

DEFINIÇÃO DE POLÍTICAS EFICIENTES DE TRANSFERÊNCIA DE ÁGUA ENTRE ALBUFEIRAS

Aplicação de modelos de programação dinâmica e de simulação

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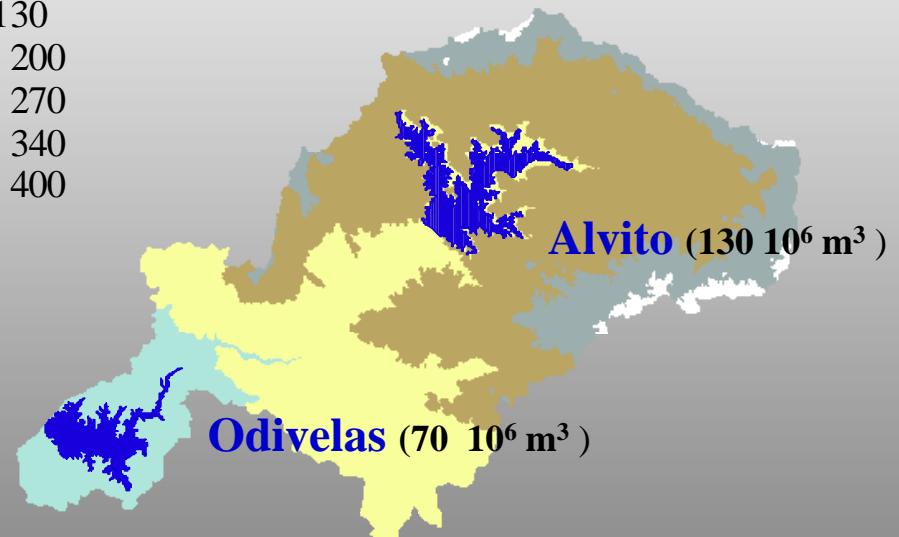
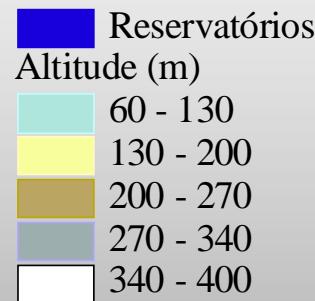


Introduction

- **Distribution of water may not be uniform in the water resources systems**
- **For better utilization of available water in these resources**
 - Surplus water from one reservoir is usually exported
 - A reservoir suffering water deficits need to import water from other to meet its demands

Study Area (Alvito-Odivelas reservoir system)

- Alvito – Municipal water demands
- Odivelas - Irrigation (6845 ha)



- If there is any deficit in irrigation at Odivelas reservoir, then the required amount of water can be diverted (imported) from Alvito reservoir

Objective

- The objective of this study is
 - to know whether import of water is required at Odivelas, if yes, then how much and when?
 - Alvito can supply (export) this water or not, If yes, how much?
 - Overall this study is to evaluate the performance of the system

Methodology

- Dynamic programming (DP) based *Water Import Model* for Odivelas Reservoir
- DP based models for reservoir operation of the two reservoirs
- Results of DP are compared with Simulation in order to examine the reliability of the DP results

Dynamic programming (DP)

- DP is one of most popular techniques used in water resources management and reservoir operation optimization in particular
 - A complex multistage problem is decomposed into a series of simple sub problems that are solved recursively one at a time
 - Can incorporate nonlinear functions
 - Global optimality is assured (discrete DP)

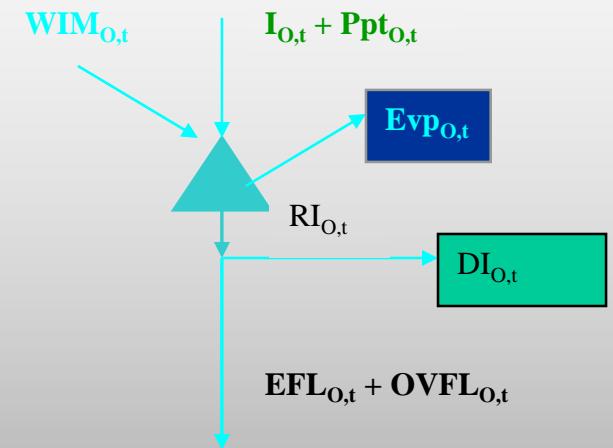
Water import DP model for Odivelas reservoir

Objective function

The overall objective function to be minimized is given by

$$\text{Min } \sum_{t=1}^N C_t \times WIM_{O,t}$$

C_t is the cost of importing water from Alvito to Odivelas reservoir during time period t.



