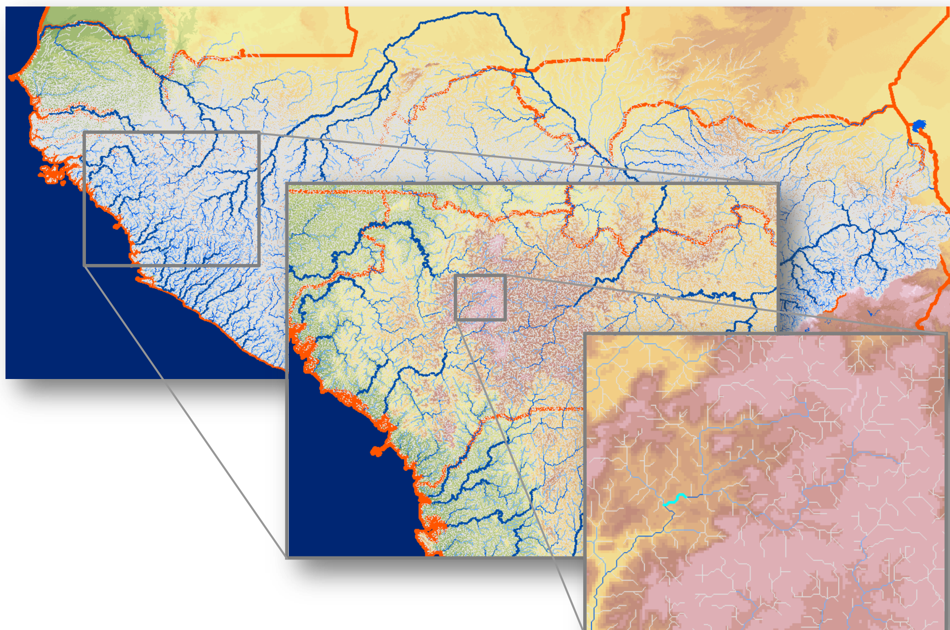
GIS Hydropower Resources Mapping for ECOWAS Region

