

The Influence of Available Water in 1997 on Yield of Arabica Coffee in 1998 at Aiyura, Eastern Highlands Province¹

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Abstract

At Aiyura, Eastern Highlands Province, PNG, a wetter season usually occurs between September and March, and a drier season between May and August. However, in 1997, very little rain fell from February to November. It was feared that the 1998 coffee crop would be significantly reduced and that this would result in severe financial problems throughout the coffee industry from producers to exporters. This fear proved to be unfounded. The relationship between the 1997 rainfall and the resulting crop yield in 1998 at Aiyura is examined. The findings contribute to a better understanding of the behaviour of Arabica coffee under varying soil moisture conditions.

RESEARCH carried out in PNG to investigate the growth cycle, crop development and nutrient demands of Arabica coffee (*Coffea arabica* L.), to optimise the time and quantity of fertiliser application, has identified a considerable variation in nutrient demands during crop development. A fluctuating nutrient demand implies that varying amounts of water are needed by the plant for optimal growth (Harding 1994). Hombunaka (1998) refined Harding's findings, and showed that even slight climate differences lead to modified crop development cycles, and that the climate of the PNG highlands is an important influence in coffee production there. In particular, in the PNG highlands:

- contrary to most other-coffee-producing countries of the world, the wet and dry seasons are not clearly defined;
- due to the equable year-round climate, coffee ripens during most months of the year; and
- a rainfall stimulus can influence yields 8–9 months later.

Wrigley (1988) refers to research work in Kenya that examined the influence of water deficiency on coffee growth. It was found that a lack of plant-available water can lead directly to water stress or indirectly to nutrient deficiencies in plants that limit crop development. As a result, coffee development is reported to be limited when available soil water is depleted by about 50%. However, low water availability at different times in the crop development cycle can lead to different outcomes. For example, a period of lowered water availability in the soil that results in water stress to the plant, followed by strong rainfall that raises the available soil water, results in a larger number of flowers and higher subsequent yields. But at other times, for example during cherry development, lowered water availability strongly hinders crop development.

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von Enden (1998) outlined the 1997–98 crop development at Aiyura, Eastern Highlands Province, using a semiquantitative approach. The sources of information was a quantitative assessment of the 1997 water balance, combined with a qualitative assessment of farmers’ perceptions of crop development. This assessment gives insights into the influence of drought (and frost) on crop development, and provides information for management strategies for smallholder coffee production.

These data were collected from the Coffee Research Institute plantation at Aiyura, where controlled conditions make the collection of reliable data possible. These conditions do not necessarily reflect village smallholdings, where different management techniques will result in different outcomes. However, the inclusion of smallholders in research and the use of PNG-wide export data strongly suggest that the findings are generally applicable to smallholdings.

Normal Weather and Cropping Pattern

Aiyura receives an average annual rainfall of 2074 millimetres (mm) (Trangmar et al. 1995). Under average weather conditions, this rainfall is divided into two periods: a slightly wetter period between September and March and a slightly drier period between May and August. The soil moisture regime is closely associated with this annual rainfall pattern. The soil moisture

model on which the analysis is based assumes a maximum water-holding capacity of the soil of 85 mm, reflecting average soil characteristics in the Aiyura area. Under this assumption, soil moisture is slightly depleted between June and September (Fig. 1). During this period, evapotranspiration exceeds rainfall, so that plants must draw on soil moisture reserves. This situation, however, does not put coffee growth in danger. Rather, it provides a situation in which a rainfall event acts as a stimulus for the onset of flowering. Figure 1 illustrates the central variables of the average weather pattern and soil water regime at Aiyura.

The variables acting upon the soil water balance are:

- rainfall, which provides the water input into the system;
- soil moisture, which represents the ability of the system to store moisture; and
- evapotranspiration, which withdraws water from the system.

