Interactive comment on: Determining spatial variability of dry spells; Markov based method, applied to the Makanya catchment, Tanzania by B. M. C. Fischer, M. L. Mul and H. H. G. Savenije

We would like to thank the anonymous Referee #2 for his/her review and valuable notes to improve the manuscript. In the final version of the manuscript we will correct the issues pointed out by Referee #2 and as we already stated in the comments to Dr. Bazrafshan's we will strengthen the section of the uniqueness of this study. Below we respond to the specific comments made.

Application, Data scarcity & Correction factor for precipitation

We agree with the comment from Reviewer #2 that in order to obtain reliable dry spell maps, high spatially distributed information is required for a long time period. This is not the case for the Makanya catchment, where data availability is problematic by the lack of long term measurements. Therefore we combined spatial scarce but long time series with spatial high resolution short time series of one season. Our approach is downscaling the long term information obtained from the Same data set, to the spatially distributed Makanya data set. There are uncertainties associated with this approach, but this can be applied in other data scarce areas. We mentioned this also in the discussion sections. With the assumption of applying one correction factor for the rain gauge of Same (0.55 [-]) creating a "synthetic" rainfall map, we could show that dry spells have a more complex spatial structure compared to previous studies like Tilya and Mhita (2007). The method gives better spatial information; further research should focus on further refining this correction factor.

Soil moisture

Regarding the comment of Reviewer #2 on the use of one value for soil moisture, we would like to correct the reviewer that we have in fact used three different values of soil moisture at three locations in the Makanya catchment. A fully spatially distributed dry spell map would require spatially distributed information on the soil moisture. As this was not available, we demonstrated the method at three locations with different soil moisture values.

Abstract

Regarding the title of the maps produced in the paper, we agree with the reviewer and will rename the figures and references in the text as "dry spell length map for fixed probabilities of non-exceedance p_{ne} = 80%, 50% and 20%"

1. Introduction

It is correct that the introduction should illustrate the main purpose of this study and as stated previously this will be corrected to underline the uniqueness of this study.

2.4 Probability of dry spell duration

Section 2.4 will be modified from line 2, p.11714 onwards:

De Groen (2002) showed that the probability (*p)* of a maximum dry spell length ($n_{dry,max}$) can be written as a cumulative density function based on transition probabilities p_{01} and p_{11} , n_m (days per month) and number of *n* (days). Assuming that a dry spell is not longer than a the number of a month or season (n_{ls}) de

Groen (2002) showed that rewriting Eq. 9 for a point, with given probability of non-exceedance (p_{ne}) , results into the maximum dry spell length ($n_{dry,max}$) Eq.10.

$$p\left(n_{dry,max} \leq n\right) = exp\left[-n_m\left(\frac{p_{01}}{1-(p_{11}-p_{01})}\right)(1-p_{11})(1-p_{01})^n\right] \quad (9)$$

$$n_{dry,max}(p_{ne}) = \frac{\ln\left(\frac{\ln(p_{ne})}{-n_{ls}\left(\frac{p_{01}}{p_{11}-p_{01}}\right)(1-p_{11})}\right)}{\ln(1-p_{01})} \quad (10)$$

3.1 Markov properties

It is correct that for the calculation of the transition probabilities per month, only one value is provided, the approach taken is to derive the values for each month and to combine these months into one graph. We will try to explain this better in the text. From line 15, p.11715 onwards will be modified to:

The Markov properties were determined by testing two methods using the eight available rain gauges of the Pangani basin (period 1940-1989, Fig. 1):

(1) For every individual month (March, April and May) the transition probabilities (p_{01} *and* p_{11}) are expressed as function of their monthly rainfall amounts (all months are presented in one graph). This resembles a seasonal average power function with parameters *a*, *b* and R^2 (Table 1) used in Eqs. (5) and (7).

(2) For a season as a whole (March - May) the transition probabilities (p_{01} *and* p_{11}) are expressed as a function of the seasonal rainfall amounts to derive the seasonal parameters *a*, *b* and R^2 (Table 1) using Eqs. (5) and (7).

Minor comments

1. Introduction

As recommended by the Reviewer# 2, the sentence of line 26, p.11708 will we modified: …population is growing rapidly and a shift to a more land and water resource intensive diet is expected (Savenije, 1999; WWAP, 2009), requiring more use of the resources.

2.2 Markov-based framework for critical dry spell analysis

A description of the flow chart of Fig. 2 will be added to the text in section 2.2.

We will rephrase the sentence "..in the Makanya catchment for which a short, but high spatial resolution data set on rainfall exists." To ".. in the Makanya catchment for which a short, but high spatial resolution data set on rainfall exists. Data for sixteen rain gauges for the year 2006 were used for further analysis."

Regarding the length of the rainfall data in the Pangani River Basin, indeed some of the stations have up to 90 year of daily data, for the analysis we used a sub-section of this data (8 rain gauges from 1949-1989), due to the availability of data and data quality. We will add a line to this sense indicating the above explanation:

"A selection of rain gauges was made based on record length, data quality and consistency. This resulted in eight rain gauges with daily rainfall data covering the period of 1940-1989 (Fig. 1)."

2.3 Spatially distributed Markov chain properties

To avoid confusion or misunderstanding the symbols in the text and equations will be modified:

To remain consistent with hydrology, the capital letter *P* is used as symbol for precipitation. The lower case letter *p* will be used for probabilities with subscripts for transition probabilities of a dry day is followed by a wet day, transition probability of a wet day after a wet day and probability of non-exceedence respectively p_{01}, p_{11} *and* p_{ne}.

2.5 Critical dry spell

We will update the reference to fig. 4, which actually refers to the location of the two Class A-pans as follows: "Data collected from a Class A-pan in locations 2 (Valley) and 3 (Mountain) was used to determine the potential evaporation (see Fig. 4 for locations)."

We follow the suggestion of Referee #2 and update the sentence of line 10-13 p.11715 to: “The critical dry spell length is then compared with maximum dry spell length derived from Eq. (10) for different probability values”.

3.1 Markov properties

To improve lines 18-22, p.11715 sentences will be rewritten as:

Figs. 3a and 3b for the seasonal transition probability values show large scatter. To demonstrate the stability of the power function the approach of De Groen (2006) was followed. Here individual transition probabilities were clustered in 6 rainfall classes with their median transition probabilities plotted using the grey squares in Figs. 3a and 3b.

In the next version of the manuscript equations for the R^2 and F-test will be added.

We will rename Fig. 4 to represent what is depicted in the figure, namely "dry spell length map for fixed probabilities of non-exceedance p_{ne} = 80%, 50% and 20%". We will also update the reference in the text.

3.2 Dry spell maps

We agree with Referee #2 to rephrase the lines 22-23, p.11716: "These three figures show the spatial distribution of dry spell length for different probabilities of non-exceedance p_{ne} = 80%, 50% and 20% (based on Eq. 9)."

Reference

De Groen, M. M.: Modelling interception and transpiration at monthly time steps; introducing daily variability through Markov chains, PhD thesis Delft University of Technology, The Netherlands, 211 pages, 2002.

De Groen, M. M. and Savenije, H. H. G.: A monthly interception equation based on the statistical characteristics of daily rainfall, Water Resour. Res., 42, W12417,doi:10.1029/2006WR005013, 2006.

Tilya, F. and Mhita, M.: Frequency of Wet and Dry Spells in Tanzania, Environ. Sci. Eng., 197– 204, doi:10.1007/978-3-540-72438-4-10, 2007.