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SIMULATION SOFTWARE FOR SMALL ECO-FRIENDLY ENERGY RECHARGE DAMS

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1 Introduction

Small irrigation reservoirs are created by constructing perpendicular to the flow of dams in small and medium-sized permanent flow streams. These reservoirs are mainly used for irrigation purposes as they contribute to the annual balancing of water demand on the downstream farm. Depending on the species, the diversity of the crops, the subsoil of the irrigation method but also the weather conditions, the water demand shows great seasonal fluctuations. Additionally, important parameter related to the demand for irrigated water is the know-how of the workers and the disposition for proper water consumption. In the literature there are several irrigation methods with the most common being the method of rotational distribution and the method of free demand. In the present work, given that the main purpose of the reservoir was to set a minimum required irrigation supply in order to be able to serve the demand marginally, a maximum value was set for the days of high water demand and the remaining values as a normal distribution of random numbers according to Equation 1.

Equation 1. Distribution of random numbers.

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Where **μ** is the mean and **σ** is the standard deviation. The assumption of random water distribution with a minimum and a maximum flow simulates the free use of water without following the irrigation schedule, something that usually happens in practice. Given that in an annual cycle the reservoirs usually exceed the irrigation needs, it is technically possible to convert an irrigation reservoir into a small hydroelectric power station (MIS) which can take advantage of the excess dynamic energy, something that is both related to the needs of demand. water as well as with the inputs to the reservoir. Although such hydropower plants do not have high efficiencies, their construction costs are significantly lower because they operate existing facilities.

Multipurpose reservoirs are divided into those where the useful volumes for each use are separated and those where there is a single volume for all uses. In the process of converting a single-use reservoir into a manifold, a single volume will be used for all possible reservoir uses. In this case, these dams can not be used for flood protection because this use presupposes a low useful volume in contrast to the hydroelectric which presupposes permanently high potentials. In most cases it is necessary to add use to a reservoir to increase the useful volume. The whole system is shown schematically in Figure 1.

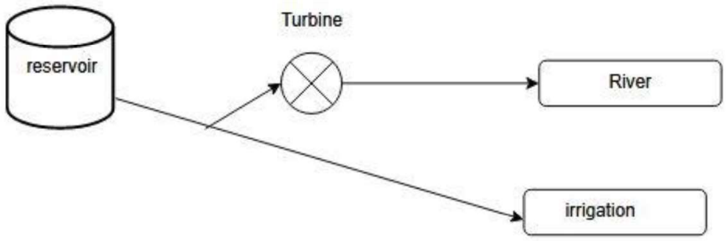

Figure 1. Schematic representation of a reservoir conversion into a small hydroelectric plant.

2 Simulation Model

The useful volume of the reservoir in relation to the height of the water in the dam and its surface is given by the Equation 2.

Equation 2. Calculation of useful volume.

$$V = \int_{h1}^{h2} A dh$$

The current volume at any given time according to the continuity equation is the linear composition of the cumulative input curve, the cumulative output-loss curve and the cumulative consumption curve. Two restrictions are imposed on the above volume, the first concerns a minimum volume of Vmin corresponding to a level below which water is unusable for energy production. The second concerns a maximum volume of Vmax corresponding to a level beyond which the water through the dam overflow ends up at the receiver. The current volume for time T is given by Equation 3.

Equation 3. Calculation of volume for time (T).

$$V_{cur} = \int_0^T Q_{in} dt + \int_0^T Q_{out} dt + \int_0^T Q_{irrigation} dt + \int_0^T Q_{turbine} dt$$

Evaporation is ignored in the model due to the small size of the reservoirs. The geometric model is the one shown in Figure 2. Given that this type of dams is constructed perpendicular to the flow of small torrents, the above geometric model is quite close to reality and offers an easy and simple way of describing the useful volume with relatively little geometric data.

Equation 4. The function between current useful volume and change in heighτ.

$$V_{cur} = \frac{1}{3} L * A_{base} = \frac{1}{3} L * \frac{DH_{cur}(B + (2A + B))}{2} \rightarrow V_{cur} = \frac{DH_{cur} * L * (A + B)}{3}$$

3 Optimization Model

The goal of the optimization model is to find the vector of daily water supplies per year used to generate electricity. That is, the problem has 365 unknown variables. Restrictions include ensuring a minimum volume in the reservoir set at 10% of the maximum volume, ensuring a minimum irrigation supply. Moreover, the volume of the reservoir is limited by a maximum value beyond which the excess water escapes from the overflow. The objective function is the annual energy production from the turbine. The energy production is given by Equation 5.

