

POLITICAL AND MANAGEMENT RULES OF WATER RESOURCES IN SCARCITY SCENARIOS

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ABSTRACT

The planning process of water resources management has been proved to need a multi-objective approach, aiming to take into account the different and often antithetic expectations of stakeholders and users. Of course, the overall process has to be based on equity, environmental safety and public welfare, beside the economic profit.

The planning process, moreover, and the decision makers have to cope with uncertainties and doubtful situations. That is the reason to welcome the use of Decision Support Systems (DSS) whose advantage consists in the possibility to compare different scenarios and political approaches to argue general management rules.

The case of study here presented is based on the Sinni River hydraulic system which has been proved to be representative of many Southern Italy complex water distribution schemes. In the specific, the scarcity of water resources and their conflictual use has been investigated. The Italian national directive (5 August 1999, ex. art. 17 D. Lgs n° 36/1994, Di Santo & Ranieri, 2000), aiming to define the agreement between Apulia and Basilicata Regions in terms of transboundaries resources, is the legal tool in order to quantify water demand from users.

Some of our findings put in evidence that proper, flexible decisions are often sufficient to solve some conflictual dynamics between users in the near and middle term periods.

1 INTRODUCTION

In order to achieve a fair management of water resources, the decision makers need to know, at its best possible detail level, the hydraulic balance, meant to be the comparison between the runoff hydrological process and the human use of water, this latter to be intended not only as the use at present time, but also the use projected in the middle and long term periods. Only this balance may allow to respect a sort of inter-generational sustainability and bio-equity (D. Lgs. n° 152/2006).

The hydraulic balance is, thus, based on the informations about volumes of water withdrawn from the stocks and volumes handed over at the beginning and at the end of a reference period, typically a monthly measure.

Provided that a sufficient amount of data, for a long period, is seldom available, but mandatory in order to obtain reliable foresights, the issue on the best way to handle

these data is more and more often solved with the use of Decision Support Systems, i.e. specific software which help in the crossing of informations.

The effectiveness of many plans and decisions is based, for sure, on contingent details, but also on a solid background of knowledge about similar situations: for this reason a case of study has been chosen among the most representatives of the Southern Italy territories: the Sinni River water distribution system, which complexity, length, number of users and their different typologies cover a wide range of possible situation and occurrences.

In the following, the description of the methodology of data collection and analysis will be presented, related to the chosen case study, and the main findings and argumentations will be addressed.

2 METHODOLOGY OF DATA COLLECTION AND ANALYSIS

2.1 The Sinni River supplying system

The Sinni supplying system presents some features extremely representative of many Southern Italy hydraulic schemes, both for technical and bureaucratic aspects.

The river has a length of 94 km and stems from the Basilicata Region hills flowing into the Ionian Sea. The preliminary studies (Di Santo & Ranieri, 2000, Claps et al., 1994) to the Agreement between the Basilicata and Apulia Regions on the Sinni River water stocks exploitation (5 August 1999, ex. art. 17 D. Lgs n°36/1994), show that this supplying system feeds at least 50% of the whole regional demands.

The main reservoir of the Sinni scheme, known as Monte Cotugno Reservoir, features $530 \cdot 10^6$ m³ capacity and a tributary basin extended 810 km²; the water flows in a 3 m diameter main pipe up to a distance of 190 km. The use of water is domestic, industrial and agricultural. In particular, the Acquedotto Pugliese S.p.a. is the institution in charge to provide water for domestic and civil purposes to the apulian territories (DU), the agricultural demand comes from several farmer's cooperatives and particularly the Bradano and Metaponto Cooperative (AU) and the industrial needs all pertain to the ILVA steel industry (IU), in Taranto.

2.2 Data analysis methodology

The data of the hydraulic balance at a river basin scale come from the E.I.P.L.I. (Ente per lo Sviluppo dell'Irrigazione e la Trasformazione Fondiaria in Puglia, Lucania ed Irpinia), i.e. the management authority of the Monte Cotugno Reservoir. The data consist in the storage volumes at the beginning and the end of each month, the storage volume curve, the monthly supplies to the three main users.

