# Allocation of Water Resources and Cost under scarcity: A case study

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## Abstract

In most Mediterranean regions, the presence of continuous sources of water stress is combined with periodic drought episodes. The decline of water resources and increasing demand for freshwater cause threats to the environment and provoke conflicts between competing uses. The need for new infrastructure to cope with the seasonal peak induced by vital economic activities (e.g. tourism and agriculture) should be taken into account in the formulation of water management plans and appropriate pricing policies. The latter, according to the requirements of the Water Framework Directive and the principles of Integrated Water Resources Management, should aim at: (a) environmental protection for encouraging conservation and efficient water use, (b) cost recovery, for the generation of funds for the operation of the water sector, and (c) cost reflectivity, for indicating to users the true scarcity value of water.

Following from the above considerations and principles, the development of appropriate, integrated water management strategies for arid regions should reconcile multiple goals and objectives: guaranteeing the provision of water of sufficient quantity and quality for sustaining and developing dominant economic activities, while protecting vulnerable ecosystems; ensuring the financial sustainability of water services and the appropriate maintenance and renewal of infrastructure, while taking into account affordability criteria.

This work aims to present the evaluation of different scenarios regarding the allocation of water resources and financial, environmental and resource costs in a semi-arid island of the Cyclades complex, Greece. Two different water management plans are formulated for a 25-year horizon, following the current system of water rights and permits for water allocation; these two plans are compared with an alternative scenario for water resource allocation and management, where there is free competition between the two economic sectors (tourism and agriculture) over scarce water resources. In this scenario, water supplies are developed through private initiatives. The overall aims are to (a) depict the appropriate way of allocating costs for the management of seasonal peak demands, and (b) arrive at a sustainable solution, which meets the requirements of the "polluter-pays" principle while at the same time minimizes economic impacts on important economic sectors.

## 1. Introduction

The implementation of the Water Framework Directive calls for the development of long-term water management plans and programmes of measures for achieving good environmental status and alleviating pressures exerted on water bodies. Under this framework, the overall objective of ensuring the long-term protection of available water resources and promoting sustainable water use should be interpreted and adapted in a more regionalised context, which would allow for the development of strategic plans adjusted to the particularities of each case. Strategic planning at the river basin or catchment scale should involve measures and instruments for meeting the following sustainability objectives (Van Hofwegen and Jaspers, 1999; Savinije, 1997):

- Technical sustainability, i.e. balanced demand and supply.
- Financial sustainability, i.e. cost recovery.

- Social sustainability, i.e. stability of demand, equitable allocation of costs.
- Economic sustainability, i.e. sustaining economic development or welfare and production.
- Institutional sustainability, i.e. capacity to plan, manage and operate the system.
- Environmental sustainability, i.e. no long-term negative or irreversible effects.

Such objectives and goals are linked to the development of pricing policies as described in Article 9 of the WFD. Following the above objectives and the WFD principles, the development of appropriate pricing policies should address at least the three objectives set out by GWP (GWP Toolbox, 2005): (a) Environmental protection for encouraging conservation and efficient water use, (b) Cost recovery, for the generation of funds for the operation of the water sector, and (c) Cost reflectivity, for indicating to users the true scarcity value of water.

In particular, and following the WFD implementation process, the terminology regarding resource and environmental costs is evolving. The most recent definition given by CIS DG ECO 2 (2004) describes environmental costs as the economic damage costs to the water environment and other water use(r)s caused by alternative competing water use (abstraction or discharge). In the same information sheet resource costs are defined as the opportunity costs of using water as a scarce resource in both space and time.

