of disease. The rate of typhoid increased tragically. In September 1997, three people were diagnosed with typhoid (two of whom died) compared with a usual rate of one or two a year. In March and April 1998, the typhoid outbreak became an epidemic. The health centre recorded more than 40 typhoid deaths over the two months of March and April, including both adults and children—and including people from more distant valleys such as Aluni (Senator J. Galo, pers. comm. 1998). This did not reflect the true rate, however. During the same period, according to a Lutheran missionary who is a trained nurse based at Dilini on the northern side of the basin, an additional 36 people on the northeastern side of the basin alone died of typhoid but were not taken to the health centre or were misdiagnosed with illnesses such as malaria. Mourning cries did not cease for two months and the usual more extensive funeral rites did not occur as people went from one funeral to another.

Impacts Upon Agricultural Practices

To understand why the drought had such a deep impact on agriculture it must be placed within a wider time frame. In the years leading up to the 1997 drought, there had been a series of serious floods. Floods in 1993 had been so widespread and lengthy (June, July and September all received more than 500 millimetres of rain each) that all the Kopiago wetland gardens except those on the very outer margins were completely inundated, and the sweet potato crops were largely destroyed.¹⁴ People used canoes to salvage their sweet potato crops from beneath the water. Repeated floods affected the pattern of wetland and dryland gardening activities of Kopiago residents. Some people had already started to make their new gardens in the drylands rather than the wetlands, and as the weather remained dry, as the drought began, people took the opportunity to clear and burn more new dryland gardens, thereby increasing the likeli-

¹⁴ I did not witness events before 1995, but was told about them by local informants, and was also provided with aerial photographs of the 1993 flood taken by Fritz Robinson as part of a reconnaissance flight over the area for Porgera Joint Venture before providing food relief.

hood of fires. By acting upon recent experience and taking the rational step of concentrating their activities in the drylands, many people acted at the expense of their investment in the wetlands. By the time the drought took hold, people say that they had fewer wetland gardens than for many years.

At the height of the drought some people began to make drained-field gardens in the deep swamp areas around the margins of Lake Kopiago and near watercourses through the swamp. These areas are normally considered to be too wet and too floodprone to be worth the investment of labour needed to make the deep ditches required, or to take the risk of planting. The new gardens beside the dry lake were only partially ditched. The ground was dry enough not to require added drainage; the gardens were far enough into the swamp and away from habitation to risk the chance of pig damage and were made in the expectation that the water levels would rise again and so destroy the garden. These gardens were created expressly for short-term goals of feeding families and pigs during the drought. People realised that, even if complete ditches were excavated, the ground chosen would be inundated frequently under normal conditions. Within four months, these novel gardens began to produce much-needed sweet potato to feed people and pigs, but in March 1999 much of the basin was flooded once more and the gardens had to be abandoned. However, the families who cultivated these lake-bed gardens did not lose any pigs to the drought. For them the investment was worthwhile and there were no real alternatives if they were to maintain their herds.

Recovery

A rainfall pattern of unusually wet periods followed by dry periods (and sometimes another wet period) is consistent with the effects of the ENSO index. Allen and Bourke (1997) have noted that ‘these wet periods often create additional food supply problems in sweet potato based agricultural systems in the PNG highlands’.¹⁵ At Kopiago, as well as elsewhere in the highlands, people reported that, although the sweet potato vines and leaves were now growing in abundance, tuberisation was poor (R.M. Bourke, Research School of Pacific and Asian Studies, The Australian National University, pers. comm. 1998). Gardens that looked lush and abundant during my final visit to Kopiago in August of 1998 were actually producing poor sweet potato crops (see *Postdrought Agricultural Rehabilitation: the 1997–98 El Niño Drought in PNG* by Matthew Wela B. Kanua and Sergie Bang, in these proceedings).

Once the drought ended and was followed by another flood, people once again invested more of their energies into cutting new dryland bush gardens. This had a number of repercussions because people made new gardens and replanted in tandem with each other, beginning with the first regular rains. So, instead of the optimum pattern of gardens being at various stages from clearance through to final harvest and fallow, an unusual proportion were at the same point in the cycle—increasing the community's vulnerability if there were to be another drought, or indeed another prolonged wet. In March and April of 1999, a period of rain and extensive flooding did result in a shortage of food from loss of crops in the basin and poor production in the dryland gardens, a consequence of both the wet period and a shadow famine effect (Bourke 1988) from the previous drought.