⇒ The objective is to minimize amount of water import

The recursive equation to minimize the above function is given by

$$f_t(S_t) = \min_{WIM_{O,t}} [WIM_{O,t} + f_{t+1}(S_{t+1})], f_N(S_N) = 0$$

Constraints

(i) Continuity equation

$$S_{t+1} = S_t + I_{O,t} + Ppt_{O,t} + WIM_{O,t} - ECFL_{O,t} - DI_{O,t} - Evp_{O,t} - OVFL_{O,t}$$

(ii) Limits on storage

$0 \leq S_{t+1} \leq K_O$, where K_O is the live storage capacity of Odivelas reservoir.

(iii) Limits on water import

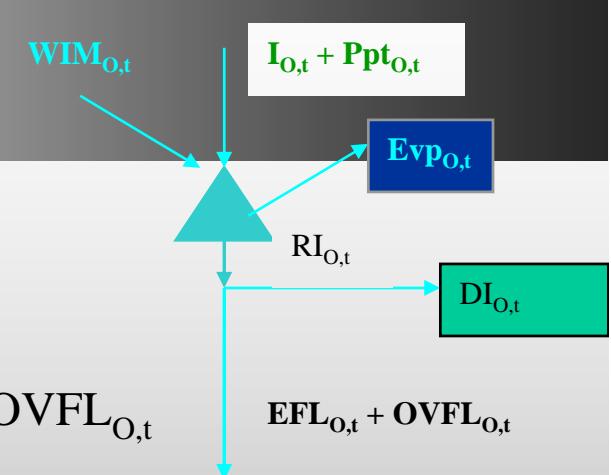
$$WIM_{O,t} \geq 0$$

$$ECFL_{O,t} + DI_{O,t} + Evp_{O,t} - S_t - I_{O,t} - Ppt_{O,t} \leq WIM_{O,t} \leq K_O + EFL_{O,t} + DI_{O,t} + Evp_{O,t} - S_t - I_{O,t} - Ppt_{O,t}$$

(iv) Overflow

$$OVFL_{O,t} = 0, \text{ if } WIM_{O,t} > 0$$

$$= S_t + I_{O,t} + Ppt_{O,t} + WIM_{O,t} - EFL_{O,t} - DI_{O,t} - Evp_{O,t} - S_{t+1}, \text{ if } WIM_{O,t} = 0 \text{ and } S_{t+1} = K_O$$



Alvito reservoir operation model

Objective function: The overall objective function for the operation of Alvito reservoir is to minimize the weighted sum of total squared deviation from target demands:

$$\text{Min } \sum_{t=1}^N \text{TSD}_t$$

where

$$\text{TSD}_t = w_1(\text{DW}_{A,t} - \text{RW}_{A,t})^2 + w_2(\text{WIM}_{O,r} - \text{TW}_{A,r})^2 + w_3(\text{OVFL}_{A,t} - 0)^2$$

$w_i = 0$ or 1 , $\sum w_i = 1$ are weights

- The first two conditions are imposed to ensure the priority in meeting demands
-i.e., firstly, to meet the municipal water supply demands of Alvito and then irrigation deficits at Odivelas reservoir.
- The third condition is applied to minimize spill/overflow from reservoir which is given last priority after meeting other requirements.

Constraints

(i) Limits on release

$$O_{A,t} \geq 0,$$

$O_{A,t}$ is total release from reservoir including: release for municipal water supply ($RW_{A,t}$), water transfer for irrigation deficit at Odivelas ($TW_{A,t}$), ecological flow release ($REFL_{A,t}$) and overflow ($OVFL_{A,t}$).

These variables are defined as :

$$\begin{aligned} REFL_{A,t} &= O_{A,t}, \text{ if } O_{A,t} < ECFL_{A,t} \\ &= ECFL_{A,t}, \text{ if } O_{A,t} < ECFL_{A,t} + DW_{A,t} \\ &= 0, \text{ if } O_{A,t} \geq ECFL_{A,t} + DW_{A,t} \end{aligned}$$

$$\begin{aligned} RW_{A,t} &= O_{A,t} - REFL_{A,t}, \text{ if } O_{A,t} - REFL_{A,t} < DW_{A,t} \\ &= DW_{A,t}, \text{ if } O_{A,t} - REFL_{A,t} \geq DW_{A,t} \end{aligned}$$

$$\begin{aligned} TW_{A,t} &= O_{A,t} - REFL_{A,t} - RW_{A,t}, \text{ if } O_{A,t} - REFL_{A,t} - RW_{A,t} < WIM_{O,t} \\ &= WIM_{O,t}, \text{ if } O_{A,t} - REFL_{A,t} - RW_{A,t} \geq WIM_{O,t} \end{aligned}$$

$$OVFL_{A,t} = O_{A,t} - REFL_{A,t} - RW_{A,t} - TW_{A,t} \quad (\text{where, } S_{t+1} = K_A)$$

where K_A is the live storage capacity of Alvito reservoir.