The monthly hydraulic balance is based on this algebraic relationship $Aff = Inv_i - Inv_f - Erog$, where "Aff" represents the reservoir inflow, "Erog" the supplied water, " Inv_i " the volume at the beginning of the month and " Inv_f " the volume of water at the end of the month. It is worth to mention that there are scarce data about the overflow of water from the reservoir spillways and/or bottom outlets. In this sense, the mentioned relationship has to be regarded as a gross water volume balance, more than in a strict hydrologic meaning. In figure n.1 it is represented the storage of water during the last 25

years. It can be clearly seen that three periods of scarcity have occurred: at the beginning of the 90s, in 2002 and 2008. This glance to the graph shows that the long-term management of the water resource, which was the aim of the original design, simply failed.

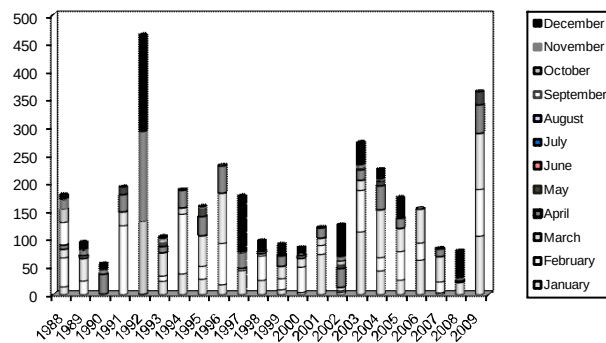


Figure 1. Monthly inflow (Millions of cubic meters)_It is shown the inflow trend curve for each month spanning over 25 years. The three main period of resource scarcity are clearly evident.

Table I. Water supply_Yearly supplies (Millions of cubic meters) to the three main users: Domestic Use, Agricultural Use, Industrial Use.

Year	Users				TOT
	DU.	AU.	IU.		
1988	95.60	109.41	3.66		208.66
1989	93.57	90.53	5.48		189.58
1990	77.89	46.00	9.25		133.14
1991	94.60	118.31	8.64		221.54
1992	110.07	146.94	10.21		267.23
1993	113.07	81.75	11.34		206.16
1994	103.69	145.66	15.09		264.45
1995	125.18	126.62	15.97		267.77
1996	116.65	144.78	17.16		278.58
1997	121.25	190.02	18.78		330.04
1998	124.25	175.32	17.98		317.55
1999	128.61	189.63	18.48		336.72
2000	116.10	141.54	16.90		274.54
2001	122.54	131.21	13.75		267.50
2002	104.94	39.36	12.88		157.18
2003	114.55	132.44	12.25		259.23
2004	120.85	146.76	16.41		284.02
2005	134.68	165.77	16.75		317.20
2006	138.58	186.96	16.46		342.00
2007	144.92	174.79	13.58		333.29
2008	131.29	99.05	11.18		241.52
2009	137.37	156.64	14.49		308.50

The data of water supplies stand that the irrigation use of water weights for the 50% of the whole delivery whilst the domestic use demands the 46%.

3 SIMULATED SCENARIOS

3.1 Description of scenarios

The data let to describe with a reasonable level of reliability some hypothetical scenarios, useful as basis of general argumentations. The inflow data, coming from the hydraulic balance described in § 1.1.2, are common to each scenarios.

The first scenario has been settled using the plain data from the management authority of the Monte Cotugno Reservoir and it can be regarded as a reference for the others.

The second scenario describes the eventuality of a reduction of water supplies due to a reduction or a lack of maintenance, both from a structural and administrative point of view.

On the contrary, the third scenario wants to stress the benefits coming from the reuse of water: some studies (Fresa et al. 2007) highlighted the great potentiality for reuse in Apulia which can make the water stocks increase up to 40 % of the average volume delivered in the last twenty years.

Of course, it is not possible to deny strong limiting factors of sociological and legal origins, but it has been considered a very interesting aspect to show the powerful enhancement of resource coming from a good social practice: the advantages are also evident in case the reuse is combined to the absence of maintenance, as shown in the forth scenario.

Beside these scenarios based mostly on the surveying of alterative solutions to what had really occurred, other scenarios for simulating possible evolutions are also presented.

The fifth scenario is based on the same inflow data of the previous ones, but consider a constant value of water demand, coming from the average of the supplied volumes in the previous twenty five years. As a matter of fact, the perspective of a somehow increased demand, represented by the average value adopted hereby, matches a possible increased availability of resource, which should be secured by some expansion projects planned by the national and local governments (Di Santo & Ranieri, 2000).

