Postdrought Agricultural Rehabilitation: the 1997–98 El Niño Drought in PNG

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Abstract

Compared to previous recorded droughts in PNG, the resources used to mitigate the effects of the 1997 drought and associated frosts were unprecedented. However, these are only scientific observations on the postdrought management of agriculture by smallholders. This paper discusses the scientific basis of postdrought agricultural rehabilitation, based on limited survey data and the experiences of the authors.

A study in February 1998 of the yields of postdrought crops of sweet potato in Simbu Province and a follow-up study in Eastern Highlands Province in March 1998 revealed that, in both these provinces, sweet potato yields in the first postdrought harvests were reduced by 70% and 30% respectively. The yield reduction was reported to be associated with lack of tuber formation. The Fresh Produce Development Company (FPDC) investigated the concern between May and July 1998 and concluded that the sweet potato tuberisation problem in the first postdrought plantings was short lived, and did not occur in subsequent plantings. However, the FPDC did not investigate associated effects of the shortfall in supply of the staple. The problem of lack of tuber formation in sweet potato not only prolonged the food shortage unnecessarily by a further six months, from about December 1997 to May/June 1998, but also meant that farmers wasted labour and other limited resources in preparing and planting large areas of crop land to sweet potato crops that subsequently failed.

COMPARED to the 1941, 1956, 1972 and 1982 droughts in PNG, the amount of resources used to mitigate the effects of the 1997 drought was unprecedented. Whilst it is not within the scope of this paper to give a comprehensive account of the 1997 drought, it is important to review the salient features of the event, particularly the management of agriculture just before the onset of the rains in late 1997.

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The 1997 Drought Assessment Reports

The first two nationwide assessments conducted by Australian and PNG scientists (Allen and Bourke 1997a; 1997b) reported that by December 1997 about 1.2 million people in rural areas of PNG, some 40% of an estimated 3.15 million, were suffering a severe and to some extent life-threatening food shortage (see The 1997 Drought and Frost in PNG: Overview and Policy Implications by Bryant J. Allen and R. Michael Bourke, in these proceedings). The December 1997 report showed all provinces were affected to some degree. Simbu Province (54,720 people affected) and Eastern Highlands Province (30,300 affected), were among the most severely affected by shortages of food. Also severely affected were Southern Highlands

Province (28,300 affected) and Western Highlands Province (28,390 affected).

The nationwide drought impact assessment surveys sponsored by the Australian Agency for International Development (AusAID) reported that by far the greatest impact of the drought was on rural life, particularly on food, water, forests and other life-supporting systems. The combined effect of drought, and frost in the very high altitude areas, together with extensive burning, destroyed food plants, depleted food reserves and reduced reserves of planting materials.

In February 1998, The Salvation Army of PNG funded surveys to assess the postdrought shortage of planting materials in two highlands provinces, Simbu Province (Kanua and Muntwiler 1998) and Eastern Highlands Province (Muntwiler and Kanua 1998). An important finding was the widespread problem of lack of tuberisation on sweet potato. The Simbu Province survey reported, among other things, that:

- garden preparation and planting started when rains were received around November and December 1997; more than 50% of the gardens surveyed were between 0.2 hectares (ha) and 0.6 ha; 90% of the gardens were planted in sweet potato only; and
- of the sweet potato gardens surveyed between October and December 1997, 70% did not produce tuberous roots; of the tubers produced, 79% were either fibrous or had other defects.

The survey in the Eastern Highlands Province, reported that, among others things:

- only one-quarter of gardens surveyed in four districts were planted in sweet potato only. Compared to Simbu Province, Eastern Highlands Province farmers had a wider range of crops in their gardens, and depended less on sweet potato; and
- the data collected showed that 33% of the sweet potato mounds examined did not have tubers, 36% had one or two harvestable tubers per mound, and 31% had three or more harvestable tubers—overall, an average of 29% of mounds contained potentially harvestable tubers.