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Odivelas reservoir operation model

Objective function

The overall objective function for the operation of Odivelas reservoir is to minimize the sum of total squared deviation from target irrigation demand:

$$\text{Min} \sum_{t=1}^N \text{TSD}_t$$

where

$$\text{TSD}_t = (\text{DI}_{O,t} - \text{RI}_{O,t})^2$$

$\text{RI}_{O,t}$ is water release for irrigation and $\text{DI}_{O,t}$ is irrigation demand at Odivelas reservoir

Constraints

(i) Continuity equation

$$S_{t+1} = S_t + I_{O,t} + Ppt_{O,t} - RI_{O,t} - EFL_{O,t} - Evp_{O,t} - OVFL_{O,t}$$

(ii) Limits on storage

$$0 \leq S_{t+1} \leq K_O$$

where K_O is the live storage capacity of the reservoir.

(iii) Limits on water release

$$RI_{O,t} \geq 0$$

$$\begin{aligned} & ECFL_{O,t} + Evp_{O,t} - S_t - I_{O,t} - Ppt_{O,t} \\ & \leq RI_{O,t} \leq K_O + EFL_{O,t} + DI_{O,t} + Evp_{O,t} - S_t - I_{O,t} - Ppt_{O,t} \end{aligned}$$

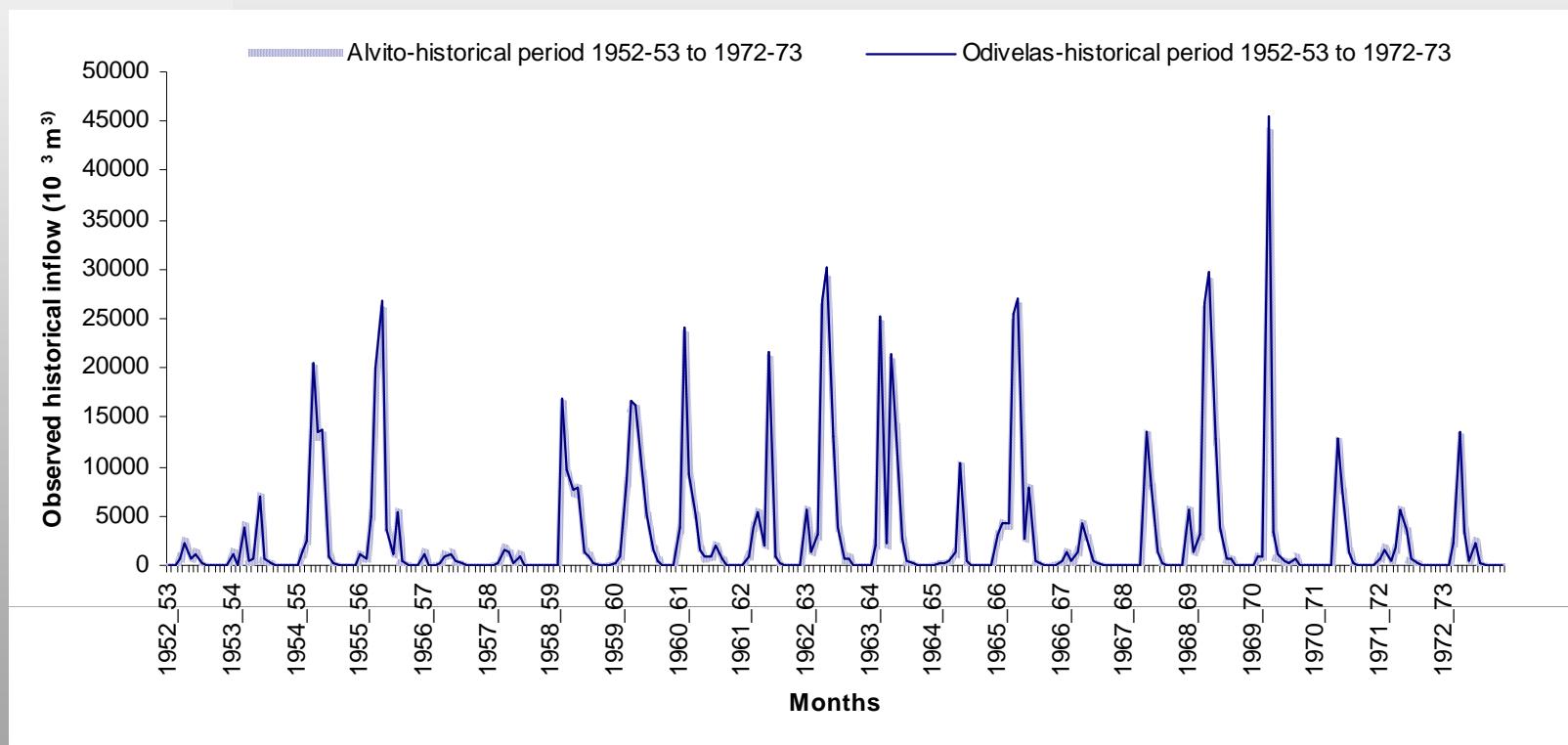
(iv) Overflow

$$\begin{aligned} OVFL_{O,t} &= S_t + I_{O,t} + Ppt_{O,t} - EFL_{O,t} - RI_{O,t} - Evp_{O,t} - S_{t+1}, \\ & S_{t+1} = K_O \text{ (in this case). } 12 \end{aligned}$$

Application of the Models

- Firstly, the water import model for Odivelas reservoir is solved to estimate the amount of water import needed from Alvito reservoir
- Operation of the two reservoirs is then carried out separately
- Results from Water import model are used as demand for Alvito reservoir
- Results of the Alvito reservoir opeartion model are then used as input for Odivelas reservoir

