

A note on inter-annual rainfall variability and water demand in the Johannesburg region

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Abstract

The demand for water in the Johannesburg area is strongly influenced by inter-annual rainfall variability mainly toward the end of the rainfall season. During the winter and early part of the rainfall season, water demand is largely unaffected by rainfall variability. The relationship is strongest from about February to May and in November, when water demand decreases with both rainfall and number of rain days. The development of skilful seasonal rainfall forecasts could provide useful indications of expected water consumption in the Johannesburg region.

Introduction

South Africa experiences a high degree of inter-annual rainfall variability with drought and wet years occurring frequently. For this reason, the careful management of water resources is a high priority. Over the last three decades the consumption of water in the Johannesburg area has risen steadily with growth in the population of the area. This increase in demand is putting increasing pressure on the limited water resources of the area. A large proportion of the domestic demand for water can be accounted for by the watering of lawns and gardens, and may be influenced by rainfall variability. The aim in this note is to identify any statistical association between rainfall and water consumption that may be useful in developing a forecasting capability of water demand.

Data and methods

Monthly data on purchases of water from Rand Water from January 1965 to December 1993 were obtained from the Water and Gas Department of the Johannesburg City Council. Apart from boreholes, the purchases represent the sole source for industrial and domestic consumers of water in the Johannesburg area. The water purchase data are therefore a good representation of total water consumption.

There is a significant upward long-term trend in the water purchases (Fig. 1), resulting from the growth in population of the Johannesburg area. The long-term trend was interrupted by the imposition of water restrictions from March 1983 to November 1987 when water purchases were artificially reduced. Detrending of the data must make allowance for the effects of the restrictions. The first few years of the data set, before the restrictions were imposed, were detrended by fitting a linear regression line and calculating the residuals (Montgomery and Peck, 1992). Immediately after restrictions were imposed, water purchases declined rapidly for a number of months before reaching a relatively stable level. After the lifting of restrictions, purchases did not immediately return to their pre-1983 levels but did increase fairly rapidly. A two-phase regression line (Solow, 1987) was therefore fitted to the data during the period of restrictions and the residuals calculated around this segmented line. The two-phase regression line indicates that demand decreased steadily over a period of eight

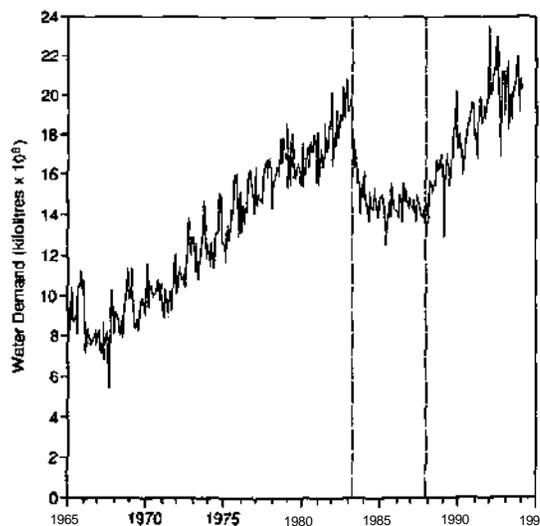


Figure 1

Detrended monthly water purchases from Rand Water for the period January 1965 to December 1993. The period of water restrictions from March 1983 to November 1987 is shown by the vertical lines.

months before reaching a new reduced level. Finally, a separate regression line was fitted to the period after the restrictions were lifted and again the residuals were calculated. The residuals were then added to the long-term mean across the entire period to provide a detrended series of water purchases (Fig. 2).

A rainfall index for the Johannesburg region was calculated from the daily rainfall records of four South African Weather Bureau-approved rain-gauge sites in the area. Rain-gauge sites were chosen on the basis of location and completeness of records over the period January 1965 to December 1993. Data for Leeuwkop Prison, Jan Smuts Airport, Vereeniging, and Krugersdorp were used. For each of the four rainfall stations, monthly totals and number of rain days were calculated from the daily data and then converted to percentage departures from the long-term mean. The percentage departures were then averaged across all four stations to provide indices of amounts and number of rain days representative of the whole Johannesburg area.

The monthly rainfall and rain-day time series were correlated with the monthly water purchases data to identify whether the

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