The sixth, seventh and eighth scenarios follow the second, third and forth in all but the different demand, maintained constant all over the simulation period and equal to the previous twenty five years averaged supplies.

Finally, the ninth scenario simulates the hypothesis of a distribution to each user equal to the maximum value occurred in the last twenty five years: it will show the impossibility to assign a yearly regulation duty for the Monte Cotugno Reservoir, which has been planned to be a long term water stocks.

3.2 Performance indicators

The performance indicators adopted hereby, are borrowed from the IWA (International Water Association, Alegre et al., 2006), from WWAP (World Water

Assessment Programme, UNESCO) and from the Italian Authority on Water Resources Use (Comitato per la Vigilanza sull'Uso delle Risorse Idriche , 2006).

These simple, sometime simplistic, indicators can help in the process of comparison among several scenarios and, even though they do not suggest any diagnosis or remedy, yet they can prove effective and user friendly.

The scientific literature (Ancarani et al., 1998, Cancelliere et al., 1998, Hashimoto et al., 1982) present a large variety of indexes, among which the following relationships has been chosen. They are expressed as function of D and E, the water demand and supply, respectively, N the length of the simulation period (years), n_d the number of shortage intervals and N_{pd} the number of shortage periods, M_N maximum year shortage:

$$\text{Shortage} \quad D_{tot} = \frac{\sum_{i=1}^{12N} (D_i - E_i)}{\sum_{i=1}^{12N} D_i} \quad (1)$$

$$\text{Frequency of shortage} \quad F_d = \frac{n_d}{12N} \quad (2)$$

$$\text{Resiliency} \quad L_s = \frac{n_d}{N_{pd}} \quad (3)$$

$$\text{Maximum yearly shortage} \quad M_D = \max M_N \quad (4)$$

$$\text{Beard Index} \quad B_i = \frac{100}{N} \sum_{i=1}^{12N} \left(\frac{D_i - E_i}{D_i} \right)^2 \quad (5)$$

$$\text{Reliability} \quad Aff = \frac{\sum_{i=1}^{12N} E_i}{\sum_{i=1}^{12N} D_i} \quad (6)$$

$$\text{Vulnerability} \quad Vul = \frac{1}{M_N} \sum_{i=1}^M (D_i - E_i) \quad (7)$$

The shortage, the frequency of shortage and the resiliency are able to describe the behavior of each scenario in terms of scarcity risk, whereas the reliability can show how fast the system may recover from a crisis. The Beard index and the vulnerability describe the damage due to the water scarcity.

3.3 Social and economical considerations

It's a matter of fact that the economical factors exert a strong influence in terms of

water resource management. The local authorities, in charge of survey the private and public water distribution societies, adopt the so called “*normalized method*” (D.Lgs. n° 152/2006, Art. 154, D.M. LL.PP.01.08.1996) according to which the cost of water for each cubic meter shall be defined through the balance between costs and benefit of the supplier. Beside this, the principle of “*Full Recovery Cost*”, well known in the industrial and financial fields, shall be applied also to the water resources distribution.

In details, the final cost for volume unit depends on financial, environmental and investment opportunities. The first ones are related to maintenance and personnel costs, but also to the depreciation and cost of capital, in this sense they vary as the supplied water quantity. The environmental costs regard the losses of resource quality and quantity, finally the opportunity costs are related to the economical losses depending on the choices about water allocation to one user more than other.

The economic data for domestic, agricultural and industrial fields, come from a society dedicated to the survey of water use in Italy: Sogesid Spa. The data, referred to the period 2002-2005 have been extrapolated to the simulation period by simple linear regression law.

The amortization rate has been chosen following the Italian regulation Decreto Ministeriale 31/12/1988, referred to hydraulic works and it is fixed at 5%.

In order to take into account also the opportunities of the best possible alternative investment, the BOT and BTP, i.e. the Italian Government Bond, have been chosen, with a rate equal to 3%.

Finally, the benefits for the water management societies derive from the tariffs of a cubic meter volume of water, furnished by the Basilicata River Basin Authority.

4 DISCUSSION OF RESULTS

An overall view of the comparison between the scenarios can be inferred by the graph in figure 2 and table 2, where the storage volume curves for each scenario are presented.