The most important findings of the Simbu and Eastern Highlands provincial surveys were that, between October, November and December 1997, 70% of the sweet potato planted in Simbu Province and 30% of that planted in Eastern Highlands Province, did not produce tuberous roots. That means that the supply of sweet potato to families in Eastern Highlands Province would have been barely adequate throughout 1998, whilst in Simbu Province, food supplies would have been severely limited during the first part of 1998. The findings prompted CARE Australia to fund the Fresh Produce Development Company (FPDC) to conduct a nationwide study of the sweet potato tuberisation problem (Bang et al. 1998).

Within the confines of the available evidence, this paper attempts to provide a scientific explanation for the lack of sweet potato tuberisation. Because no systematic postdrought follow-up research was undertaken, the available evidence is based on field observations made in late 1997 and early 1998, and the literature on sweet potato physiology.

The Fresh Produce Development Company Study

In May 1998, the FPDC commissioned a study into the yields in postdrought sweet potato, in particular the reported problem of sweet potato tuberisation in Simbu Province and Eastern Highlands Province. A report was completed in July 1998 (Bang et al. 1998).

This study used three sources of data:

- yield data from village gardens at three altitude classes—low (0–500 metres above sea level), mid (1600–1800 metres above sea level) and high (1900–2780 metres above sea level);
- the quantity and prices of sweet potato sold in a number of highlands markets; and
- soil analytical data from gardens in Gumine, Simbu Province.

Sweet potato yields

Average yields were 10 tonnes per hectare (t/ha) in Simbu Province and 42 t/ha in Eastern Highlands Province by June 1998. For all gardens sampled, the lowest yield was 5 t/ha and the highest yield was 50 t/ha. When yield was stratified by altitude, the average yield recorded was 9.7 t/ha at low altitude, 26 t/ha at midaltitutde, and 13.3 t/ha at high altitude. These yields are within the range of PNG smallholder yields (2–50 t/ha) reported by Bourke (1985).

The survey results suggested that by June 1998, whilst the level of sweet potato supply was satisfactory in the midaltitutde areas, at high altitudes it had not reached a satisfactory level. This outcome was probably more due to the effects of altitude on sweet potato yield, than any other cause. It was possible that soil compaction impeded tuber enlargement but it is not possible to demonstrate this with the data available.

Market data

Limited data on sweet potato market prices were collected at a roadside market at Dom, in Gumine District from May to June 1998. These data have been supplemented with data from the Goroka market.

At Dom, sweet potato supply increased over the period of the survey but had almost certainly not reached predrought levels by mid-1998. The predrought price of sweet potato at Dom was around 0.15 PNG kina per kilogram (PGK/kg)[1] but in May 1998 it was still 0.35 PGK/kg. In contrast at Goroka market, the lowest price for sweet potato in January 1998 was 0.71 PGK/kg, in April it was 0.32 PGK/kg and by June 1998 it had fallen to 0.22 PGK/kg (FPDC 1998abc). The steady fall in price at Goroka from December 1997 to June 1998 indicates a correspondingly steady increase in supply to near predrought levels by June 1998.

The yield data and the market price trends suggest that the recovery in sweet potato supply was slower in Simbu Province than in Eastern Highlands Province. Gumine and Goroka are within the same altitude class. The slow recovery at higher altitudes is to be expected. This suggests that the retarded recovery in Simbu Province was the result of the lack of tuberisation, as discussed above. This leads us to ask what actually happened in Simbu Province, that did not happen elsewhere? To explain this, we will examine the analytical data from Gumine garden soils. Similar information is not available from Eastern Highlands Province gardens. Nevertheless, we believe the Simbu Province data provide a reasonable explanation of what happened in Simbu Province, and what is likely to happen again, under similar climatic conditions.

Soil analytical data

The Gumine soil samples came from three adjacent sweet potato gardens at Omkolai village (1750 metres above sea level) collected in February 1998 by Kanua and Muntwiler and in July 1998 by Bang et al. A sample from a nondrought year for comparison was collected from a garden at nearby Boromil village (1850 metres above sea level) by Kanua in 1987 (Table 1).