The estimation of the above cost components, the allocation of costs to water uses and the formulation of cost recovery policies in areas characterised by water scarcity presents specific challenges. New infrastructure (dams for interseasonal storage, extensive conveyance systems) is required to address the need for adequate supply; this in turn raises the question of adequate funding, institutions and administration that can enable the development and management of such infrastructure. Further compounding the problems, the coastal regions, where population tends to concentrate, are an attractive tourist destination. This seasonal peak, which normally coincides with the irrigation season, creates strong competition of users over scarce resources and should be taken into account in infrastructure planning. The imposed economic burden and low water availability potentially result in low recovery of costs, especially under drought conditions. At the same time, environmental impacts from water usage are significant: wastewater collection and treatment systems are inadequate or even barely developed, while in many regions water resources are overexploited. The development of cost recovery mechanisms and appropriate pricing schemes also needs to address the potentially high resource and environmental costs, and existing cross-subsidies between use sectors and users.

This paper presents a framework for the development and evaluation of water management plans and cost recovery policies for water deficient regions, which focuses on the mitigation of water shortage. The adopted methodological approach is based on the application of a prototype Decision Support System, and is presented through a tentative application in the island of Paros of the Cycladic Complex in Greece. The island faces intense supply coverage problems during the summer tourist season, while, as in most Mediterranean coastal regions, groundwater resources are overexploited in order to address the high irrigation and domestic water requirements.

## 2. Methodological approach

### 2.1. The WSM DSS and the economic analysis of alternative water management scenarios

Decision-making processes associated with water resource allocation and planning are complex, requiring multidisciplinary information for evaluating their effects on a social, economic and environmental level (Salewicz and Nakayama, 2004). In the context of formulating water management plans, the evaluation of the cost-effectiveness of different water management options should be performed under alternative scenario assumptions in order to address potential future changes and uncertainties.

For meeting the above objectives, a variety of simulation tools have been developed with the aim to assess the behaviour of water systems to extreme, non-equilibrium conditions, as well as the effectiveness of different instruments with regard to sustainability criteria and objectives (Mc Kinney et al., 1999). The analysis of environmental and economic impacts of water allocation decisions and instruments should be based on the integration of hydrologic, agronomic, economic and institutional modelling, usually at the river basin scale. Towards this end, a number of models and decision support systems have been developed for representing the interrelationships in the real world.

The analysis described in this paper is based on the Decision Support System developed in the framework of the EC-funded WaterStrategyMan project ("Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions", Contract no: EVK1-CT-2001-00098). The (prototype) DSS has been developed with the purpose of formulating alternative water management scenarios for water deficient regions. The DSS is able to model, simulate, analyse and evaluate alternative management responses, operating under the basic principle of promoting effectiveness, economic efficiency, environmental sustainability, and equity in the provision of water supply and the allocation of costs among the water system users.

The DSS is based on a simulation model for water allocation that minimizes water shortage under limited water availability (Manoli et al., 2001). In situations of water shortage, distributing the water available from the various supply sources to the connected uses creates conflicts. The allocation model solves this problem using two user-defined priority rules. First, competing demand sites are treated according to specified priorities. Those can express social preference or constraints, economic preference (prioritization to activities with highest economic values), or a system of water rights. In case that a particular use can be supplied by more than one resource, supply priorities are used to rank the choices for obtaining water. Supply priorities express cost preference; quality preference of uses (e.g. domestic or industrial use) for supply sources with high water quality; need for the protection of resources and the formation of strategic reserves.

One of the objectives behind the development of the DSS was the assessment and development of cost recovery policies. The aim was to develop a Decision Support Framework for the evaluation of policies which could achieve the requirements set out in Article 9 of the Water Framework Directive for the:

- Adequate recovery of (financial, environmental and resource) costs for water services' provision,
- Application of the polluter-pays principle, and
- Provision of adequate incentives for efficient water usage.

For this purpose, on the basis of the water allocation performed by the model, the DSS estimates financial, environmental and resource costs linked to water management interventions, and allocates them to water use(r)s. The estimation of financial costs is straightforward, depending on data entered for the amortization of capital investments, specific energy consumption and cost, and other operation and maintenance costs associated with each part of the infrastructure, as well as demand management interventions. A distinction is made between measure costs that are implemented by the managing authorities (e.g. infrastructure) and costs of measures that are implemented by the users.