Session 7: Water balance



Training, Dakar, Senegal, July 2016

Trainer: Harald Kling

Pöyry, Hydro Consulting, Hydropower, Austria

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Water balance

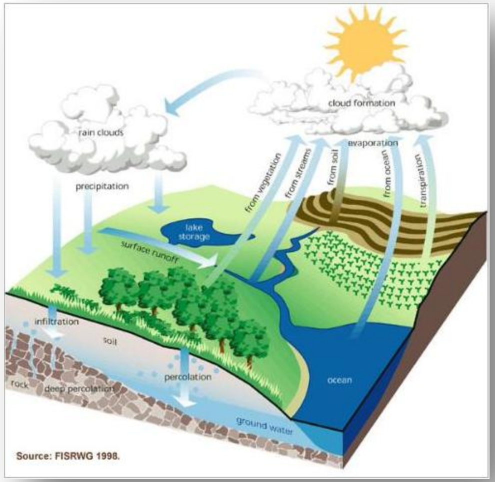
Overview

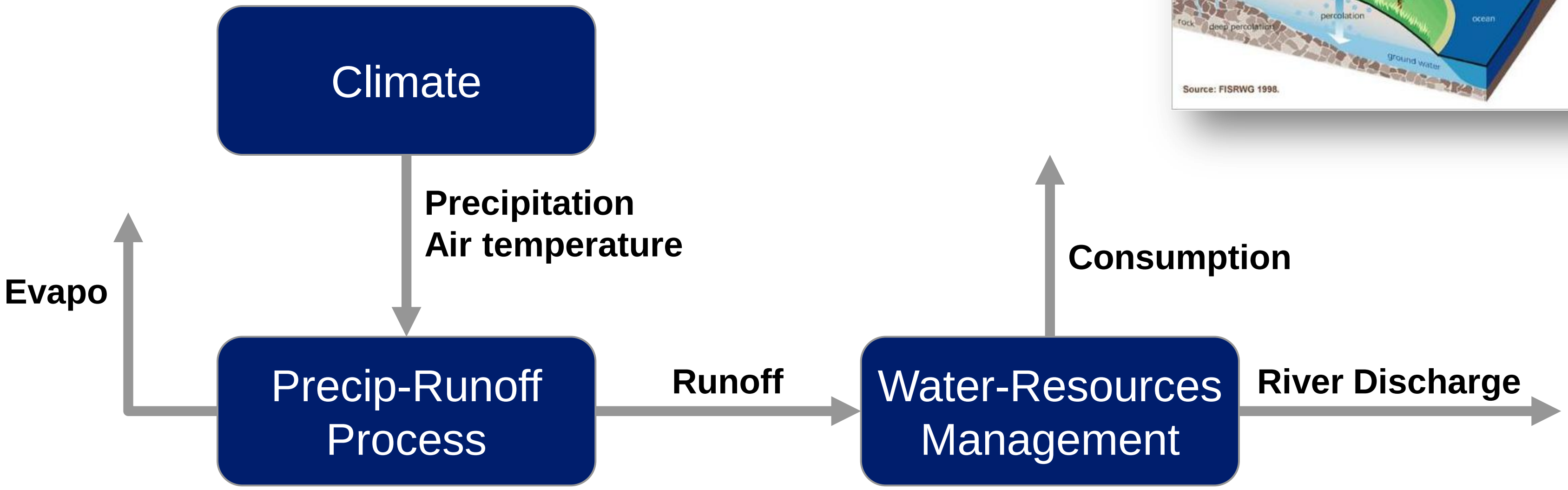
- Water balance theory

- Group work
  - Simple water balance calculation
  - Simple climate change scenario analysis

Water balance theory

Main drivers for water availability





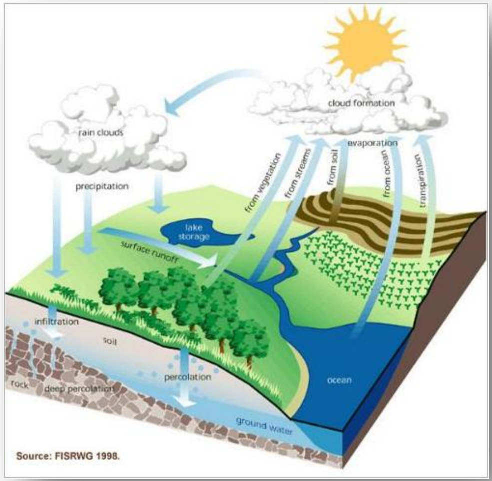
Water balance

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)

Precip = **Runoff** + **Evapo** + **ΔS**

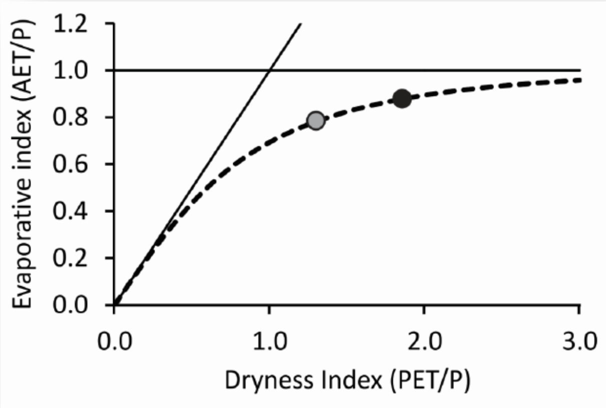
1000 mm/y | 100 mm/y | 900 mm/y | 0 mm/y

Runoff is only a small component of the water balance!

Budyko annual water balance relationship:

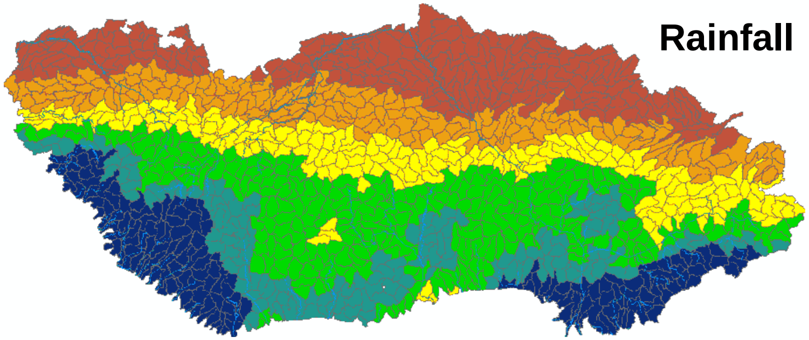
$$\frac{ETA}{P} = \left[1 + \left(\frac{ETP}{P}\right)^{-c}\right]^{-1/c}$$

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



Water balance in West Africa

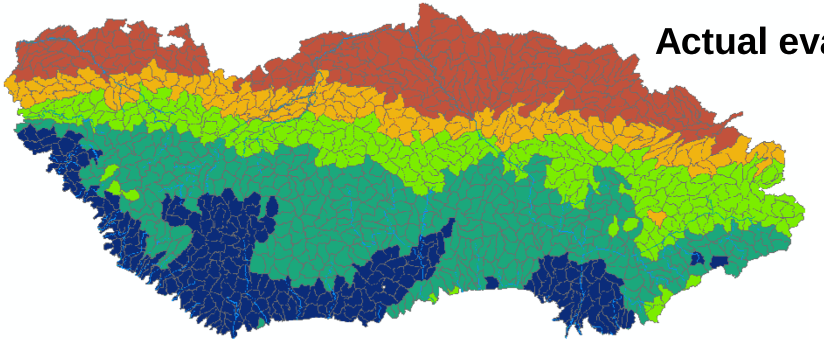
Sub-area simulation results for 1998-2014