Of all the major nutrients, sweet potato is most tolerant of low soil phosphorus (P) levels (de Geus 1967). Goodbody and Humphreys (1986) obtained highly significant positive linear correlations for first harvest yields on available P in soils in Simbu Province. Those soils contained 0.6–5 mg/kg available P (Olsen's method). The available P level of the Omkalai soil in July 1998 was about half-way in that range, but the ability of sweet potato to take up P can be limited by the high soil pH. It is noteworthy that the Olsen P value of the Boromil soil in a nondrought year is less than half the value from Omkalai in February 1998. Research on similar soils elsewhere in the highlands of PNG shows that the efficiency of a crop of sweet potato in obtaining soil P is positively influenced by local mycorrhiza (Floyd et al. 1988) and is modified by intervarietal differences (Kanua 1998). However, it is unlikely that the level of P observed at Omkalai in 1998 would have adversely affected sweet potato production.

It is more likely that sweet potato production at Omkalai in 1998, and the lack of tuberisation observed there was influenced by soil moisture and the availability of nitrogen and potassium.

A clear negative relationship exists between sweet potato yield and rainfall during the cropping period (Gollifer 1980; Kanua 1995; King 1985). Bourke (1988) has shown that the phenomenon of reduced tuber formation or the complete lack of tuberisation in sweet potato can be caused by high soil moisture at the time of planting, and/or high soil moisture during the critical tuber initiation around eight weeks from planting. Given that the first postdrought crop in Simbu Province was planted with the first significant rainfall for almost six months, high soil moisture would not seem to have been a major cause of the lack of tuberisation and the low yields observed.

Nitrogen influences tuber development, in particular the growth or enlargement of tubers. The exceptionally thin, elongated tubers observed in Simbu Province in February 1998, could have been caused by excess nitrogen, which would have promoted lignification of the roots, rather than bulking of tubers.

Potassium, on the other hand, influences yields in two ways. First, potassium determines the number of tubers that a sweet potato plant produces. The number of tubers is decided during the tuber initiation period that occurs about eight weeks after planting (Bourke 1988). Second, potassium accelerates photosynthesis in the leaves and facilitates the translocation of the products of photosynthesis to the developing tubers (Fujise and Tsuno 1967). Magnesium is required in small amounts by the sweet potato plant, but excessive available magnesium can negate the effects of potassium.

1. In 1998, 1 PGK = approx. US$0.49 (A$0.77).

The experimental evidence suggests that an absolute value for a physiological optimum nitrogen:potassium ratio cannot be given, because the levels of nitrogen and potassium are determined by the individual levels of nitrogen and potassium, leaching (Bourke 1985), and the intensity of land use (Godfrey-Sam-Aggrey 1976). At Omkalai in July 1998, nitrogen and potassium levels were both high, but magnesium was low. This probably would have offset the nitrogen:potassium balance in favour of potassium. The nitrogen:potassium ratio in July (1:0.125) was marginally (20%) lower, in favour of potassium, than in February (1:0.098). Together with the low magnesium levels, and the high carbon:nitrogen ratio, the conditions would have been ideal for tuber initiation and development in July 1998, compared to the less favourable soil conditions in February.

Magnesium levels at Omkalai were almost twice as high in February 1998 than they were in July, in two out of three gardens. The corresponding potassium levels were lower in early 1998. In contrast, in July 1998, the potassium levels were high and the magnesium levels low. Thus, in February the magnesium:potassium balance is in favour of magnesium, which would have resulted in magnesium competing vigorously against potassium at cation exchange sites. A high proportion of potassium would have been displaced and then leached from the soil, despite the high cation-exchange capacity. Furthermore, a relatively lower nitrogen:potassium ratio in July than in February would have increased potassium availability in July, which would have promoted sweet potato growth. At Boromil in 1987, high magnesium was responsible for a potassium deficiency, and the direct application of potassium led to significant sweet potato yield increases. Elsewhere in the highlands, potassium deficiencies have been shown to be responsible for significantly reduced growth and lower yields of sweet potato (D'Souza and Bourke 1986; Goodbody and Humphreys 1986). The other demonstrated requirement of sweet potato in highlands PNG is the micro-nutrient boron (Bourke 1983; O'Sullivan et al. 1997), but there is no information on boron from Omkalai in 1998.