Equation 5. Calculation of energy production.

$$E_{turbine} = \rho * g * Dh * Q_{turbine}$$

E_{urbine} : The energy produced
ρ : The density of water
g : The acceleration of gravity
Dh : The net height of water drop
$Q_{turbine}$: The discharge of water

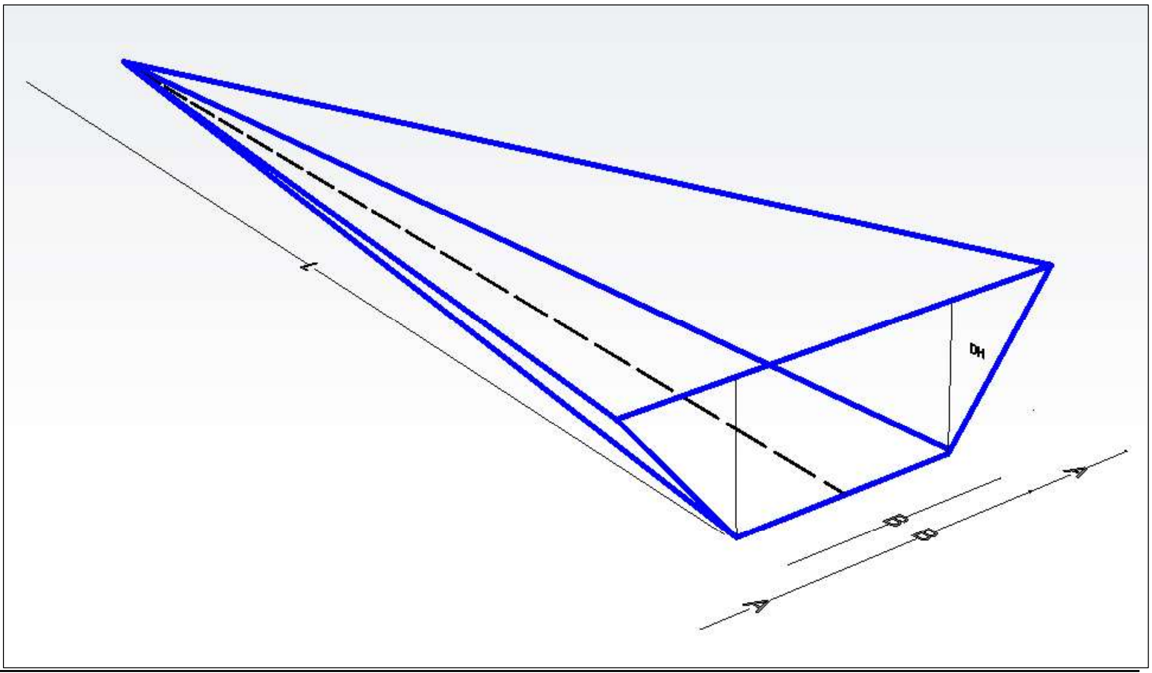

Figure 2. Geometric reservoir model. The function between current useful volume and change in height is calculated in Equation 4.

Based on the above the model is presented in the equations of Table 1.

Table 1. The equations of model.

Variables	Restrictions	Objective Function
$\overrightarrow{Q_{turbine}} = \begin{cases} x1 \\ x2 \\ x3 \\ .. \\ .. \\ x364 \\ x365 \end{cases}$	$V_{min} < V_{cur} < V_{max}$ $Qirri_{min} < Qirri < Qirri_{max}$	$F = \sum_{0}^{365} \rho * g * Dh * Q_{turbine}$

The model is solved by the harmony search algorithm and the whole process is organized in Python language. The code is shown in Figures 3 and 4.

```
Qin = np.loadtxt("data2.csv", dtype=float)
qirr = np.array([random.(86400, 259200) for i in range(364)])
vmax = 1500000
v_initial = 0.75*vmax
A = 50
B = 100
L = 1000
dh_initial = 3 * v_initial / (L * (A + B))
Vin = np.cumsum(Qin) + v_initial - qirr
n = 0.75
vmin = 200000
# ------------------------------------------------------------------
time = [x for x in range(364 + 1) if x > 0]

seed(datetime.now())
#x1 = np.array([randrange(1, 500000, 1) for i in range(364)])

def objective_function(Vin,x1,L,A,B,n) :
    Vcur = Vin-x1
    dh = np.array((3 * Vcur) / (L * (A + B)))
    E = (1000 * 9.81 * n * (x1 / 86400) * dh) / 1000000
    return sum(E)
```

