Session 7: Water balance

Training, Dakar, Senegal, July 2016
Trainer: Harald Kling
Pöyry, Hydro Consulting, Hydropower, Austria
Water balance

Overview

- Water balance theory

- Group work
  - Simple water balance calculation
  - Simple climate change scenario analysis
Water balance theory
Main drivers for water availability

- Climate
  - Precipitation
  - Air temperature

- Precip-Runoff Process
  - Runoff

- Water-Resources Management
  - Consumption
  - River Discharge

Evapo
Water balance

Why is it important for hydropower?

- The water balance describes how much runoff is generated from rainfall.

- Understanding the water balance is crucial for understanding regional variations in discharge, and thus hydropower potential.

- Any changes in the water balance causes changes in hydropower generation:
  - Natural variations in rainfall from year to year
  - Climate change
Water balance modelling

Basics: Annual water balance equation

Example: Upper Black Volta (Burkina Faso)

\[ \text{Precip} = \text{Runoff} + \text{Evapo} + \Delta S \]

1000 mm/y \hspace{1cm} 100 mm/y \hspace{1cm} 900 mm/y \hspace{1cm} 0 mm/y

Runoff is only a small component of the water balance!

Budyko annual water balance relationship:

\[
\frac{\text{ETA}}{P} = \left[ 1 + \left( \frac{\text{ETP}}{P} \right)^{-c} \right]^{-1/c}
\]

ETA: annual actual evapotranspiration [mm]
ETP: annual potential evapotranspiration [mm]
P: annual precipitation [mm]
c: model parameter
Water balance in West Africa

Sub-area simulation results for 1998-2014

Rainfall

Actual evapotranspiration

Runoff
Water balance

Show sub-areas
Switch view between
PRECIP_Y, ETA_Y, RUNOFF_Y
Click on sub-areas and show attributes
Annual water balance

How to make a simple water balance estimation

\[
\frac{\text{ETA}}{P} = \left[ 1 + \left( \frac{\text{ETP}}{P} \right)^{-c} \right]^{-1/c}
\]

ETA: annual actual evapotranspiration [mm]
ETP: annual potential evapotranspiration [mm]
P: annual precipitation [mm]
c: model parameter
Annual water balance

How to make a simple water balance estimation

- **Step 1: Get input data**
  - Precipitation (P) [mm]
  - Potential evapotranspiration (ETP) [mm]
  - Area [km²]

- **Step 2: Use Budyko plot**

- **Step 3:**
  Compute Runoff [mm]
  \[ \text{Runoff} = P - \text{ETA} \]

- **Step 4:**
  Compute Discharge [m³/s]
  \[ Q = \text{Runoff} \times \text{Area} / \text{Time} \]
  \[ \text{Discharge} = \text{Runoff} \times \text{Area} / (365 \times 24 \times 60 \times 60) \times 1000 \]

**ETA/P**

**ETP/P**

**c** = 2.5

\[
\frac{\text{ETA}}{P} = \left[ 1 + \left( \frac{\text{ETP}}{P} \right)^c \right]^{-1/c}
\]

ETA: annual actual evapotranspiration [mm]
ETP: annual potential evapotranspiration [mm]
P: annual precipitation [mm]
c: model parameter

**Budyko plot**

0
0.5
1
1.5
2
2.5
3

0
0.2
0.4
0.6
0.8
1

0
0.5
1
1.5
2
2.5
3

c = 2.5

SOURCE: PÖYRY
Group work

Water balance estimation

- Groups of 3-4 people (same as before)
- Select river of interest (use your maps)
- Ask me for input data from GIS

- Make water balance calculation
  - Use Budyko plot (see hand-out)
  - Compute Runoff
  - Compute Discharge

- Report results
  - We will compare to discharge value of GIS river network layer
Group work

Water balance estimation

- Reasons for difference in discharge between simple estimation and GIS river network layer
  - Different Budyko curve parameter (result of model calibration!)
  - Non-linear water balance relationship
    - In practice example we made lumped water balance calculation.
    - But water balance model was applied spatially distributed (for each river reach).
  - Diversions
    - Irrigation
    - Floodplains

- Simulation results are more sensitive in semi-arid basins than in humid basins
  - A small “error” in model parameter can cause large bias for simulated discharge of semi-arid basin
  - Discharge of semi-arid basin is also more sensitive to possible changes in climate
Group work

Water balance estimation & Climate change scenarios

- Same method as before

- Use climate change scenarios:
  - Future increase in precipitation: +10%
  - Future decrease in precipitation: -10%
  - Warming by +2°C: +5% in potential evapotranspiration

- Re-calculate the water balance for climate change scenarios
  - Use Budyko plot (see hand-out)
  - Compute Runoff
  - Compute Discharge

- Report results
  - Percentage change in discharge for climate change scenarios

Example:
Precip = 1000 mm
Precip + 10% = 1000 mm * 1.10 = 1100 mm
Precip – 10% = 1000 mm * 0.90 = 900 mm

Funded by