The 1997–98 Weather and Cropping Pattern

The 1997 and 1998 weather data have been examined on a 10-day basis, which allows a detailed analysis of the climate and crop. The weather in 1997 was characterised by exceptionally low rainfall that resulted in low soil moisture levels for extended periods. In total, evapotranspiration exceeded precipitation for five months in 1997, and at times this led to fully depleted

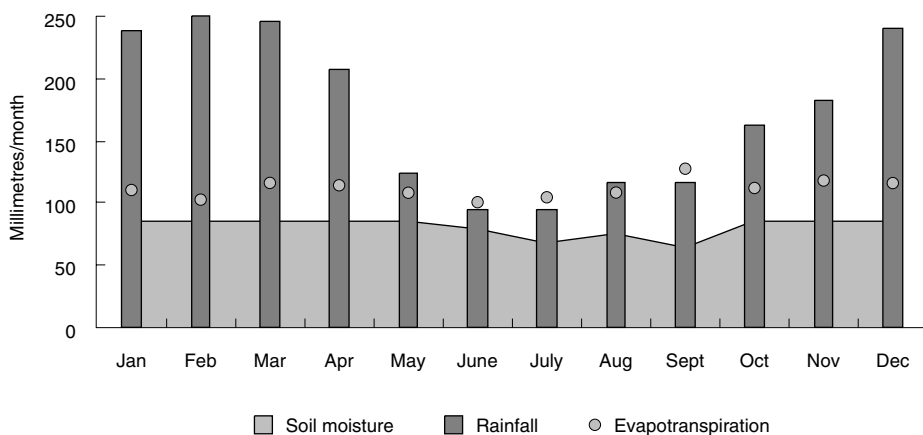


Figure 1. Monthly rainfall, soil moisture and evapotranspiration at the Coffee Research Institute, Aiyura, Eastern Highlands Province, PNG, 1997.

soil water resources. Water demands could not be met by rainfall inputs, consequently water deficits were experienced, a rare event in the PNG highlands (McAlpine 1970). In addition, low temperatures were experienced during the dry periods, especially at night. Clear night skies led to longwave radiation, and hence to heat lost to the atmosphere.

The pattern of 1997 and 1998 soil moisture, and its influencing variables, at Aiyura are shown in Figure 2. Four periods can be identified: in the first period from March to May 1997, a fall in soil moisture during late March and April is followed by a recovery in May; in the second period from May 1997 to July 1997, there is a larger fall in soil moisture from May to June, followed by a smaller recovery in July; in the third period from July to October 1997, soil moisture is very low to zero and there is a water deficit, but there is also rain and a consequent minor recovery in soil moisture during October; and in the last period from October to November 1997, the water deficit continues, but soil moisture again falls to zero and then has a minor recovery. In each of these periods, soil moisture falls sharply but then, to a limited degree, recovers again. Each partial recovery of soil moisture favours the onset of flowering of the coffee tree and the start of a new crop cycle.

During the third period, in addition to the low rainfall, unusual low minimum temperatures were experienced. Minimum temperatures below 10°C, together with dry conditions, were likely to have acted as an added stimulus for flowering.

If it is assumed that an increase in soil moisture that exceeds 20% of the total water storage capacity of the soil is likely to have stimulated the onset of flowering, then flowering stimuli occurred four times during 1997: in May, July, late October and late November.

Coffee Yields in 1998

The 1998 cropping pattern should reflect these four flowering periods; production peaks can be predicted for around eight months after each such stimulus. The 1998 coffee production data shows a clear peak yield across May, June and July (Fig. 3). The marked variation in coffee yields in 1998 can be explained by the pattern of water availability during 1997. Each increase of rainfall and soil moisture was the starting point of a new plant development cycle.

Dry weather and reduced soil moisture levels occurred from March to April 1997, which were very

unusual for that time of the year, and were followed by a clear flowering stimulus in May. This flowering was reflected in a production peak eight months later in January 1998. The peak was small because water supply during the cherry development phase, between July and October 1997, was insufficient.

Dry conditions and the lack of a rainfall stimulus in the beginning of the second period in June 1997 suppressed flowering. In addition, a lack of soil moisture after any flowering that occurred probably led to high proportion of cherries not going on to reach maturity. The resulting outcome in 1998 was yields in February, March and April that were 92% lower than the corresponding yields in 1997.

The yield peak in May 1998 is more difficult to explain because it is not possible to identify a rainfall stimulus eight months earlier. The crop is likely to have originated from a flowering caused by low temperatures in September. Low temperatures were observed during September, but temperature records are not available for Aiyura (an inexcusable situation for a research station). A reasonable yield occurred because of adequate soil moisture from October onwards, which is the period of rapid expansion, endosperm formation and weight gain in cherries. If there had not been adequate soil moisture from late October, then most of the cherries would have been aborted.

The strongest water deficits during 1997 occurred from August to November. A strong flowering stimulus was received in October and November 1997, that led to a marked increase in coffee yields in June and July 1998 (slightly more than double the yields for the same period in 1997). The extreme dry spell before the strong stimulus increased the level of flowering. The good availability of water from the end of October 1997 onwards was also important for optimal cherry development.