Before the drought, sweet potato runners used as planting stock were freely available. In the drought, the sweet potato vines in the dryland gardens, and in many of the wetland gardens too, withered and could no longer be used as planting stock.¹⁵ Following the rains, some people were given new planting stock by their kin and close friends who had gardens in those areas of the wetlands that had remained productive, or at least just wet enough to keep the vines from a state of dormancy. During the drought some people planted sweet potato runners in wetland areas which remained moist, not to produce a crop but only so that planting stock could be maintained. The places that provided most of the runners to restock the gardens in the basin and the valleys beyond were the areas with a history of intensive gardening, where the soils are peaty and less likely to dry into a hard crust. These places remained productive for longer and all maintained planting

stock even when tubers were no longer produced. Many people were forced to replant using stock bought for anything from 6 to 20 PGK per *bilum*. People came from distant valleys of up to two days' walk away to collect runners from Kopiago.

In contrast to people in the Hewa region to the north, the people that I asked in the area around Kopiago did not know of any sweet potato varieties that had become extinct due to the drought.¹⁷ It is unlikely that the drought itself eradicated many varieties of sweet potato in the Duna territory, but the sweet potato dormancy period following the drought and the collection of runners from a limited area will, for a time, reduce the range of varieties commonly propagated. After a time, the variety range would be renewed from new varieties that appear in old gardens (probably new phenotypes resulting from sexual reproduction and seed propagation) (Yen 1991).

When people replanted gardens or made new gardens, their choices of planting stock were governed primarily by the need to provide food for pigs in order to renew pig herds that had been depleted during the drought. People chose from varieties of sweet potato that tend to produce numerous small tubers, since the smaller tubers are usually used as pig fodder, while the larger tubers are for human consumption. Another change that occurred was that some women chose to plant greater numbers of sweet potato runners into each mound than they had before. The stated reason was not just to increase total production per mound but to produce the smaller tubers suitable for feeding pigs.

Thus, a kind of agricultural intensification, driven by the socially-prescribed need for pigs, occurred at Kopiago in the wake of the drought. Before the drought, people did not explicitly plant sweet potato gardens for their pigs but incidentally produced enough surplus in the form of lesser quality or smaller tubers to feed their pigs. During the drought, people explicitly made deep-swamp gardens in order to keep their pigs alive. Afterwards they deliberately planted more sweet potato runners per mound, either to feed more pigs to quickly replenish their herds or to make up for a short-

¹⁵ Here they do not refer specifically to the effects of flood but more generally to the way that sweet potato production reacts to excessively dry and wet periods. The combined effect of a long wet period during the tuber initiation phase and a drought during the tuber-bulking phase depresses yields (Bourke 1989). The return of excessive rains following the drought also added to sweet potato production problems throughout the highlands as a result of a 'nitrogen flush' inhibiting growth of the tubers in the recovering plants (R.M. Bourke, Research School of Pacific and Asian Studies, The Australian National University, pers. comm. 1998; Kanua and Muntwiler 1998). This effect is one of the main reasons that researchers have concluded that wet periods often precede food shortages (Bourke 1988).

¹⁶ Sweet potato plants grown under such conditions may remain dormant for up to four months before sprouting again (Allen and Bourke 1997).

¹⁷ At Wusai, in Hewa, people noted that some varieties of sweet potato were lost during the drought of 1972 and at Wanakipa people said that local stocks of the *wanumin* variety had died out in the 1997–98 drought—although the same named variety elsewhere has been successful as a postdrought recovery variety. *Wanumin* had been a common variety in Wanakipa gardens and postdrought gardens were largely restocked using unknown new varieties that emerged in old gardens. (*Wanumin* means one month.)

fall of fodder due to having fewer gardens than 'normal' (since many gardens had fallen out of production during the drought). A consequence of the decline in pig numbers was that some compensation payments, at the insistence of the claimants, were made with live pigs. Not since the early 1970s had it been common for compensations to be paid with live pigs.¹⁸

Conclusion

The floods that preceded the drought motivated people to reduce their reliance upon wetland gardening and increase their dryland gardening activities. During the drought, parts of the wetlands remained as a refuge for human food production and pig fodder and as a source of vital replacement planting stock with people extending their gardening activities into the deep swamp. Finally, many wetland gardens were destroyed by floods following the drought and people began once again to shift their efforts to the drylands, often into old secondary or primary forest.

Use and abandonment of the wetlands at Kapiago can and does occur within a short time span, facilitated by a traditional system of land tenure and the availability of relatively abundant arable drylands. However, the pattern of use and abandonment does not occur evenly.

Some people continue to garden in the wetlands even after the floods. They do so because they live there, because their wetland gardens are better off in drought than the dryland gardens and because they have invested energy in the drainage ditches around the gardens. Provided people are willing to take the risk, the wetlands can provide better quality and greater quantities of sweet potato for potentially longer periods of time, at a slower rate of soil fertility decline.

