APPENDIX 2

WATER BALANCE ACCOUNTING TECHNIQUES USED FOR ANEITYUM AND TANNA

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Water balance accounting techniques provide a means of analysing the individual components of the hydrological cycle. The main components are rainfall, evaporation, runoff and soil moisture storage, and water balance analysis allows comparison between these components over time and space. The analysis allows estimates to be made of components which are difficult or impossible to measure, such as estimates of past soil moisture regimes (Mather 1978). Estimates of soil moisture regimes through time may be used to assess the frequency and duration of soil water deficits that might be significant for production of crops such as taro.

The form of the water balance accounting used for this analysis is based on a generalised water balance model described by Keig and McAlpine (1974). The models are calculated on a weekly time interval and, by estimating inputs and withdrawals of moisture from soil, provide information on the nature of changing soil moisture levels. The models function thus:

1. An estimate is made of the maximum soil water capacity which is available to the plant or crop. This is normally the amount of available water that can be held within the rooting depth of the plant. Available water is the amount that can be withdrawn from the soil between wilting point of the plant (approx. 15 bars pressure) and field capacity (approx. .3 bars). Field capacity can be thought of as the point at which a saturated soil ceases to drain. The maximum available water capacity of the soil can be estimated from standard tables such as Strahler (1960), from where Figure 2.3 is taken, if no direct measurements are available.

2. Total weekly rainfall is taken as input to soil moisture storage (the actual amount of moisture in the soil at any given week).

When soil moisture storage exceeds the maximum available water capacity, the excess is considered to be water surplus available for deep percolation or runoff.

3. Weekly withdrawals of moisture from soil result from evapotranspiration from plant and soil. These are calculated as a function of measures of estimated free water evaporation. The functional relationship requires:
   a. An estimate for each week of the year of the ratio of maximum potential evapotranspiration for the plant or crop, given that soil moisture is freely available (i.e. close to maximum available water capacity). The purpose here is to simulate the seasonal variability in the plant's or crop's rate of withdrawal of moisture from the soil.
   b. The relationship of actual evapotranspiration to the amount of moisture present in the soil. In fact soil water levels may be such as to restrict evapotranspiration in reaching its potential rate. The purpose here is to simulate the changing rate at which moisture will be withdrawn from soil between field capacity and wilting point. The form of the relationship will depend on the soil type, as shown in Fig. 2.4.
4. The water balance calculations proceed on this basis giving weekly estimates of soil moisture levels, water surplus, and evapotranspiration.

To investigate crop water demands and availability for taro in the south of Vanuatu, data for two stations on Tanna and Aneityum were analysed by means of water balance procedures. Actual weekly rainfall for the period 1958 to 1978 was applied. Estimates of mean monthly free water evaporation for a sunken tank evaporimeter were calculated using maximum and minimum temperature and estimates of vapour pressure by the method of Fitzpatrick (1963). It should be noted that these show a minimum in the low sun period (see Fig. 2.5) as could be expected and thus the Penman estimates presented by Quantin (1979: 3) are anomalous in this respect and must be rejected. Fifty-two mean weekly estimates of evaporation were derived from these mean monthly estimates by Fourier analysis.

Although long term measurements or estimates of actual evaporation are not available, this is not a limitation in this application as it will only result in more conservative estimates of soil water deficits. The reason for this is that net withdrawals from soil moisture storage will be at a maximum in those weeks where there is no rainfall. It could also be expected that in those weeks radiation and other conditions could be such as to result in higher evaporation rates than average. In this application of water balance however only the average figure is used, thus giving a lower and more conservative estimate of the level of decrease of soil water for this situation.

The available water capacity of the soil has been estimated at 100 mm and the soils generally used for taro production are taken to be clay loams. The relation between actual evapotranspiration and the soil moisture conditions for this soil is shown in line (b) of Fig. 2.4.

Two sub-models have been employed in this analysis. The first using the data and parameters given above assumes a potential maximum evapotranspiration for a generalised vegetation cover (such as secondary forest) to be 0.7 of free water evaporation for each week of the year. This has been used to give a representation of the soil water deficit at the two stations given a non-irrigated generalised vegetation cover. The average values of each component of the water balance for the two stations are shown in Fig. 2.5. Fig. 2.6 presents the sequences of significant and severe soil water deficit periods for the two stations. It can be seen that at Tanna there is a chance of crop stress every year and that in one out of every two years the stress is severe. This condition would probably result in crop failure. The incidence at Aneityum is less severe although still significant, and crop production would certainly not be at an optimum without irrigation.

The second sub-model simulates taro production more closely. Kato et al. (1969) present potential evapotranspiration coefficients during a crop production sequence for Colocasia in Japan which after establishment and during tuber development range from 1.0 to 1.4. Allowing for differences in seasonality between Japan and Vanuatu and taking into account factors such as differing advection and saturation deficit conditions, it is likely that these coefficients would range around .9 to 1.1. A value has been derived of 1.0 and applied throughout the year for this use of the model, which assumes no set planting season. The results are presented in Fig. 2.7 which gives the sequences of significant and severe water deficit periods for the two stations, given Colocasia taro as the crop grown. Results are discussed in the text (pages 14-15).