

Generalised Storage-Yield-Reliability Relationships for the Sizing of Rainwater Harvesting Systems in South Africa

ABSTRACT

A challenge that still exists in rainwater harvesting system (RWHS) design is the need for quick and accurate tools with which to determine the appropriate dimensions of the system given specific performance criteria. Very limited work has been done in southern Africa for the development of models or general guidelines to assist in the design and simplified assessment of RWHS across any scale. This study was therefore carried out using multiple daily simulations and regression analysis on a sample of 118 rainfall gauging stations located across South Africa, with the goal of improving the predictive abilities of a recently developed generalized storage-yield-reliability model. This was achieved through a re-evaluation of the relationships between the key variables of interest namely: the supply-demand ratio, yield ratio and storage-demand ratio, rainfall variability characteristics, rainwater losses and variability of demand.

Regression analysis on the data collected under conditions of constant unvaried demand revealed the non-linear power model to fit the relationship between the ratio of supply-demand and yield ratio best, whilst the non-linear exponential model fitted the relationship between the storage-demand ratio and the yield ratio the best. Variability in demand was modelled using a wave function whose amplitude quantified the magnitude of variability and whose lag quantified the time difference between the peak demand and the peak of the 61-day moving average rainfall. Variability in demand was found to affect the number of days of supply from a RWHS and the magnitude of this effect depends on both lag and amplitude. However, the two parameters of amplitude and lag have a limited impact on the optimum tank size. It was also noted that areas with rainfall peaks in December, January and June tend to show high sensitivity to the lag whilst areas with rainfall peaks in March and September appear minimally sensitive to the same. A new parameter relating number of days of supply under variable demand to the number of days of supply under constant demand is proposed and regression against amplitude, lag, supply-demand ratio and reliability is done. Three sets of regression models are proposed and analysed, two of which account for the effects of rainfall variability through incorporation of the coefficient of variation of daily rainfall and the ratio of dry days to rainy days. An adjustment to the supply-demand ratio to account for rainwater losses by first flush is also explored.

Verification of the models incorporating rainfall variability characteristics and those that do not indicates that incorporating rainfall characteristics results in some improvement in the prediction of the number of days of supply and tank size.

However if only average annual rainfall (MAP) data is available, a model whose only climatic input is the MAP could still be satisfactorily used to estimate tank size and number of days of supply for a RWHS. The extended model that incorporates rainfall variability characteristics nonetheless offers better predictive performance as it is able to distinguish the effects of two different rainfall intra-annual distributions affecting systems which describe identical supply-demand values. Applying this extended model however requires the availability of daily time series data which may not be as easily available as the MAP. In conclusion, this study recommends the use of the proposed models for the basic preliminary assessment of rainwater harvesting systems in South Africa.

Key words:

Rainwater Harvesting, Storage, Yield, Reliability, Intra-annual rainfall variability, Variable demand, First flush