The flowering stimuli in April, May, July and August were countered by insufficient water availability during cherry development. Wrigley (1988) states that coffee yields are negatively associated with soil water deficits 8–17 weeks after flowering, which is the time of the most rapid weight gain in cherry development.

At Aiyura, the changing water availability in 1997 led to multiple flowering, resulting in three yield peaks in 1998. The El Niño weather patterns appear to have brought about higher coffee yields rather than have put the crop in danger. The increased yields in peak months more than compensated for the reductions of yield caused by soil water deficits at other times.

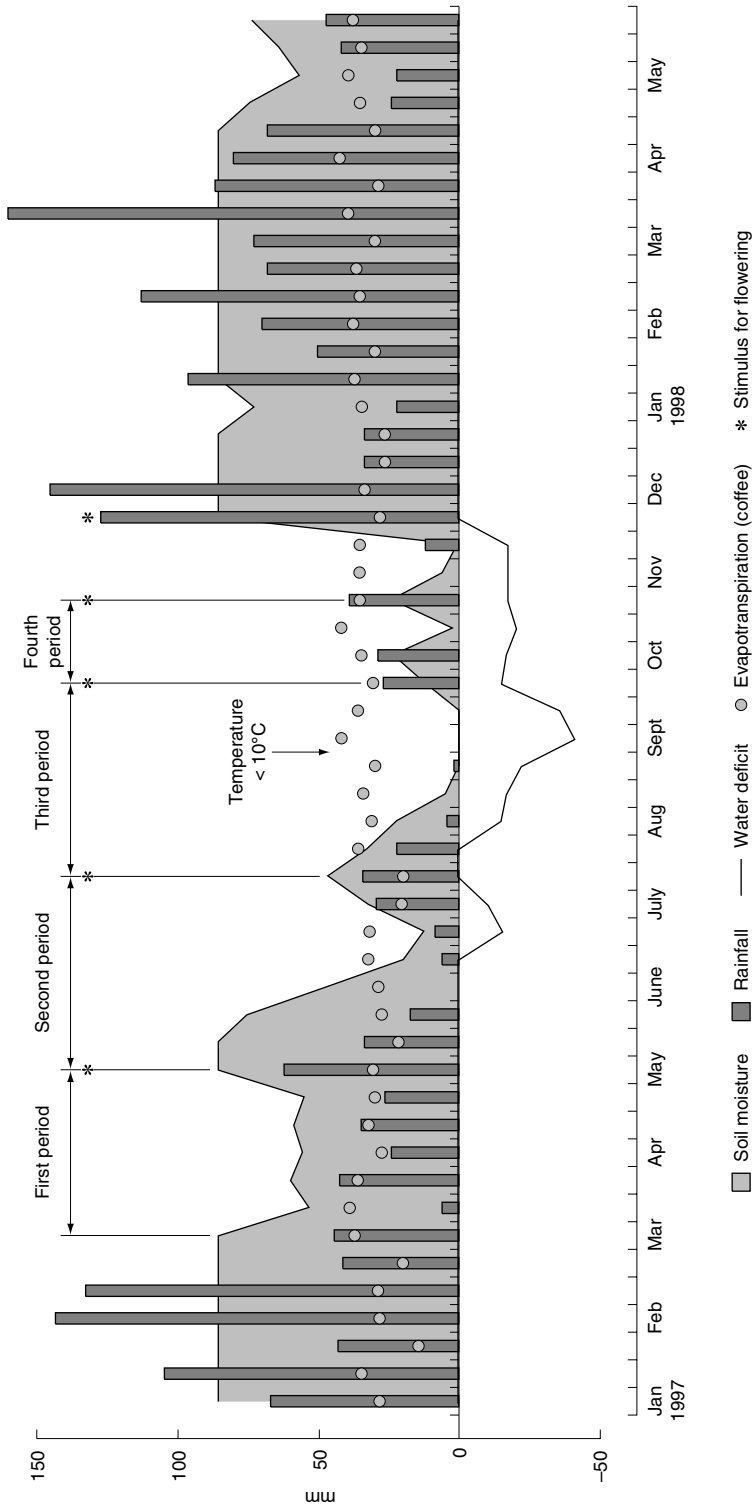


Figure 2. Soil moisture and its influencing variables between January 1997 and May 1998.