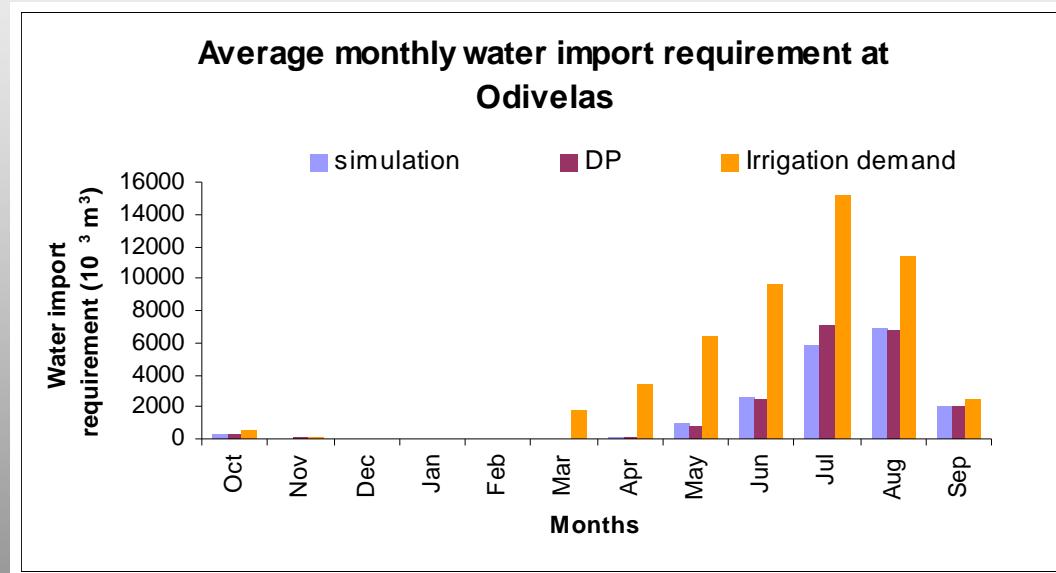
21 years historical data



Monthly inflows at Alvito and Odivelas reservoirs

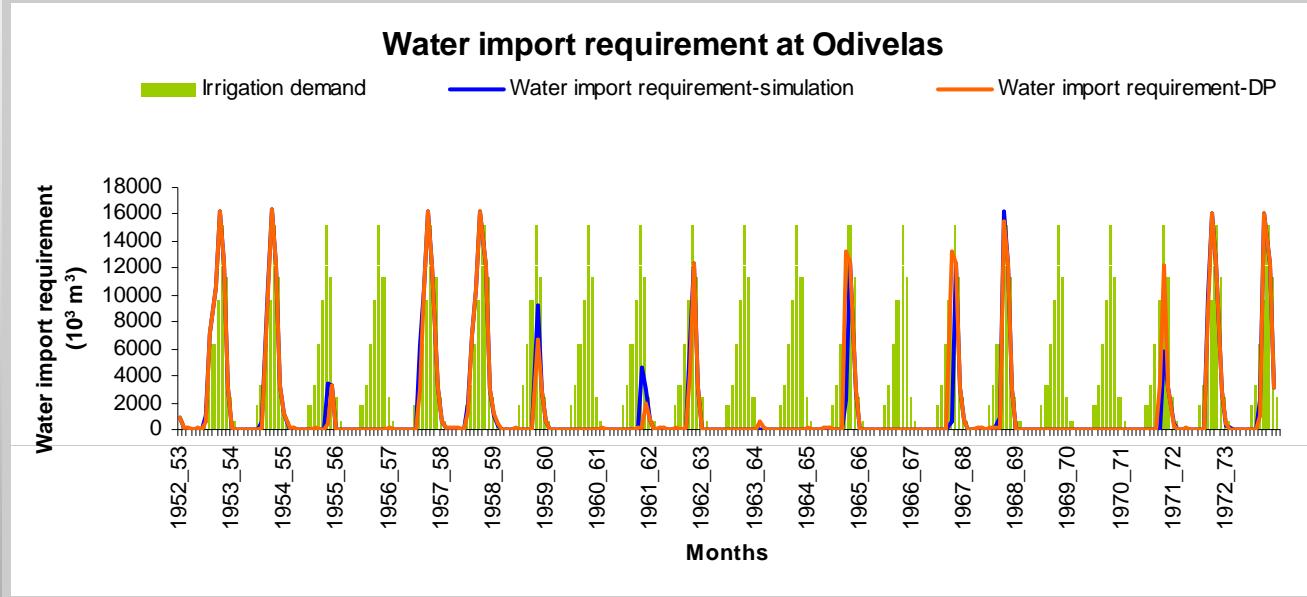
Results and discussion