Figure 3. The code of Harmony search.

```
# Harmony Search Algorith
# Harmony Memory
hms = 10
hm = np.array([])
for i in range(hms):
    hm=np.append(hm,np.array([random.uniform(10000.00, 600000.00) for i in range(364)]))
hm=np.reshape(hm,(364,hms))
row = []
for i in range(hms):
    row.append(objective_function(Vin,hm[:,i],L,A,B,n))
hm=np.vstack([hm,row])
# sorting harmony memory
hmsort = hm[:, hm[-1, :].argsort()]
#New Harmony
hmcr= 0.7
par = 0.5
#-------------------------------------------------------------------------------
for k in range(1):
    NewHarmony=np.array([])
    if random.random() < hmcr:

        for i in range(0,364):
            a=randint(0, hms-1)
            NewHarmony=np.append(NewHarmony,hm[i,a])

        if random.random() < par:
            NewHarmony = NewHarmony+random.uniform(-100000.00, 100000.000)

    else:
        NewHarmony = np.array([randrange(1, 500000, 1) for i in range(364)])
    NewHarmony2=np.append(NewHarmony,(objective_function(Vin,NewHarmony,L,A,B,n)))
    if objective_function(Vin,NewHarmony,L,A,B,n) > hmsort[364,0]:
        hmsort[:,0]=NewHarmony2
#sort again
    hmsort = hmsort[:, hmsort[-1, :].argsort()]
```

Figure 3. The code of Harmony search.

4 Results

During the execution of the code, the cumulative input curve in the reservoir, the daily values of the water supply for irrigation and hydroelectric use as well as the current volume of the reservoir are generated. The curves are shown in Figure 5.

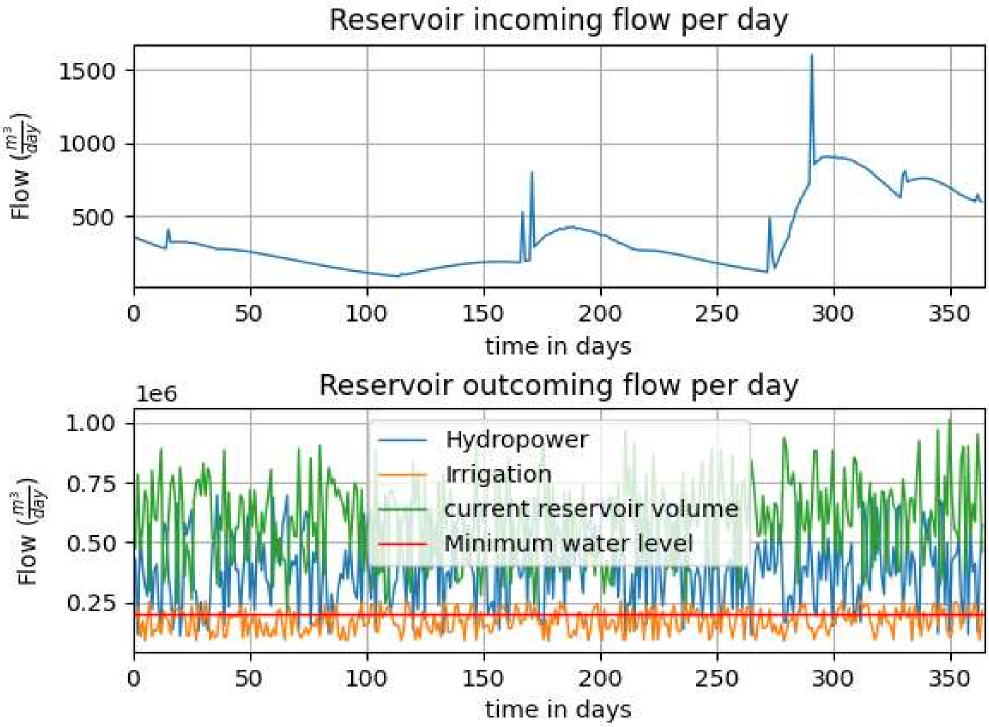

Figure 5. Hydrograph of income and outcome.

5 Conclusions

The transformation of small dams to energy production plants can significantly contribute to the green energy supply worldwide. Additionally, considering the accelerated problem of groundwater depletion the application of managed aquifer recharge by using the dam water can contribute to the reversion of the phenomenon. The developed code harmonized the energy production and the recharge of the aquifer. Additionally, the dams contribute to the mitigation of flood events in lowlands.

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