For the estimation of external environmental costs the model applies a cost-based valuation approach. In particular, external environmental costs are approximated through the cost of measures needed to prevent/mitigate environmental damage or achieve good status. In this regard, environmental costs are associated with impacts on the water environment from pollution discharges and overexploitation. As described in the DG ECO 2 Information Sheet (CIS, 2004), the estimation of environmental costs implies that the underlying reference or target situations are established for each water body. For this purpose, the model takes into account impact coefficients to reflect the sensitivity of each water body, and thresholds to describe the level above which abstractions or discharges can result in potential environmental damage or have a significant impact on the water status.

Resource costs in the DSS are approximated by the scarcity rent of the water resource, which is defined as a surplus, the difference between the opportunity cost of water (equal to the market equilibrium price P) and the per unit (marginal) financial costs (associated with e.g. abstraction, treatment, conveyance, distribution) of turning that natural resource into relevant products. The estimation of resource costs is based on a generalised network algorithm under the assumption that user-defined priorities reflect water values, which consists of the following steps:

1. Estimation of water shortage for each modelled water use;
2. Estimation of water values at the user's location;
3. Ranking of water users on the basis of the water values estimated in Step 2;
4. Identification of system elements that model joint infrastructure (infrastructure supplying more than one water user) and are related to the exploitation of freshwater supply sources (e.g. boreholes, dams, diversions etc.);
5. Identification of cases of inefficient allocation (i.e. water shortage for a water use(r) with a higher economic value);
6. Estimation of the additional financial cost for transferring an additional cubic meter of water to the particular water user;
7. Estimation of the scarcity rent for the supply source following the above definition.

Allocation of estimated financial, environmental and resource costs is performed according to the "polluter-pays" principle, on the basis of quantities abstracted or pollution discharges which determine (a) the share of infrastructure costs that should be allocated to each user and (b) the share of environmental and resource costs incurred from overexploitation, pollution discharges or inefficient allocation. The overall aim is to provide meaningful results for the formulation of cost recovery strategies and schemes, as described in Section 2.2 below.

### 2.2. A methodology for strategy formulation

In addition to providing adequate information towards the formulation of policies for reaching the above objectives, economic analysis indicators are also used for the evaluation and ranking of single water management interventions or strategic plans. The approach developed for strategy formulation is based on the application of the DSS and an iterative process, which is outlined in Figure 1.

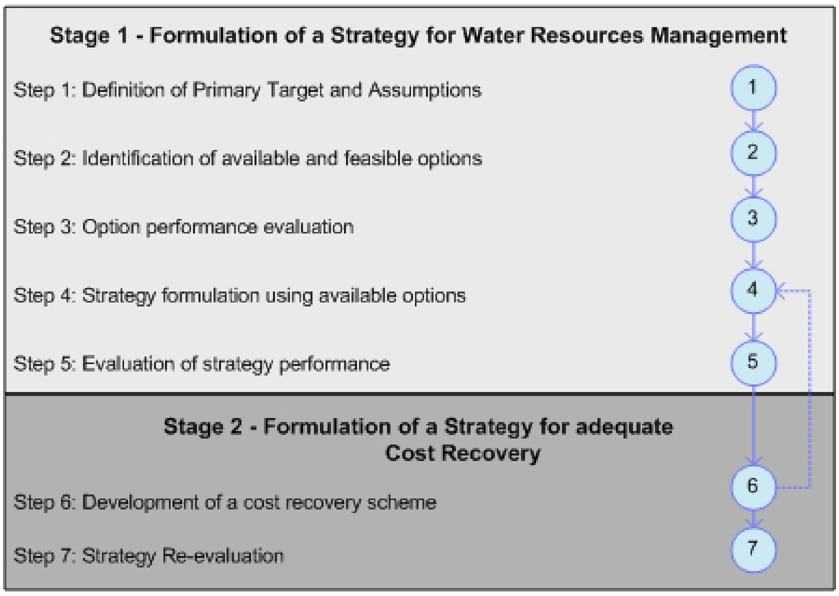



*Figure 1: The process of Strategy Development*

The adopted approach is elaborated into two stages with a total of seven steps. Throughout these two stages, the governing principles are those of Integrated Water Resources Management, namely (Jønch-Clausen, 2004):