- Significant amount of water needs to be transferred from June to September using both simulation and optimization



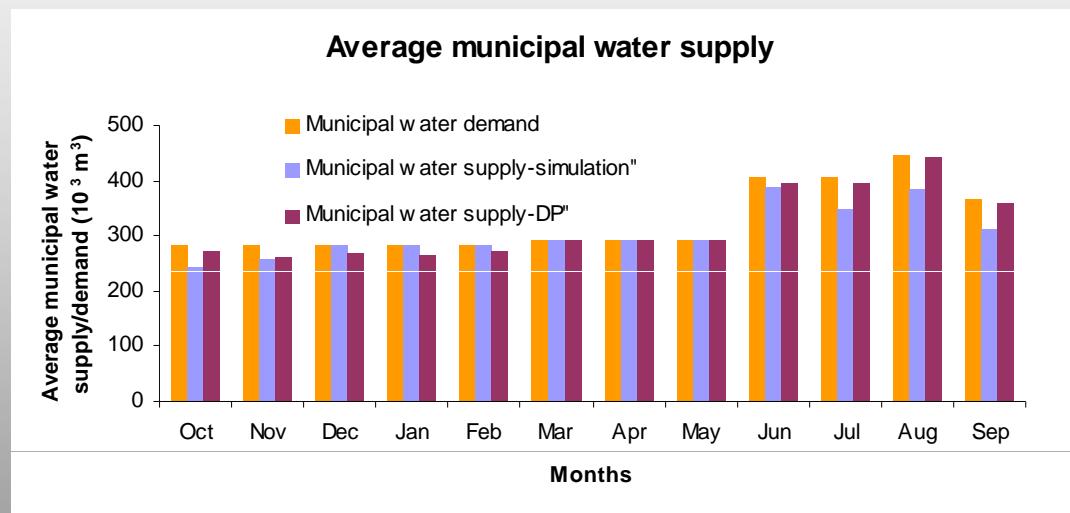
- Approximately 39 % of the annual irrigation demand need to supplied by Alvito

