Short communication

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

SJ Mason* and AM Joubert

Climatology Research Group, University of the Witwatersrand, Private Bag 3, Johannesburg 2050, South Africa

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

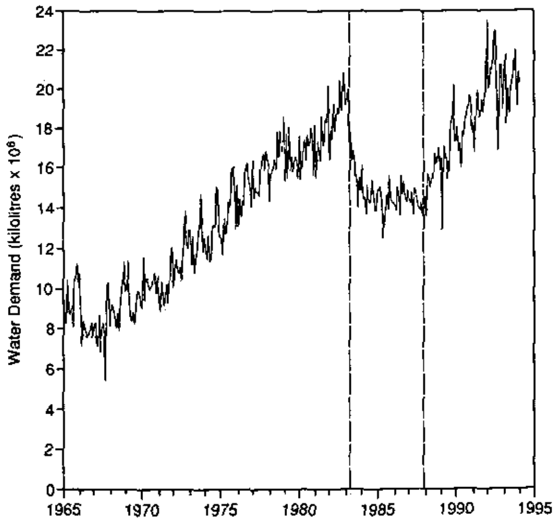

Figure 1

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

* To whom all correspondence should be addressed.
☎(011) 716-2993; Fax (011) 716-3161; e-mail simon@crg.bpb.wits.ac.za
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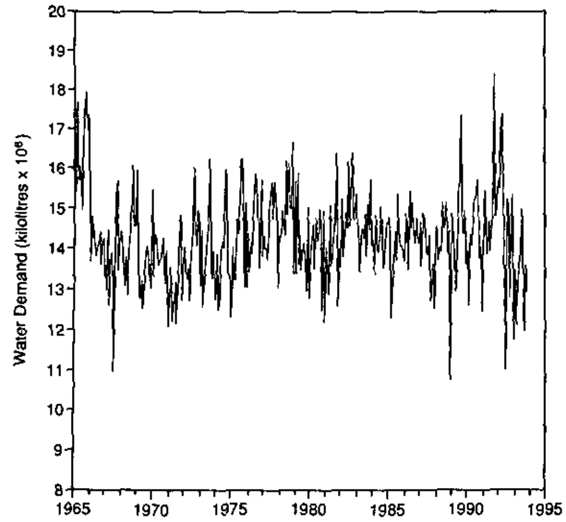

Figure 2

Detrended monthly water purchases from Rand Water for the period January 1965 to December 1993.

TABLE 1
CORRELATIONS BETWEEN WATER PURCHASES AND MONTHLY RAINFALL TOTALS AND RAIN DAYS, 1965 TO 1993. AN ASTERISK INDICATES A CORRELATION THAT IS SIGNIFICANT ABOVE THE 99% LEVEL.

Month	Correlation	
	Rainfall total	Rain days
January	-0.220	-0.380*
February	-0.457*	-0.250*
March	-0.282*	-0.252*
April	-0.506*	-0.497*
May	-0.334*	-0.571*
June	+0.095	-0.068
July	-0.022	-0.047
August	-0.036	-0.096
September	+0.005	+0.110
October	-0.363*	-0.020
November	-0.399*	-0.478*
December	-0.280*	-0.218

demand for water in any given month is affected by the amount of rainfall received in that month. The calculation was performed on each calendar month separately.

Results

Significant correlations between water purchases and monthly rainfall totals are evident throughout the year except for the winter period June to September when rainfall totals are very low (Table 1). The correlations are strongest during February and April. Throughout the rainfall season water purchases tend to be higher during months that are drier than normal. Conversely, water purchases decrease during months that are wetter than normal. Significant correlations between water purchases and the number of monthly rainfall days are also evident throughout the rainfall season (Table 1). As with the rainfall totals, correlations are poor during the winter period June to October when rainfall totals are very low. The association is strongest during April to May at the end of the wet season (Table 1). Again the correlations are negative, suggesting that water purchases are greater during months that have fewer than normal rain days, and lower during months with more rain days than normal.

The effects of rainfall on water purchases are strongest at the end of the wet season, suggesting that an early end to the season can result in a significant increase in the purchases of water at that time of year. In addition, correlations with number of rain days are strong during November, shortly after the beginning of the season. A possible explanation is that November is often the first month in which significant rains are recorded. Infrequent rain events during the early part of the season can result in large increases in the demand for water. During the peak rainfall months of December and January, demand for water is low because of the closure of factories and the migration of people during the holidays. Correlations between water demand and rainfall are weak at this time of year because of the low domestic demand for water.

Summary

The demand for water in the Johannesburg area, as measured by water purchases from Rand Water, is strongly influenced by rainfall. Correlations between rainfall amount and water demand indicate a decreased demand during periods of increased rainfall. Similarly, during months of increased number of rain days, water purchases tend to decrease. It has been shown, however, that the relationship between water demand and rainfall is evident only at certain times of the year. The effect of rainfall on water demand is strongest during the summer, and particularly at the end of the wet season. Given the relationship between rainfall and water demand, it should be possible to provide reasonable estimates of future demand based on an understanding of possible future rainfall conditions.

Acknowledgements

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