- The goal of **Equity**; in addition to an equitable allocation of the water resource in itself, this goal also involves the equitable distribution of costs equitably among the water users, including households, the tourist industry, the farmers and Industry.
- The goal of **Environmental Sustainability**, mainly through the mitigation of the impacts incurred in the production and supply of water, which in arid and semi arid areas dependent on groundwater involves the reduction of drillings to sustainable levels.
- The goal of **Economic Efficiency**, involving the minimisation of costs and maximization of output associated with the provision of water, achieved through the selection and application of management options that are most efficient and making use of best practices, new technologies and improvements.

**Steps 1 and 2** of the approach are strongly related to stakeholder consultation, since in the past a number of developed strategies, even if essential, failed to win stakeholder acceptance. Work undertaken in these steps involves the identification of potential stakeholders, the selection of representatives, the organisation of awareness meetings and the identification and synthesis of opinions, wishes and expectations. **Step 3** involves the evaluation of the performance of the proposed interventions through their modelling and simulation using the DSS, and the derivation of the Performance Matrix that permits their ranking. This evaluation is performed under different combinations of scenarios on pressures (demand and availability), in order to define the maximum extent of application, technical constraints, incurred costs, and associated environmental impacts. **Step 4** involves the integration of the most suitable options in coherently formulated water management strategies. Their actual formulation involves the selection of instruments, based on the recommendations of Step 2 and the results of Step 3. The definition of an appropriate timeframe is based on successive simulations in DSS, taking into account technical and environmental constraints, and the achievement of the set out targets. In **Step 5**, strategies are evaluated against each other, as well as against the reference case for the water system. From a wide set of available indicators, those that are chosen on a preliminary basis consist of: (a) the relative sustainability index for demand coverage, including criteria for reliability, resilience, and vulnerability (ASCE, 1998), (b) financial costs incurred from the application of the strategy and the provision of water services, (c) associated environmental impacts and costs, including groundwater and surface water abstraction costs, pollution costs and (d) resource costs incurred by the allocation of water to specific uses. Subject to user-defined criteria, these indicators can be used to provide an overall score for each strategy. The approach is complemented through the development of appropriate cost recovery schemes, taking into account institutional and governance framework constraints and the need for the adequate contribution of water uses to costs incurred by water services. In **Step 6**, an appropriate cost recovery target is set, depending on affordability criteria. Then, the current pricing scheme is analysed with respect to the recovery of financial, environmental and resource costs, thus providing an estimate of the increases in price required in order to reach the set targets. As the elevated water prices will in most cases influence the water demand, each strategy is then re-formulated and re-evaluated in Step 7, using the same indicators as in Step 5.

The following section presents the adopted methodological approach and the application of the Decision Support System for the formulation of strategies and water allocation scenarios in the island of Paros of the Cycladic Complex in Greece.

## 3. Case Study Analysis

The island of Paros (Figure 2) is one of the most popular tourist destinations in the Cycladic Complex. During the summer months the seasonal population is almost three times greater than the permanent residents, while during the winter months local authorities estimate that only 50% of the registered permanent population in fact remains on the island.