Results and discussion



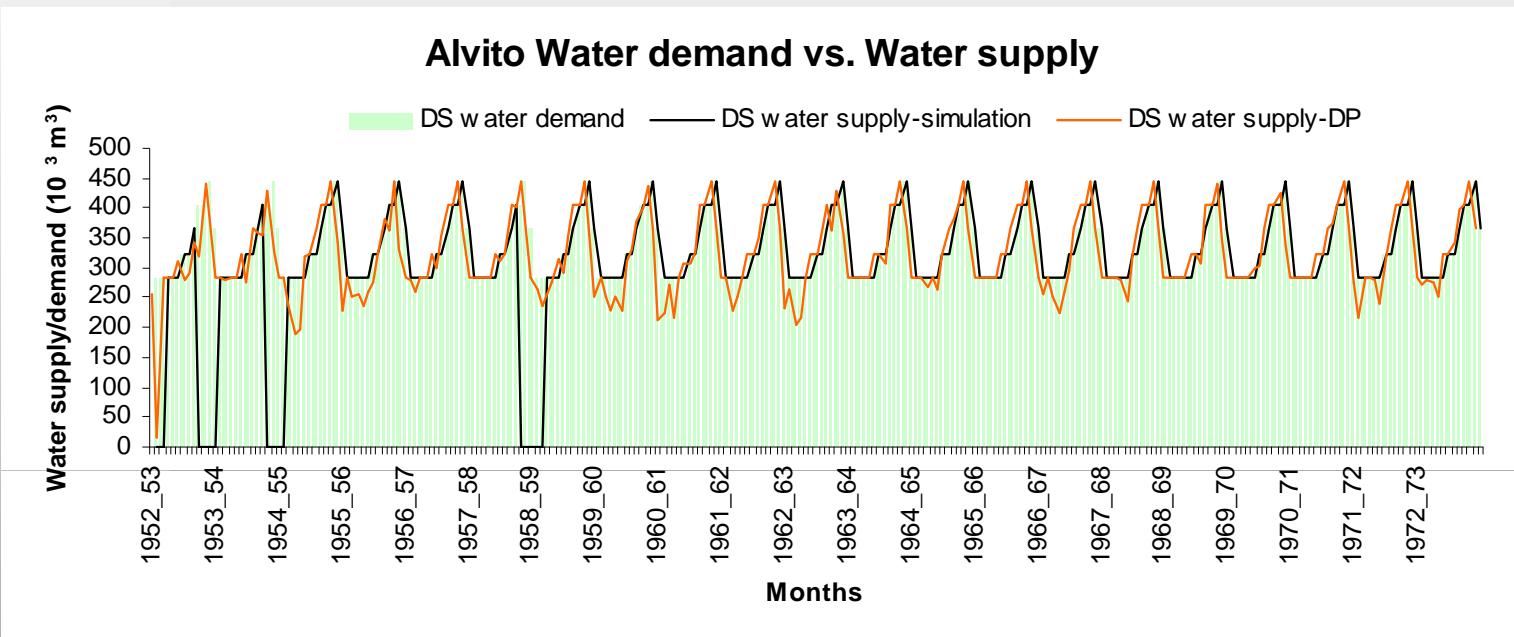
- Monthly results show that DP tries to minimize the amount water import

Results and discussion



- 96% of annual municipal water demand can be met using both simulation and optimization