The first finding arising from the graph is that an average constant distribution, in particular in the irrigation use, helps in the long term resource regulation as the curve of the 5th scenario shows, being higher to the 1st scenario, chosen as a reference.

This is true also in case of significant losses when comparing the second and sixth scenarios, both based on a reduction of resources equal to the 30 % : the sixth scenario states that also in this case the choice of a temporal averaged distribution, even in time of relative abundance, helps in preventing scarcity during crisis.

The practice of water saving through reuse of domestic and agricultural stocks clearly shows a significant improvement of resource availability (3rd scenario), also in case of lack of maintenance (4th scenario), mainly with a controlled average distribution in the long terms (7th and 8th scenarios).

The ninth scenario wants to stress, just for comparison's sake, the obvious assert that it is not possible to maintain a high rate of distribution in the long term, since the reservoir has not been designed for a single year cycle.

In the overall, the 8th scenario represents the best compromise between the need for the resource storage and the need of avoiding the overflow. The best practice of water reuse, in fact, reduces the shortage and frequency of shortage to acceptable values, such as the damage due to scarcity being the Bears index and vulnerability the lowest

possible, without neglecting the resources losses as in third and seventh scenarios.

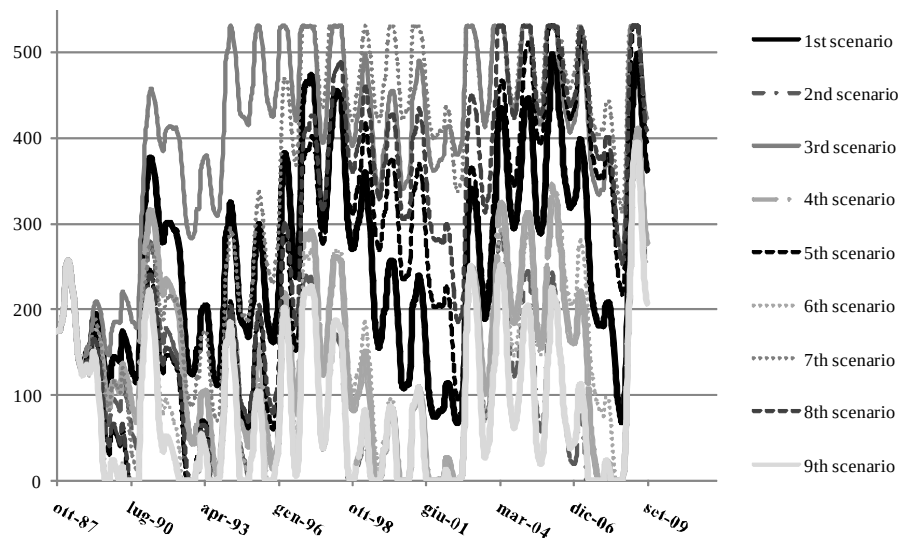


Figure 2. Storage volume_Curves of storage volume (millions of cubic meters) of water referred to the nine scenarios: the bold type line represents the 1° scenario, chosen as the reference one.

Table II. Performances Indicators_Values of each performance indicator for each scenario.

	D_{TOT}	F_d	L_s	$M_D (m^3 \times 10^6)$	B_i	Aff	$Vul (m^3 \times 10^6)$
1° scenario	-	-	-	-	-	-	-
2° scenario	0.14	0.21	4.82	183	125.34	0.86	85
3° scenario	0	0	0	0	0	1	0
4° scenario	0.06	0.10	3.13	124	51.26	0.94	43
5° scenario	0.03	0.04	3.67	78	25.54	0.97	60
6° scenario	0.13	0.19	4.70	172	111.89	0.87	88
7° scenario	0	0	0	0	0	1	0
8° scenario	0.02	0.04	3.33	58	18.71	0.98	44
9° scenario	0.23	0.28	4.73	239	185.50	0.77	115

For completeness' sake, the optimized value of resources distribution for each user and each scenario are also referred in table 3, where the monthly water volumes are shown. With respect to the average monthly water volume delivered in the years 1988/2009, a reduction of about 7% to the domestic user and 50% to the irrigation should have been adopted to optimize the water allocation.