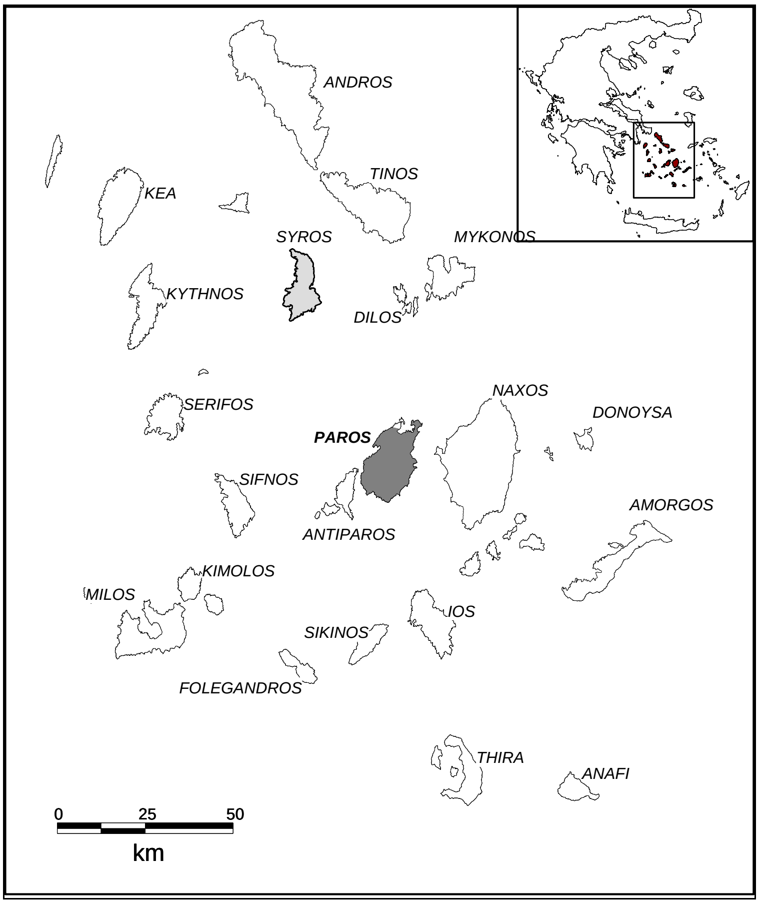



*Figure 2: The island of Paros in the Cycladic Complex*

The development of tourism and the consequent prosperity of the island began slowly in the early 1960s, after many years of decadence. In the 1950s the local inhabitants were mostly farmers and fishermen, and between 1950 and 1965 a large emigration trend was observed that resulted in a great population decrease. In the 1970s this trend was reversed due to tourism, which then grew rapidly during the 1980s, bringing about changes in the traditional way of living. Unfortunately this development took place without planning and control, leading to the problems that the island is facing today, both in terms of economic – offer of accommodation being greater than demand of accommodation – and environmental impacts– great seasonal pressures exerted on water resources. At the same time, the once abandoned agricultural activity was enhanced to a large extent by this growth and the resulting demand for local traditional products.

Water demand growth in these last decades was mostly addressed through the drilling of numerous boreholes. The uncontrolled abstractions of the previous years for both irrigation and domestic consumption have had severe impacts on the water quality of the most productive aquifers of Paros. Additionally, during the last 20 years and due to the intense exploitation of groundwater resources, especially during the summer months, a lot of wells and springs have dried out. As expected, the areas facing water deficiency and overexploitation are those that concentrate the main tourist and irrigation activities of Paros. At present, responses to cope with the emerging water deficit are shifting towards more technical solutions, such as desalination. Currently, one brackish desalination unit with a capacity of 1,450 $m^3/d$ operates in the northern part of the island, while the majority of local stakeholders are favourable towards the construction of additional plants to supply tourist areas.

### 3.1. Strategy Formulation

The goal for the formulation of strategies for the island of Paros was to reconcile water supply and demand in order to promote tourism development, while at the same time preserving traditional agricultural activities. The strategies that were formulated aimed at medium to long-term planning, and therefore take into account a 25 year horizon, spanning the period 2005-2030. The targets set for the analysis were to meet (a) at least 80% of the domestic and irrigation needs in the peak summer period, and (b) 100% of the demand during the rest of the year. At the same time, secondary objectives in the overall process was the achievement of (a) economic efficiency, through the maximisation of economic output, (b) environmental sustainability through impact mitigation and reduction of groundwater extractions to sustainable levels, and (c) equity by achieving a more equitable allocation of incurred financial, environmental and resource costs to users.