Rainfall

[mm/a]

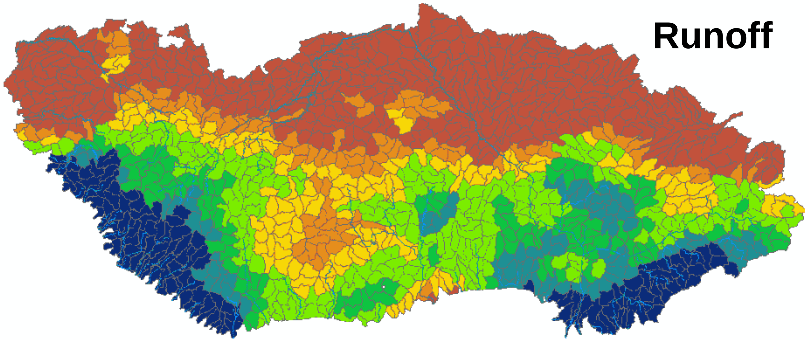
PRECIP_Y
- 204.5 - 500.0
- 500.1 - 750.0
- 750.1 - 1000.0
- 1000.1 - 1250.0
- 1250.1 - 1500.0
- 1500.1 - 2957.0



Actual evapotranspiration

[mm/a]

ETA_Y
- 204.3 - 500.0
- 500.1 - 700.0
- 700.1 - 900.0
- 900.1 - 1100.0
- 1100.1 - 1401.4



Runoff

[mm/a]