The analysis of costs and benefit suggested that the yearly average cost of one cubic meter of water shows a continuous increase in water costs, even if in the years of scarcity (e.g. 2002) the water reuse (7th scenario) and losses reduction (8th scenario) is the possible way to maintain the costs lower than in the other cases. Anyway, it is impelling to state the strong increase of costs highly depends on the *Full recovery*

Costs, a principle which is hardly applicable to the social services of public utilities such as the water distribution.

Table III. Optimized monthly supplies ($\text{m}^3 \times 10^6$)

	Domestic	Agricultural	Industrial
1° scenario	9,28	4.19	0,42
2° scenario	10,08	3.86	0,02
3° scenario	6,72	6.91	0,27
4° scenario	7,15	6.29	0,47
5° scenario	7,23	6.07	0,02
6° scenario	7,50	6.40	0
7° scenario	6,58	6.92	0,40
8° scenario	7,54	6.37	0
9° scenario	5.57	8.32	0

5 CONCLUSIONS

The study case of the hydraulic scheme pertaining to the Sinni River has proved useful to describe some considerations on the management of water resources during shortage periods.

The main reservoir, the Monte Cotugno Reservoir, is characterized by a long-term regulation plan and it has been shown that, in order to mitigate the shortages, it is important to follow constantly an average supply of water, mainly to the agricultural users, also during the periods of relative abundance.

Beside this, it is important to foster on large scale the best practice of water reuse: it has been shown that, even in case of few or null maintenance and reduction of losses, the reuse can cover in a proper way a great part of demands. The tariffs of water for end users are also positively influenced by this practice.

These general considerations apply to many cases of the Southern Italy, characterized by complex hydraulic schemes and long-term regulation reservoirs.

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REFERENCES

- Alegre, H. Baptista, J.M., Cabrera, E., Cubillo, F., Duarte, P., Hirner, W., Merkel, W., Parena, R. (2006). *Performance Indicators for Water Supply Service- Second Edition*, IWA Publishing, London, ISBN 1843390515, pp. 289.
- Amoruso, V., Balacco, G., Giuliani, A., Renna, F.M. (2007) *Gestione della risorsa idrica in situazioni conflittuali*, Proceedings of the workshop "Approvvigionamento e distribuzione idrica: ricerca ed innovazione". Ferrara, 13-15 giugno.
- Ancarani, A., Cancelliere, A., Rossi, G. (1998). Valutazione degli effetti delle misure di mitigazione delle siccità in un sistema idrico complesso. XXVI Convegno di Idraulica e

- Costruzioni Idrauliche, Catania, 9-12 Settembre.
- Cancelliere, A., Ancarani, A., Rossi, G. (1998). *Susceptibility of water supply reservoirs to drought conditions*, Journal of Hydrologic Engineering, Vol. 3 (2), pp. 140-148.
- Castorani A.(2002) La valutazione dei consumi idrici industriali in Puglia, *scientific report*, Fondazione IPRES e Politecnico di Bari.
- Comitato di Vigilanza sull'Uso delle Risorse Idriche (2006). *Indicatori di prestazione dei servizi di acquedotto, fognatura e depurazione*. Delibera n.° 7 del 27/04/06.
- Di Santo A., Ranieri M.(2000). Studi propedeutici all'accordo di programma Puglia-Basilicata per la gestione delle risorse idriche. *L'acqua*, Vol. 2, pp.65-76
- Decreto Legislativo 5 gennaio 1994, n. 36 Disposizioni in materia di risorse idriche (G.U. 14marzo 1996, n. 62)
- Decreto Ministeriale 1 agosto 1996 "Metodo normalizzato per la definizione delle componenti di costo e la determinazione della tariffa di riferimento del servizio idrico integrato". (G. U. n. 242 del 15/10/1996)
- Decreto Legislativo 3 aprile 2006, n. 152 "Norme in materia ambientale"(G.U. n. 88 del 14/04/2006 - S.O. n. 96)
- Fresa, F. Melli, A.F. Piccinni, V. Santandrea, V. Specchio (2007). La pianificazione del riuso delle acque reflue; International Conference on Water Saving in Mediterranean Agriculture & Future Research Needs – 14-17 Feb.
- Hashimoto, T., Loucks, D.P., Stedinger, J. (1982). *Reliability, Resilience and Vulnerability for Water Resources System. Performance Evaluation-* Water Resources Research, 18 (1), pp. 14-20.