Application of a Basin Scale Hydrological Model for Characterizing flow and Drought Trend

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Contents

- Introduction
- Study area description and data
- Statement of problems and Objectives
- Methodology
  - Simulation model (SWAT)
  - Analysis of hydrological drought: threshold level and streamflow drought index
- Results and Conclusions
Introduction: How extreme climate hits Thailand?

Areas affected by flooding:
- Severely affected
- Critically affected
- Affected
- Under restoration
- Flood warnings

Source: thaiflood.com

Floods vs. Droughts
Types of drought

Relationship between meteorological, agricultural, hydrological and socio-economic drought
(Source: national Drought Mitigation Center, University of Nebraska-Lincon, USA)

a lack of precipitation over the region for a period of time

declining of soil moisture and consequent crop failure without any reference to surface water resourced

inadequate surface and subsurface water resources

failure of water resources systems to meet water demands occurring when demand exceeds supply

(http://drought.unl.edu/whatis/concept.htm)
Study area

- Total catchment Area: 49,477 km² (60 % rainfed agricultural area)
- Most area is high plateau (steep at the upstream mountain area and flat at the lower part)
- The tropical monsoon region

Drought events:
- Dry spells always occurred in Jun –July: an important period for agriculture
- Dry up in river always occurred in dry season
- Frequency, severity and duration of drought are higher than other regions (Suwanabatr and Mekhora, 2002).
Statement of problems

• Thailand: experienced with repeated deficit of river discharges but there is still less research conducted for hydrological drought analysis in the basin.

• The suitable evaluation will be useful to predict and monitor drought events in the future leading to a disaster risk reduction through early warning.

Objectives

propose the criterion for evaluating hydrological drought using two methods; the threshold level method and the standardized streamflow drought index (SDI).
Scope of this study

Data collection
- Meteorological data:
  - Precipitation
  - Winds speed
  - Relative humidity
  - Solar radiation
  - Temperature
- GIS data:
  - DEM
  - Soil map
  - Land use map

Hydrological model
- SWAT model
- Sensitivity analysis
- Calibration and validation
- Flow time series

Drought Analysis
- Threshold level method
- Standardized drought index (SDI)
Methodology: Hydrological Simulation Model

The Schematic Hydrologic Cycle

Evaporation and Transpiration

Root Zone

Vadose Zone

Unconfined aquifer

Confined aquifer

Infiltration/plant uptake/Soil moisture redistribution

Revap from shallow aquifer

Percolation

Flow out of watershed

Surface Runoff

Precipitation

Lateral Flow

Return Flow (baseflow)

Recharge to deep aquifer

SW = Soil Water Content (mm H2O)
Rday = Amount of precipitation
Qsurf = Amount of surface runoff
ET = Amount of daily evapotranspiration
Wseep = Amount of water entering the vadose zone from the soil profile
Qgw = Amount of return flow
Methodology: SWAT Simulation model

- steep slope at the upstream mountain area and flat at the lower part.

**Land use**
- Rice 43.5%
- Forest deciduous 20.4%
- Agricultural area 25.4% (cassava, corn, sugarcane)
- Others 19.0%

**Soil Types**
- Loam
- Sandy clay
- Clay loam

**HRU Determination**

**Sensitivity Analysis**

**Calibration and Validation**

**Simulated Flow Evaluation**

**Flow simulation**

**Base flow Separation: Automated Base flow Separation &Recession Analysis Technique (Arnold et al.1995)**

**Watershed Delineation**

**DEM**
1) **Threshold level method:** a constant or a variables threshold which can be chosen in several ways: the mean or median over a long period of flows.
Methodology: Drought Analysis

**Standardized Streamflow drought index (SDI)**
- identical to the monthly standardized streamflow volume.

To calculate SDI index, average of monthly streamflow was estimated as following formula:

\[
v_i = \text{mean} \left( \sum_{0}^{j} v_{ij} \right)
\]

designed drought characteristic by standardized streamflow volume, which used threshold level as monthly basis as follows:

\[
SD = \frac{v_i - \overline{v_i}}{S_i}
\]
Results: Calibration and Validation model

Parameters | Description | Model default
---|---|---
CN | Initial SCS CN II | 10% to +10%
Esco | Soil evaporation compensation factor | 0.01-1.0
SOL_AWC | Available water capacity | 15% to +15%
Alpha_BF | Baseflow alpha factor | 0.0-1.0
GW_REVEP | Groundwater ‘revap’ coefficient | 0.02-0.2
Rchrg_dp | Deep aquifer percolation fraction | 0.5-1
Gw_Delay | Groundwater delay | 0-50 days

Calibration: Nash = 0.81  
$R^2 = 0.81$

Validation:  

Ranking of the seven most sensitive parameters

Time (monthly)
Results: Calibration and Validation model

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World Meteorological Organization (WMO) recommended a minimum density for precipitation gauge network of 100-250 km² per station for mountain area.
Results: Assessment of drought duration and severity

1) Threshold level method

Define Threshold value:
- Flow Duration Curve (FDC)

Flow Duration Curves 30 yrs (1975-2004)

95 percentile of flows
## Results: Drought duration and severity

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<tr>
<th>No.</th>
<th>Year of event</th>
<th>Onset date</th>
<th>Termination date</th>
<th>Durations (days)</th>
<th>Severity (MCM)</th>
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Results: Assessment of drought duration and severity

2) Standardized streamflow drought index (SDI)
Conclusions

The SWAT model was applied to assess changes in hydrological drought occurrences.

✓ The model performs sufficient well to simulate flow in the basin with relatively high values of coefficient of determination and Nash-Sutcliffe coefficient.
✓ Most sensitive parameters are the parameters representing surface runoff and soil properties such as CN, Esco and SOL_AWC.

Propose criteria to characterize hydrological drought conditions (in terms of duration, frequency and severity.)

✓ These results showed that the drought trends computed by threshold level and SDI are broadly consistency and likely reliable coinciding with such a kind of actual drought as El Niño events.
✓ However, drought analysis are subjective depending on objective, perspective and region of interest, thus application is much more significant.
Thank you for your attention