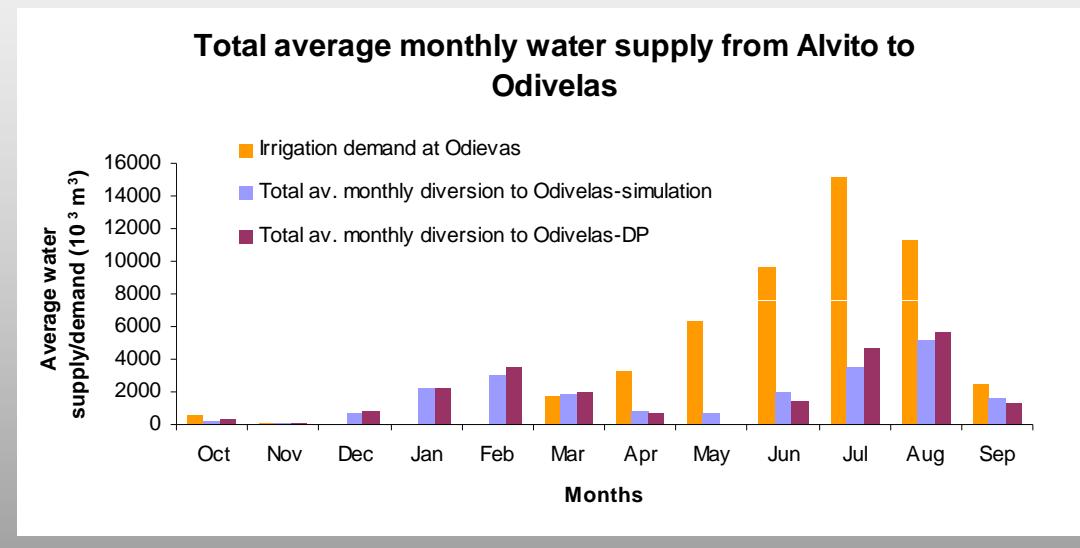
Results and discussion



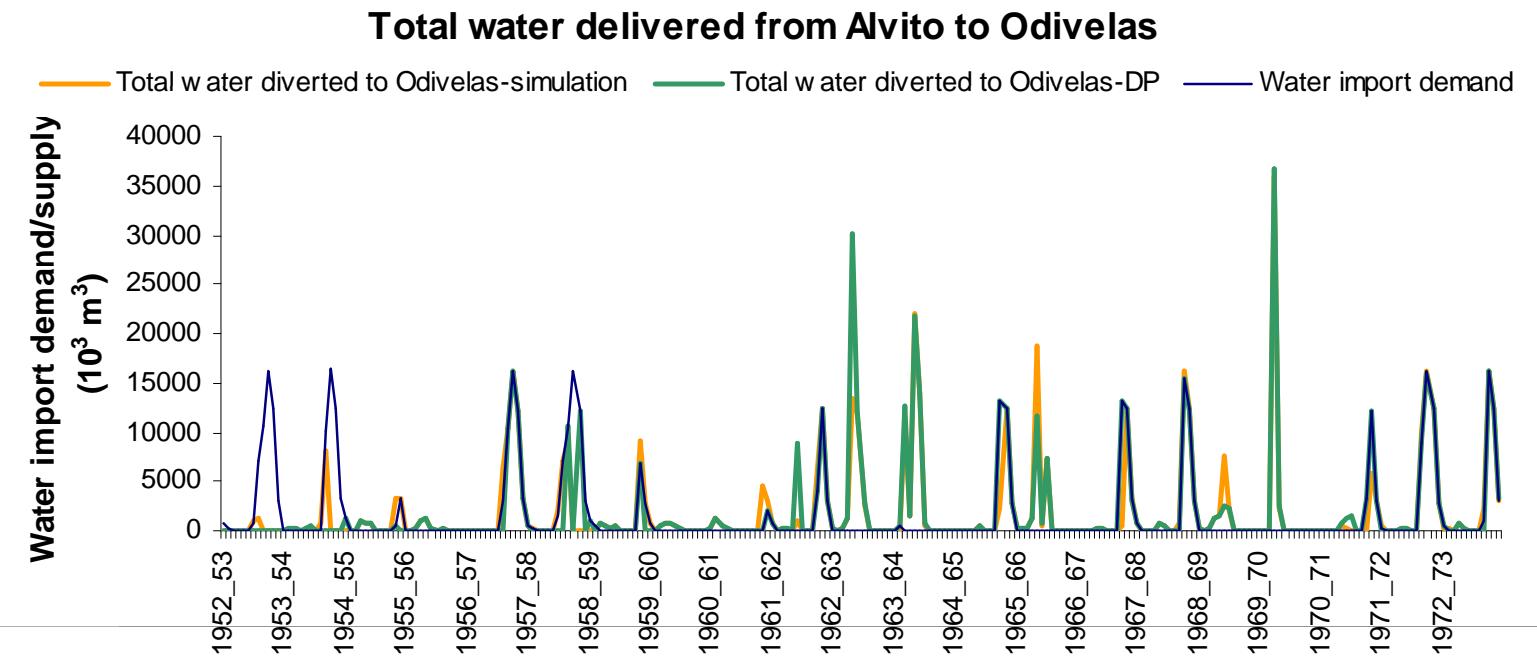
- Monthly municipal water supply

Results and discussion

- Results show that the total annual amount of water delivered from Alvito to Odivelas is approx. 115% of the amount of annual water import requirement, this is because the total water delivered from Alvito accounts the water released for ecological demands and the overflow



