Simple Reservoir Simulation Problem, and Different Optimization models

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This is a minimization problem, getting the minimum unmet demand for each use, under the same prioritization constraints (prioritize covering the urban, and then if there is water available to release it for irrigation, and hydropower demands).

[releases with priorities: cover the urban, agricultural, and hydropower demands,

while minimizing the unmet demand (shortage minimization)].

The first priority is again to meet the urban demand (Priority = 1). Then, if there is available water, it can go to the agricultural and the hydropower uses (Priorities = 2). Below there are indicative example data:

Parameters:

- K: Reservoir capacity (maximum storage) = 60 million m³
- S_0: Initial storage in the reservoir at t=0, = 30 million m³
- S_{min}: Minimum required storage in the reservoir for safety = 2 million m³

Variables:

- S_t: Storage in the reservoir at time t. The amount of water stored in the reservoir.
- I_t: Inflows into the reservoir at time t. The amount of water flowing into the reservoir (from all sources, such as Precipitation, river or other inflows). Data as follows (in million m3):

t1: 40, t2: 58, t3: 62, t4: 54, t5: 48, t6: 40, t7: 42, t8: 40, t9: 56, t10: 64, t11: 62, t12: 60

- O_t: Outflows from the reservoir at time t. The total outflow from the reservoir, including spills and losses from evaporation or other unmanaged outflows. Data as follows (in million m3):

t1: 20, t2: 20, t3: 20, t4: 20, t5: 20, t6: 25, t7: 30, t8: 25, t9: 20, t10: 20, t11: 20, t12: 20

- $D_{u,t}$: Urban demand at time t. Data as follows (in million m3):

t1: 5, t2: 5, t3: 5, t4: 5, t5: 6, t6: 7, t7: 8, t8: 9, t9: 7, t10: 6, t11: 5, t12: 5

- $D_{irr,t}$: Agricultural demand at time t. Data as follows (in million m3):

t1: 10, t2: 14, t3: 15, t4: 20, t5: 22, t6: 30, t7: 35, t8: 32, t9: 20, t10: 15, t11: 10, t12: 10

- $D_{hydro,t}$: Hydropower demand at time t. Data as follows (in million m3):

t1: 10, t2: 10, t3: 10, t4: 10, t5: 12, t6: 13, t7: 15, t8: 15, t9: 12, t10: 10, t11: 10, t12: 10

Decision Variables = Releases (R):

$R_{u,t}$: Releases for urban use at time t.

$R_{irr,t}$: Releases for agricultural use at time t.

$R_{hydro,t}$: Releases for hydropower use at time t.

Objective Function:

The objective is to prioritize covering the urban, and then (if there is water available) agricultural, and hydropower demands, while minimizing the unmet demand.

We aim to minimize the total unmet demand across all time periods:

$$Zmin = \sum_{t=1}^{T=12} [(D_{u,t} - R_{u,t}) + (D_{irr,t} - R_{irr,t}) + (D_{hydro,t} - R_{hydro,t})]$$

Constraints:

1. Storage balance equation: $S_t = S_{t-1} + I_t - O_t - R_{u,t} - R_{irr,t} - R_{hydro,t}$, for all t.
2. Storage capacity constraint: $S_{min} \leq S_t \leq K$, for all t.
3. Release constraints = Prioritization of Demands: The releases should prioritize covering urban demand first, then agricultural and hydropower demands. The releases for each demand should not exceed the available storage of the reservoir.

Urban Demand Coverage (should be met):

$R_{u,t} = D_{u,t}$, for all t.

If there is not enough water at month t to cover all the urban demand, then still all releases will go to the urban demand: $R_{u,t} \leq D_{u,t}$

The rest of the available water, goes to agriculture and hydropower (as releases).

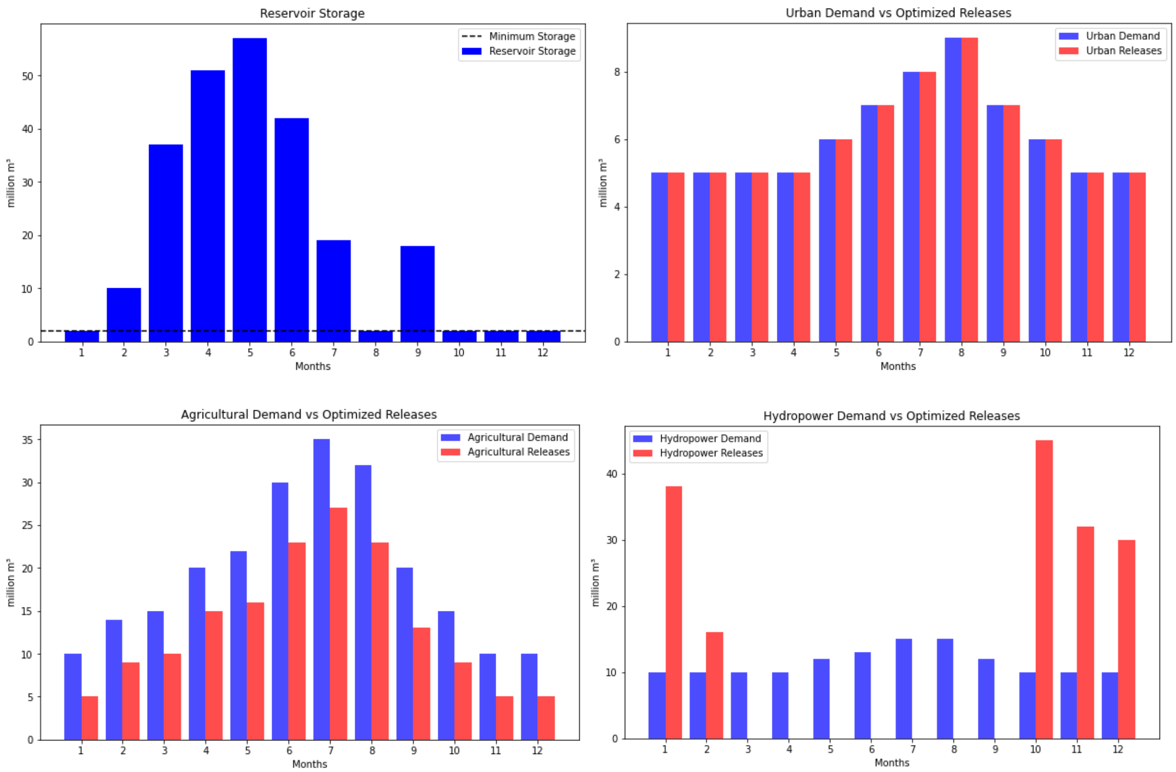
Agricultural Demand:

$R_{irr,t} \geq D_{irr,t} - R_{u,t}$, for all t.

Hydropower Demand:

$R_{hydro,t} \geq D_{hydro,t} - R_{u,t} - R_{irr,t}$, for all t.

Indicative Results:



We see that with this example mode, the optimization achieves some surpluses (since there was water available), which can be better allocated to the different months with persisting shortages.