Assessment of soil moisture budget using a water balance model and use of model results for drought early warning. Case of a moderate semi arid watershed in northern Tunisia

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Motivation

- Drought is an adverse meteorological situation.

- Economical issues of drought have multiple faces such as deficit of the trade balance, food insecurity and loss of population incomes.

- For an agricultural country such as Tunisia, drought preparedness is an important task.

- The purpose of this study is to build an early warning drought system on the basis of watershed water balance assessment.
basin physiographic characteristics

- Oussafa watershed
- Semi arid climate conditions
- Area: 397 km²
- Maximum elevation: 1294 m
- Minimum elevation: 508 m
- Concentration time: 16 h
hydrometeorological Data

• Observed river discharge series cover three periods: 1928-1938; 1960-1963; 1966-1972;
• Observed daily rainfall series are available during the period 1928-1982.
• Monthly Piche evapotransporimeter data are available for 8 years and help estimating monthly averages.
Average monthly precipitation mm

monthly average rainfall mm
Average Monthly Piche evaporometer mm
Example of daily time series of rainfall and runoff volumes (1960-1961 / 1962-1963)
The model (BBH Bucket Buttomo Hole)

- **The Kobayachi et al. (2001)** water balance model is adopted at daily time scale. It is a single soil bucket model.

- Model reparametization so as to limit the number of tuning parameters to three have been performed (**Bargaoui et Houcine, 2010**). Remaining (four) parameters are estimated according to soil texture information.

- It represents at watershed scale the water flux exchanges between the atmosphere, the root zone as well as exchanges with deeper soil horizons (percolation and capillary rise).

  - \( W_t \): soil water content (mm) at day \( t \)
  - \( P_t \): precipitation (mm)
  - \( ETR_t \): Actual evapotranspiration (mm)
  - \( R_{st} \): Surface Runoff (mm)
  - Percolation (\( G_{dt} > 0 \)) (mm)
  - Capillary rise (\( G_{dt} < 0 \)) (mm)

\[
W_{t+1} = W_t + P_t - ETR_t - R_{st} - G_{dt} + ETP_t
\]

Initial value \( W_0 \)
The model calibration criteria

• The annual runoff bias < 20%,
• The Nash Sutcliffe coefficient > 0.4 for decadal and monthly time scales,
• The simulated vegetation relative productivity (Eagleson, 1994) representing the ratio $K_v = \frac{ETR_{an}}{ETP_{an}}$ (at annual scale) meets semi arid conditions of the watershed.
The model verification

• The model is calibrated using data from a given calibration period
• Sets of calibrated parameters are used to run the model and test its performance for other observation periods.
• The sets of parameters giving the best performance compromise with respect to both calibration and testing periods are retained.
• The average model output is assumed as model output (mean model).
The soil water content analysis

- Monthly soil water content are computed for the simulated series
- Minimum and maximum monthly values are reported
- Monthly Percentiles are estimated
- A comparison to some fixed percentiles (0.15; 0.20; 0.30; 0.5) is completed.
Results

• Simulated and observed runoff during the calibraton period (1928-1933) are reported versus precipitation inputs at
  – monthly and
  – yearly resolutions.

• They report acceptable matching for high and moderate runoff.

• However, the model underestimates small runoff values.

• The existence of springs upstream might explain this mismatching.
Simulated and observed runoff compared to precipitation inputs at monthly resolution

inverse runoff (1/ mm)

monthly precipitation (1928-1933)

Obs runoff
Mean Mod runoff
Simulated and observed runoff compared to precipitation inputs at annual resolution (test period 1972-1982)
Interannual and inter mensual Variability of simulated soil water content (sample distribution of monthly values)

November (fall) peak

March (spring) peak

Seasonal variation of monthly median W

Simulated soil water content at monthly resolution (1972-1980)
Simulated monthly soil water content values compared to precipitation data (1972-1982)

Months that are important for crop yield are November, February, March, April.

Those for which the 0.15 percentile is not exceeded are indicated in orange in the table.


Months indicated « Orange » for soil water content are either « orange » for precipitation or in shortage (rainfall < 0.30 percentile) or in deficit during preceding months.

If they are not in situation of important rainfall deficit (<0.3 Percentile) for the actual month, they were in that case either in the precedent month or in the precedent two months.

If a month has a severe precipitation deficit but a surplus was in place during the precedent month, soil water content is not identified as « orange » (example of April 1973).
Conclusions

• A lumped water balance model at watershed scale is worth to assess drought occurrence at monthly scale provided that potential evapotranspiration, rainfall and river discharge data are available for its calibration and quality assessment.

• Drought identification using simulated soil water content analysis differ from identification using only rainfall data.

• Monthly shortages or deficits detected on the basis of soil water content come either from a rainfall deficit in the present month or in the two previous months.
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