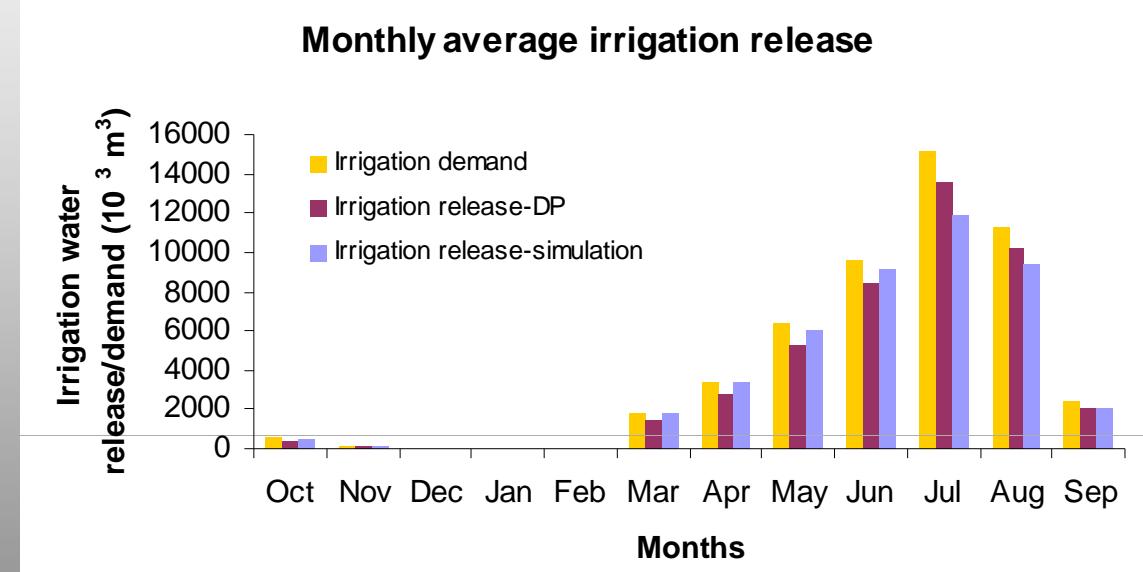
Results and discussion



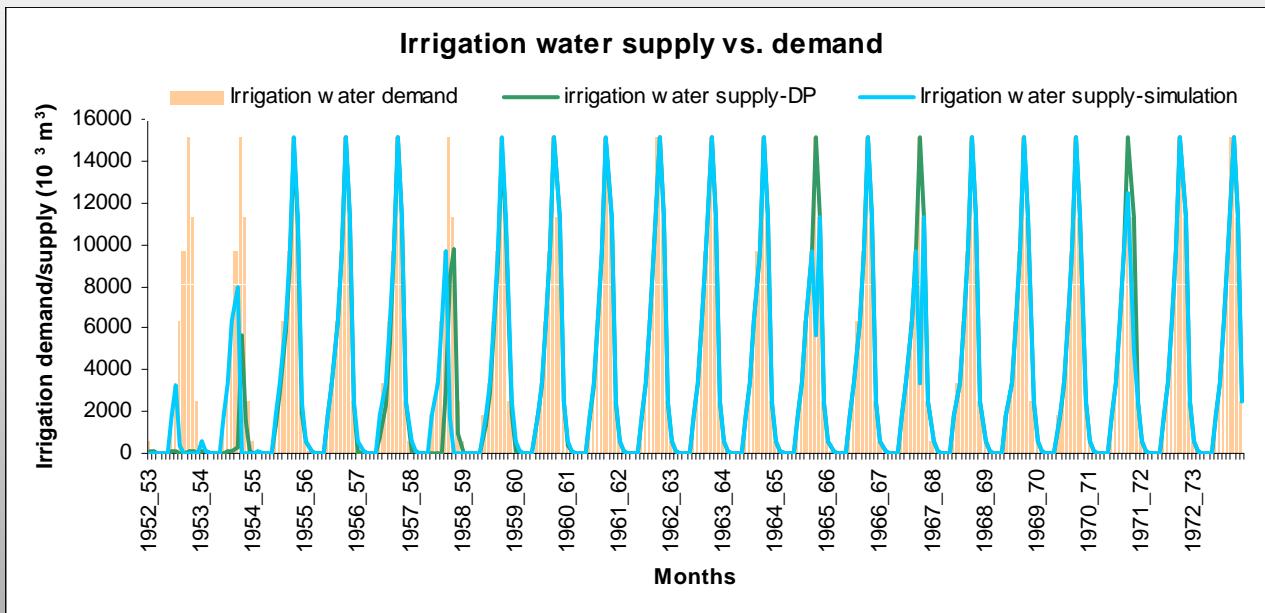
Total monthly water from Alvito to Odivelas

Results and discussion

- Results show that 87% of annual irrigation demand can be met using both simulation and optimization



Results and discussion



The most deficit month is july.

Conclusions

- *Water import model* can provide guidelines for export of water from a reservoir
- Combined use these models can be successfully applied for development of operating policies for the reservoirs

Conclusions

- The study results showed that Alvito-Odivelas system can not meet irrigation demands completely
- This deficit can be met by tranferring water from Loureiro, through recently built Loureiro-Alvito link
- *Water import model* would be useful in study of the inter-basin water transfer of the Alqueva subsystem

Thank you