RUNOFF_Y
- 0.2 - 25.0
- 25.1 - 50.0
- 50.1 - 100.0
- 100.1 - 200.0
- 200.1 - 300.0
- 300.1 - 500.0
- 500.1 - 2041.0

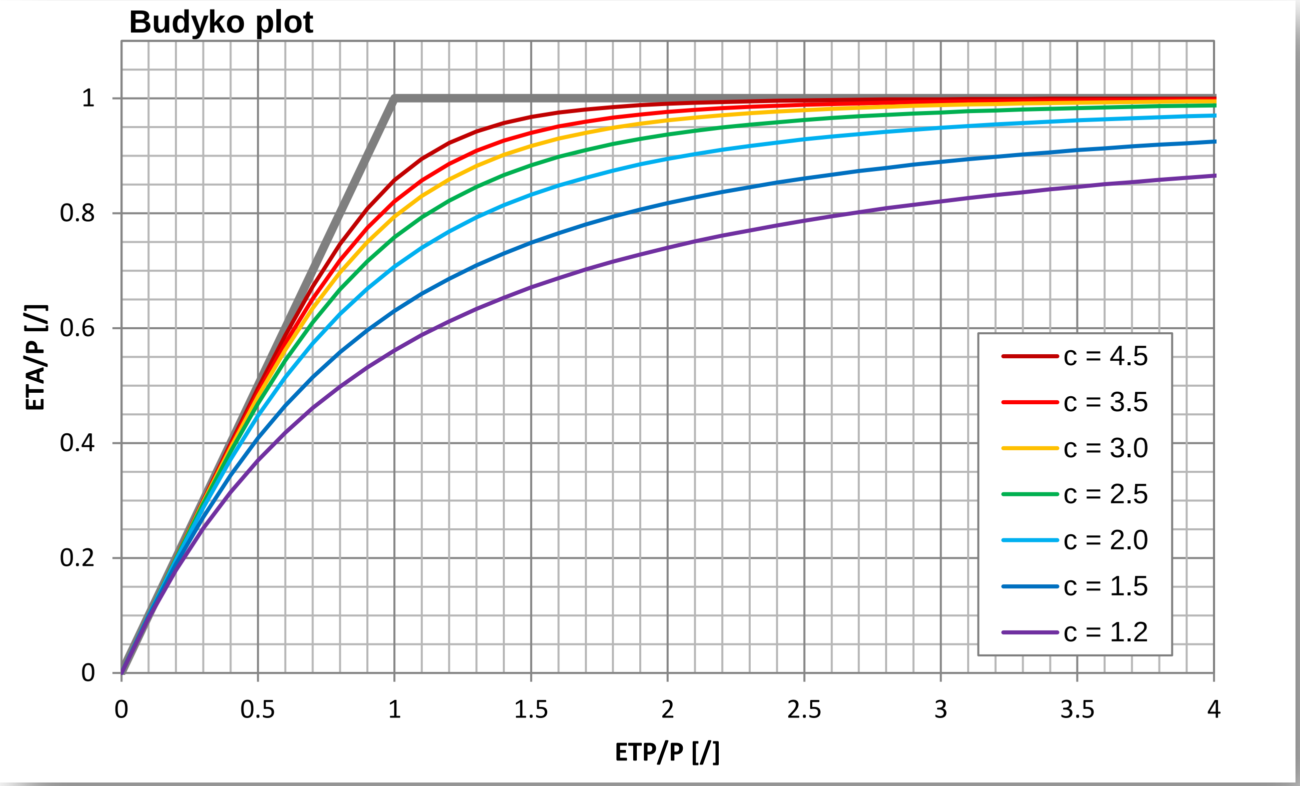
Water balance

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

switch to GIS presentation...

Annual water balance

How to make a simple water balance estimation



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

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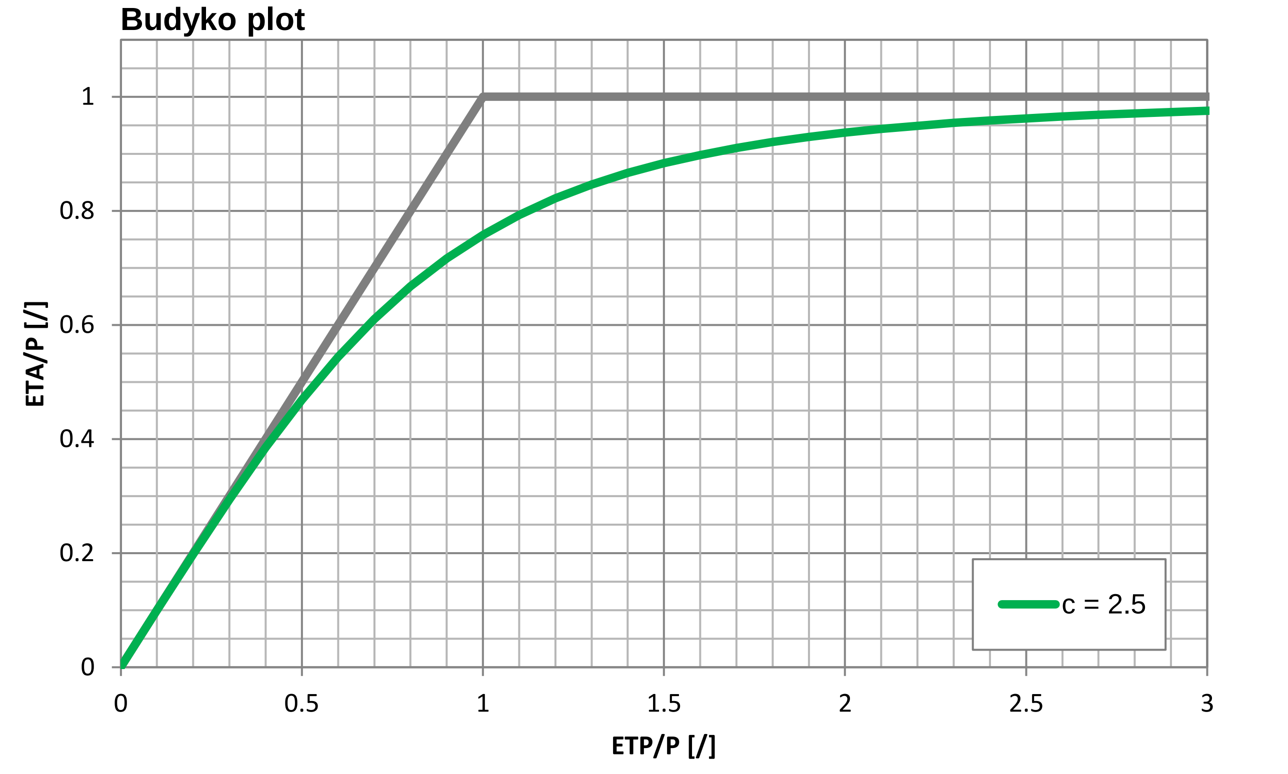
Annual water balance

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]
  Runoff = P – ETA
- Step 4:
  Compute Discharge [m³/s]
  Q = Runoff * Area / Time

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

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

Discharge [m³/s] = Runoff [mm] * Area [km²] / Time [s] * 1000
Time [s] = 365 days * 24 hours * 60 minutes * 60 seconds

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

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

- 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

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