PNG Coffee Exports in 1998

Coffee exports from PNG in 1998 are shown in Figure 4. It is assumed that about two months passes from the time of picking of ripe cherries to the time that the green beans are exported. The January and February 1998 exports of green beans were largely the harvest of November and December 1997. The exports from March to December 1998 were the harvest of January to October 1998. Between March and December 1998, more than 1.2 million 60-kilogram (green bean equivalent) bags of Arabica coffee were exported from PNG.

The increase in exports that began in June 1998 was related to harvesting that began in April 1998. The most severe water deficits were experienced from July

to September 1997 (Fig. 2), implying that the massive flowering that occurred in October 1997 resulted in the harvest of June 1998, as recorded in the export statistics in August 1998.

Conclusion

The rainfall conditions of 1997, a year in which one of the most severe droughts this century occurred in PNG, did not lead to an Arabica coffee crop failure in 1998. On the contrary, it almost certainly resulted in increased production. After severe soil water stress, sharp rises in soil water as a result of rainfall brought on massive flowering. This occurred even in coffee trees under heavy shade, which under normal weather

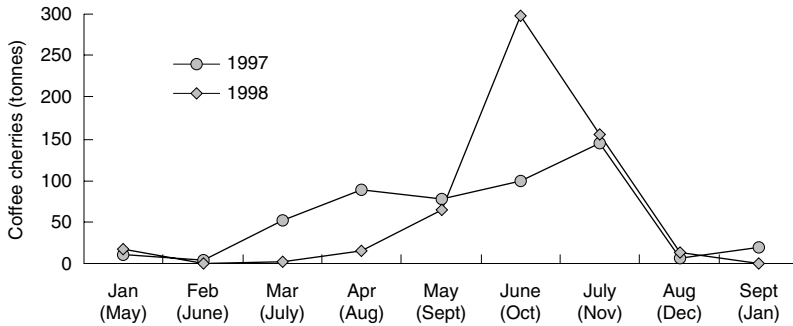


Figure 3. Coffee production at the Coffee Research Institute, Aiyura, Eastern Highlands Province, PNG, 1997–98. Months in brackets indicate the month of stimulus eight months earlier.

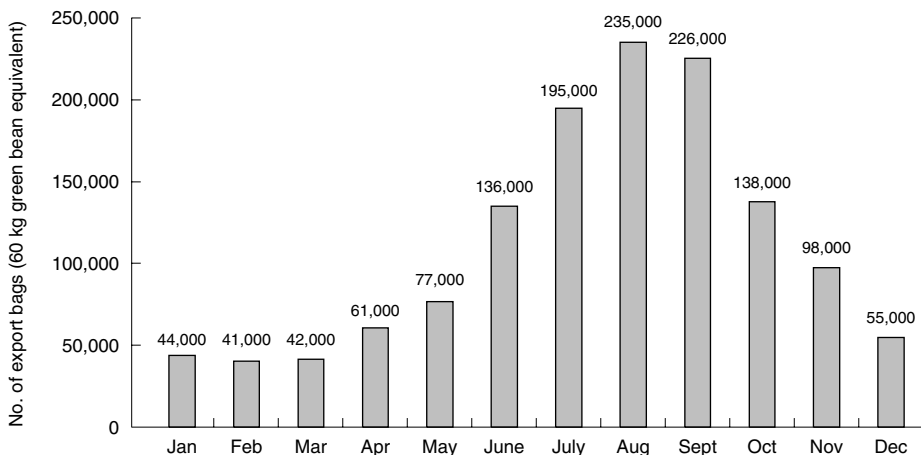


Figure 4. PNG coffee exports, 1998. (Stapelton et al. 1998).

conditions do not flower heavily. Coffee growing above 1800 metres above sea level, which does not normally yield as well as coffee at lower altitudes due to lower ambient temperature, also had massive flowerings in 1997 that resulted in exceptionally high yields in 1998.

The 1997–98 green bean coffee exports from PNG were more than 1.2 million 60 kilogram bags. This is the highest level of exports on record, apart from 1988–89 (Stapleton et al. 1998). While some of this increase may have been due to people selling coffee from village stores in order to release cash to buy food, the major part of the increase was caused by the excellent drought tolerance of Arabica coffee and its ability to survive low soil moisture regimes and to respond quickly when soil moisture recovers again.

Acknowledgments

The PNG Coffee Research Institute provided coffee yield figures and rainfall data.

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