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DEFINING OPERATING RULES FOR MITIGATION OF DROUGHT EFFECTS ON WATER SUPPLY SYSTEMS

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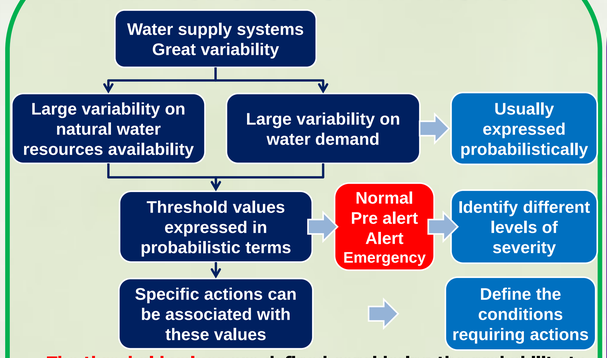
1 - INTRODUCTION

Optimization of reservoir releases, related to drought mitigation rules is particularly required. The hydrologic state of the system is evaluated defining some threshold values, expressed in probabilistic terms. Risk deficit curves are used to reduce the ensemble of possible rules for simulation. Threshold values can be linked to specific actions in an operational context in different levels of severity, i.e. normal, pre-alert, alert and emergency scenarios. A simplified model of the water resources system is built to evaluate the threshold values and the management rules.

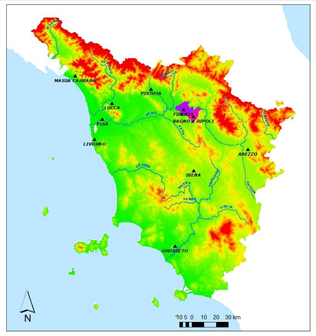
The threshold values determine some curves that define reservoir releases as a function of existing storage volume. A demand reduction is related to each threshold level. The rules to manage the system in drought conditions, the threshold levels and the reductions are optimized using long term simulations with different hypothesized states of the system. Synthetic sequences of flows with the same statistical properties of the historical ones are produced to evaluate the system behaviour. Performances of different values of reduction and different threshold curves are evaluated using different objective function and performances indices.

2 - METHODOLOGICAL APPROACH



The threshold values are defined considering the probability to satisfy a given fraction of the demand in a certain horizon. The probability distribution of demand shortages is estimated through Monte Carlo simulation. The critical situations are assessed month by month, considering an ensemble of hydrological inflows represented by historical series, for each initial storage level in the reservoirs (Rossi et Al. WARM 2012).

3 - STUDY AREA



The methodology is applied to the urban area Firenze in central Tuscany, in central Italy. The catchment of the investigated area has a surface of 1.230 km². The considered demand centers are Firenze and Bagno a Ripoli that have, accordingly to the census ISTAT 2001, a total of 395.000 inhabitants.

4 - MODEL IMPLEMETATION - WEAP SOFTWARE

The complexity of the systems suggests to evaluate the area with a decision support systems (DSS). The software WEAP, developed by the Stockholm Environment Institute's U.S. is implemented for the analysis (Rossi et Al. WARM 2012).

Several software tools were evaluated and it is decided to use WEAP for three main reasons.

- **It can simulate a broad range of natural and engineered components of a basin system**
- **It permits to simulate and to compare different possible scenarios**
- **There is a general agreement about its performances among the scientific and non scientific communities worldwide**

For each month 1725 simulations were performed

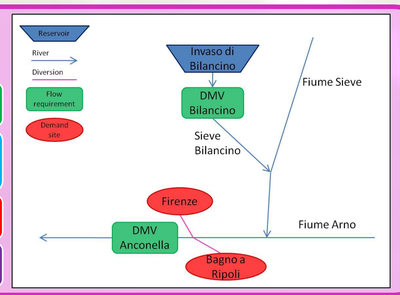
2 years time horizon	34 couple of years (1970-2005)	X	25 degrees of filling
1 year time horizon	35 years (1970-2005)	X	25 degrees of filling

The 25 degree of filling are distributed in unequal intervals: 20 interval between 0% and 50% (every 2.5%) and 4 intervals between 50% and 90%. The following simulations were performed using the first months for hydrologic seasons (Oct, Jan, Apr and Jul) as starting point. Then simulations were performed starting in all the 12 months.

5 - MODEL IMPLEMENTATION - THE CASE STUDY

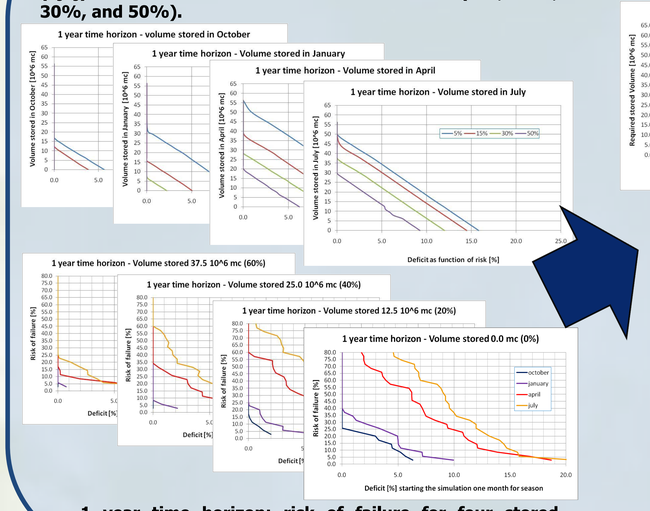
A simplified scheme of the area is modeled considering the 2005 settings:

- **1 reservoir: Bilancino. The storage capacity is evaluated as the conservation storage capacity: 62˙500˙000 m³.**
- **3 rivers: Arno, Sieve and Sieve Bilancino. The discharges are evaluated using the data of gauge stations by Servizio Idrologico Regionale Toscano (Regional Hydrologic Service of Tuscany).**
- **2 demand sites: Firenze and Bagno a Ripoli. Considering a monthly fluctuation based on 2005 demands**
- **2 flow requirements on Sieve Bilancino downstream Bilancino, on Arno downstream Anconella outlet**



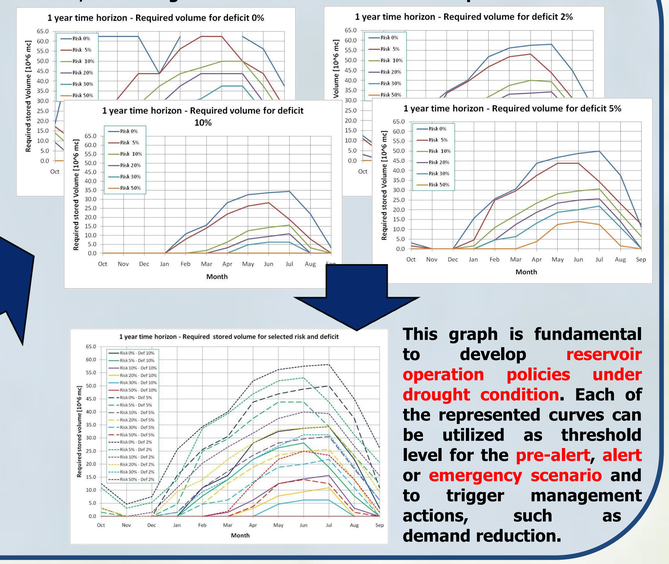
6 - DISCUSSION OF RESULTS – Drought risk assessment

1 year time horizon: stored volume in four reference months (ojaj) function of deficit for four selected risks (5%, 15%, 30%, and 50%).



1 year time horizon: risk of failure for four stored volume function of deficit for 4 reference months (ojaj)

1 year time horizon: the required volume is represented month by month, for six degrees of risk of failure for four acceptable deficit values.



This graph is fundamental to develop reservoir operation policies under drought condition. Each of the represented curves can be utilized as threshold level for the pre-alert, alert or emergency scenario and to trigger management actions, such as demand reduction.

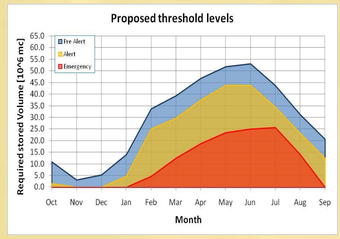
7 - DISCUSSION OF RESULTS – Reservoirs management rules

The group of graphs in the previous box is fundamental to develop reservoir operation policies under drought condition. Each of the represented curves can be utilized as threshold level for the pre-alert, alert or emergency scenario and to trigger management actions, such as demand reduction (Rossi et Al. WARM 2012).

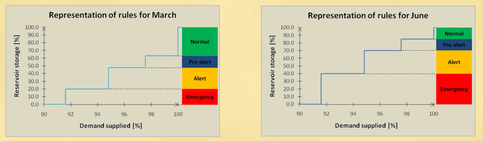
The threshold values and the rules to be imposed on the system for the drought mitigation are optimized through simulations of the water supply system under drought management rules for two long term conditions. The system is evaluated firstly with the inflows and precipitation of the period 1975-2005, then a second state, considering a progressive reduction of Arno River stream flow is evaluated to verify the performance of the operating rules in a future situation in which there could be a reduction of streamflow due to demands increasing and climate change effects.

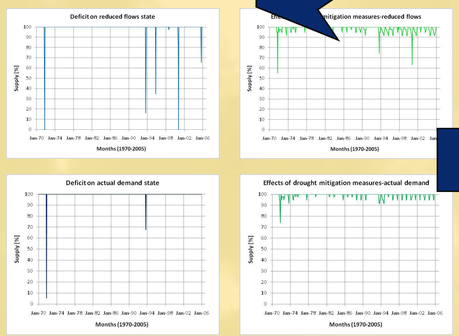
The objective function Z is defined as an aggregate of the squared ratio between D, deficit on water supply, and S, designed water supply, for all the demands i and all the time steps t:

$$Z = \sum_{t=1}^{T} \sum_{i=1}^{N} \left(\frac{D_{ti}}{S_{ti}} \times 100 \right)^2$$



State of the system	Threshold levels	Demand reduction (%)
pre alert	risk 5% - deficit 2%	2.43
alert	risk 5% - deficit 5%	5.18
emergency	risk 20% - deficit 5%	8.40





Synthetic sequences of flows are produced to verify the proposed rules. A Markov or first-order auto-regressive (ARMA) model, applied to monthly series, is used to generate synthetic flows. Correlation between sites is considered.