¹⁸ The proximal causes for each of the compensation claims were unrelated to the drought. However, the reason behind the switch in these cases from payments as pork to payments as live pigs was a direct result of diminished pig herds. For the past 30 years, compensation payments have been made with pork while bride price payments have been made with live pigs. Any compensation payment led to a diminution of total pig numbers. In the months following the drought it may have been that, in addition to people making claims for payments in live pigs, the people paying also did not want to see a 'waste' of livestock at such a time. The change to payments in live pigs marked a return to traditional patterns of compensation payment, and also a shift closer to the form still practiced by their Huli neighbours.

Subsistence sits at the nexus between the physical and social environments. The changes in subsistence activities during and following the drought at Kapiago were environmentally driven but were socially prescribed. They would not have occurred as they did had there not been a drought or floods. The changes in subsistence activity are associated with socially conceived notions of the importance of the pig as 'social capital', as Modjeska (1991) has put it. It has been suggested that it is 'necessary to understand who benefits from change and why and when'. The people who benefited from change at Kapiago included those who wanted to ensure survival during and after the drought; those who wanted to ensure that they could continue to eat; and those who wanted to continue to maintain herds of pigs and thus remain active members of society. That is, the majority of people benefited. It is only by adaptation to social and environmental changes that people can survive severe environmental crises.

References

- Allen, B.J. and Bourke, R.M. 1997. Report of an assessment of the impacts of frost and drought in Papua New Guinea. Australian Agency for International Development, Port Moresby.
- Bourke, R.M. 1988. *Taim Hangre*: variation in subsistence food supply in the Papua New Guinea highlands. PhD thesis, Department of Human Geography, Australian National University, Canberra.
- Bourke, R.M. 1989. The influence of soil moisture on sweet potato yield in the Papua New Guinea highlands. *Mountain Research and Development*, 9, 322–328.
- Brookfield, H. and Allen, B. 1989. High altitude occupation and environment. *Mountain Research and Development*, 9(3), 201–209.
- Golson, J. 1997. From horticulture to agriculture in the New Guinea highlands: a case study of people and their environments. In: Kirch, P.V. and Hunt, T.L., eds, *Historical Ecology in the Pacific Islands: Prehistoric Environmental and Landscape Change*. New Haven, Yale University Press, 39–50.
- Haberle, S.G. 1993. Late quaternary environment history of the Tari Basin, Papua New Guinea. PhD thesis, Department of Biogeography and Geomorphology, Australian National University, Canberra.
- Haley, N.C. 1995. Where ritual roads converge: exploring some of the myths associated with ritual performance at Gelote. Unpublished paper presented at the conference on *Importing Cultures: Regional Transformations in Myth and Ritual in the Western Highlands of Papua New*

- Guinea, Brisbane, University of Queensland, September 1995.
- Haley, N.C. and Robinson, R.P. 1998. Bogaia, Yeru and Duna Census: Mbulago to Galaga. Unpublished report prepared for Community Affairs, Porgera Joint Venture, October 1998.
- Kanua, M.B. and Muntwiler, M. 1998. A survey report of the impact of drought on availability of planting materials in Simbu Province, 20–23 February 1998. Port Moresby, The Salvation Army.
- Modjeska, C.J.N. 1991. Post-Ipomoean modernism: the Duna example. In: Godelier, M. and Strathern, A., eds, *Big Men, Great Men: Personifications of Power in Melanesia*. Cambridge, Cambridge University Press and Editions de la Maison des Sciences de L'Homme.
- Robinson, R.P. 1999. Big wet, big dry: the role of extreme periodic environmental stress in the development of the Kopiago agricultural system, SHP, Papua New Guinea. MPhil thesis, Department of Archaeology and Anthropology, The Australian National University, Canberra.
- Robinson, R.P. and Haley, N.C. 1998. A social and genealogical study of the Bogaia, Yeru, Duna and Hewa people of the Lagaip and Upper Strickland Rivers. Unpublished report prepared for Community Affairs, Porgera Joint Venture, February 1998.
- Strathern, A. 1998. Sacrifice and sociality: a Duna ritual track. In: Goldman, L.R. and Ballard, C., eds, *Fluid Ontologies: Myth, Ritual and Philosophy in the Highlands of Papua New Guinea*. Westport, Bergin and Garvey, 31–42.
- Sturzenhofecker, G. 1995. Sacrificial bodies and the cyclicity of substance. *Journal of Polynesian Studies*, 104(1), 89–109.
- Yen, D.E. 1991. Domestication: the lessons from New Guinea. In: Pawley, A., ed., *Man and a Half: Essays in Pacific Anthropology and Ethnobiology in Honour of Ralph Bulmer*. Auckland, The Polynesian Society, Memoir, 48, 558–569.