Using ArcSWAT for Evaluation of Water Productivity and Economics of Crops in Canal Irrigation Command

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Importance of Irrigation Water Management in Water Scarce Regions

Development of framework using SWAT for irrigation water management of command area

Case study

Application: Root zone moisture status, Crop Net benefit and Water Use Efficiency
Water - most critical natural resource for agriculture in the twenty-first century

Use of water for irrigation is by far the greatest consumer of fresh water globally

Irrigated regions globally consume more than 70% of the world’s water resources

Saving just a small amount of water destined for irrigation and using it for drinking purpose instead, could improve the living conditions of millions of people

Increasing irrigation efficiencies seem to be the practical way to save water

Deficit irrigation strategy - application of water below full crop-water requirements

Deficit irrigation can lead to greater economic gain in case of drought and water scarce condition
Components of Framework

- Tool framework mainly comprises three modules:
  - Allocation rules module
  - SWAT modules
  - Economic module
- Framework also has a facility to use crop growth module externally
- Water allocation rules can be given as input according to water availability in reservoir
- Soil water balance is done through SWAT module
- External crop growth model uses output of ETp and ETa from SWAT
- Economic module computes cost of cultivation of crops, gross and net benefits of individual crop as well as project net benefit for respective allocation rule
- Tool framework is able to estimate daily updates of reservoir storage
Development of Conceptual Framework

**Input Data:** Allocation Units (AUs), crop, soil, weather related data, reservoir storage data

- Provide various combinations of Water Allocation Rules

- Allocation Rules

- Initialize Reservoir Storage

- Day = 1 (Max. 365 days)

- AU = 1

- Soil = 1

- Crop = 1

- Initialize soil moisture

- Estimate root zone depth, \( ET_0 \) and effective rainfall

- 1

- 2

- 3

- 4

- 5

- 6
1. Update soil moisture in root zone
2. \( \text{AU} = \text{AU} + 1 \)
3. Estimate depth of irrigation according to Allocation Rule
4. Is the event day of irrigation? 
   - Yes: Go to step 5
   - No: Go to step 3
5. Estimate ETa
6. Is the event day of irrigation? 
   - Yes: Go to step 5
   - No: Go to step 3

Additional steps:
- All Crops over? 
  - No: Go to step 3
  - Yes: \( \text{Crop} = \text{Crop} + 1 \)
- All Soils over? 
  - No: Go to step 3
  - Yes: \( \text{Soil} = \text{Soil} + 1 \)
- All AUs over? 
  - No: Go to step 3
  - Yes: Go to step 2
- Calculate Canal Water Release
Update Reservoir Storage

Is reservoir storage less than or equal to dead storage or predefined stage?

No

All days over?

Yes

Obtain crop growth stage-wise ET₀, ETₕ for each crop, soil and in AU

Plant Growth Model

Estimate Crop Yield

Economics Model

Estimate Net Benefit

Estimate carry over storage

Output: Canal Water Storage, Net Benefit, Crop Yield for each Crop, Soil and AU, Carry over Storage
External Crop Growth Model

- Stewart water production function (or any other suitable model)

\[
\frac{Y_a}{Y_m} = 1 - \sum_{s=1}^{ns} K_{y_s} \left( \frac{ET_{o_s} - ET_{a_s}}{ET_{o_s}} \right)
\]
Location of Study Area

- Sina Medium Irrigation Project
- Tributary of river Bhima in Krishna basin
- Location: Nimgaon Gangarda village, Tal. Karjat, Dist. Ahmednagar
- Location: Latitude 18°49’0”N Longitude 74°57’0”E
- Topo-sheets No.: 47 J/13, 47 J/14, 47 N/1 and 47 N/2
Features of Study Area

- Annual rainfall: 503.80 mm
- Reservoir gross capacity: 67.98 M cum
- Live storage: 52.33 M cum
- Dead storage: 15.65 M cum
- Observed percentage of live storage in reservoir over a period of 25 years is 69.92 (36.57 M m³)
- Culturable Command Area (CCA): 9677 ha
- Irrigable Command Area (ICA): 8445 ha
- ICA under Right Bank Canal: 7656 ha
- SRTM images (SRTM_51_091 and SRTM_52_091) were mosaiced and used for preparation of DEM
- Pre-defined stream definition option was selected for watershed delineation
- User-defined canal network (stream) and outlet command (sub-basins) were linked with each other and input to SWAT
Cropping pattern in study area

- **Kharif season (June to October) crops:**
  - Sunflower (4154 ha)
  - Pearl millet (3320 ha)
  - Mung bean (89 ha)
  - *Kharif* sorghum (14 ha)

- **Rabi Season (November to March) crops:**
  - Wheat (4154 ha)
  - Groundnut (3320 ha)
  - *Rabi* sorghum (89 ha)
  - Onion (14 ha)

- **Annual crops:**
  - Sugarcane (78 ha)
Soils of study area

- Mirajgaon series (Clay): 1566 ha
- Ratanjan series (Silt clay): 1820 ha
- Ghumari series (clay loam): 3084 ha
- Nagalwadi series (Silt loam): 1185 ha
Soil Slope in study area

- 0-0.5% slope: 75 ha
- 0.5-1% slope: 1276 ha
- 1-3% slope: 6265 ha
- 3-5% slope: 38 ha
- Above 5% slope: 2 ha
Water Allocation Rules

- **Percentage of area to be irrigated**
  - 100% ICA
  - 80% ICA
  - 60% ICA
  - 40% ICA
  - 20% ICA

- **Release rate from reservoir**
  - 5 m³/sec
  - 4 m³/sec
  - 3 m³/sec
  - 2 m³/sec
  - 1.5 m³/sec

- **Irrigation depth**
  - 90 mm
  - 70 mm
  - 50 mm
Irrigation Rotations

- Kharif season (June to October): 28 days
- Rabi season (November to February): 21 days
- Summer season (March to May): 14 days
Allocation Units Analysis

- SWAT sub-divided irrigation command area (7656 ha) of 72 units in 305 AUs
- First unit was allocated as Reservoir
- Most of the crops are concentrated in 0.5 to 1% followed by 0 – 0.5% slope category
Soil moisture status in root zone of sunflower due to water application

Clay and silt clay soils
Soil moisture status in root zone of sunflower due to water application

Clay loam and silt loam soils
Soil moisture status in root zone of wheat due to water application

Clay and silt clay soils

Days after sowing
Clay loam and silt loam soils
Percent yield reduction in *kharif* season crops
Percent yield reduction in annual and *rabi* season crops
Net Returns from *kharif* season crops
Net Returns from annual and *rabi* season crops
Irrigation water use efficiency for *kharif* season crops
Irrigation water use efficiency for annual and *rabi* season crops

![Chart showing irrigation water use efficiency for different crops and soil types.]
Thank you!