Table 1. Soil analyses from Omkalai and Boromil Villages, Gumine District, Simbu Province, 1987.

Parameter	Unit	Critical value	Boromil 1987		Omkalai February 1998		Omkalai July 1998
			Lower slope	Upper slope	Block 1	Block 2	Block 3
pH (H_2O)		< 5.5	5.2	5.2	5.7	5.4	6.1
Calcium		< 5.0	4.6	4.1	11.4	13.6	11.1
Magnesium	me %	< 1.0	3.7	3.4	4.9	6.3	2.3
Potassium	me %	< 0.3	0.2	0.2	0.3	0.2	1.2
Sodium	me %	> 0.7	0.1	0.1	0.05	0.08	0.02
CEC	me %	< 6.0	16.9	17.9	18.6	17.2	17.8
Base saturation	me %	< 30	51	43	89	117	82
Phosphorus (Olsen)	mg/kg	< 5.0	3.0	1.0	6.1	3.8	3.6
Organic carbon (C)	%	< 3.0	7.3	0.79	1.79	0.9	5.2
Total nitrogen (N)	%	< 0.3	0.52	0.58	0.10	0.08	0.37
C:N ratio		< 10	14	14	18	11	14
Phosphorus retention			96	93	na	na	na

me = milliequivalent; mg/kg = milligrams per kilogram
Source: Kanua (1987)

Conclusions and Recommendations

No other postdrought follow-up research was undertaken. Consequently there is an absence of experimentally proven scientific data on postdrought management of sweet potato. Hence the scope of the paper is limited to a small amount of survey data, existing literature and the observations of the authors in one district in Simbu Province. The observed yield data and the market price information confirm that the problem of lack of tuberisation experienced by the first postdrought crops observed in Simbu Province was short-lived. However it resulted in the wasted efforts of farmers in preparing gardens and planting large areas of sweet potato and, more importantly, extended the period of the food shortages by up to six months. At midelevation areas, there were other starchy foods such as banana, cassava, corn, taro, yam and pumpkin that supplemented sweet potato. But, at higher elevations, this was not the case and people's food supplies remained vulnerable. Where food sources were more diverse, as they were in Eastern Highlands Province, people were better off.

On the basis of these conclusions, the following recommendations are made.

- The first crops planted postdrought should be heavy nitrogen and phosphorus feeders such as maize, brassicas, legumes and Irish potato.
- Monocrop sweet potato as a first postdrought planting should be discouraged. The first postdrought crops of sweet potato should be extensively intercropped with legumes and maize. Mixed cropping will result in a wider capture of available nutrients and will improve the nutrient balances in favour of sweet potato. These other crops would also supplement the diet if the sweet potato yields remained adversely affected.
- Crop diversification research should be undertaken, including an assessment of prospective crops such as Andean yams, avocado, banana, and nut and stone-fruit trees. Suitable plants that can withstand frost should be sought.
- Frost-tolerant sweet potato cultivars should be identified and distributed in the high altitude areas (some breeding may be necessary).
- The very low number of scientists working on sweet potato in PNG should be addressed immediately.
- Experiments should be designed to test the hypotheses put forward in this paper and by Bang et al. (1998) on the phenomenon of the lack of tuberisation and yield decline in the first postdrought sweet potato plantings.
- Plans should be made for a rigorous program of postdrought research on agricultural rehabilitation, ready for the next drought event.
- The reports listed below about the impact of the drought and frost in 1997 and 1998 should be brought together and secured in at least two locations in PNG and one in Australia for future reference.

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