Appropriate measures and instruments, and their potential limitations, were identified through the examination of the current responses to water stress issues and consultation with the local stakeholders. A summary is portrayed in Figure 3.

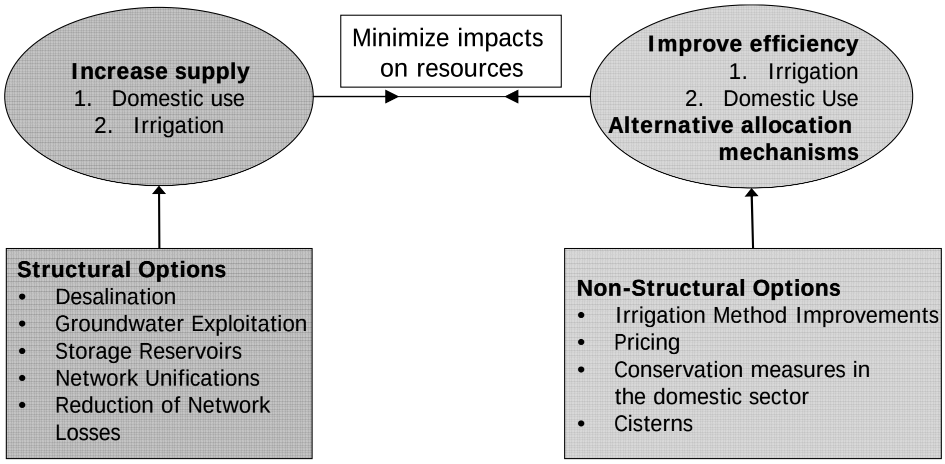



*Figure 3: Summary of identified feasible and available options for the island of Paros*

Subsequently, the most suitable options were integrated into coherently formulated water management strategies. Two alternative approaches were distinguished, based on the water resource planning paths elaborated by Gleick (2003):

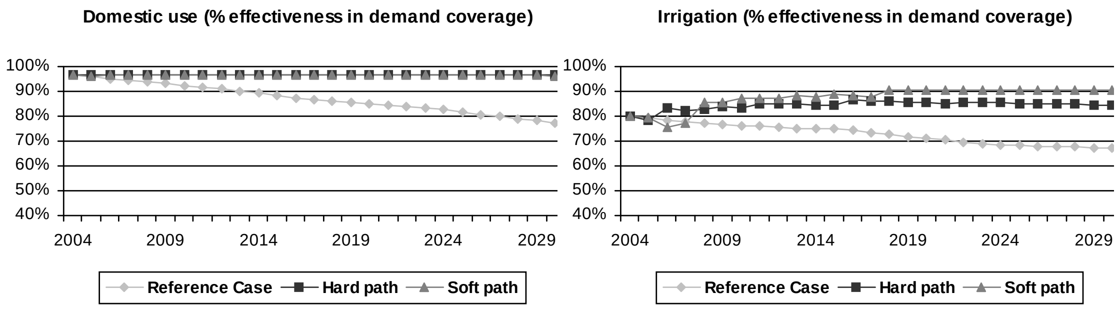
- The **hard-path approach**, mostly oriented towards supply enhancement through the application of structural solutions, and incorporating new technologies such as desalination;
- The **soft-path approach**, integrating demand management options, and small-scale decentralised structural interventions to alleviate major water shortages. Potential demand management responses for the island concern mostly conservation efforts and efficiency improvements, promoted through economic incentives.

A summary of the measures incorporated in the two strategies is presented in Table 1. Measures were subsequently formulated in a suitable timeline, determined through an iterative procedure, and were compared and evaluated against each other and against the reference case on which they were built. The reference case was defined as the foreseen evolution of the water system, including a business-as-usual demand scenario (1.5% growth for permanent and tourist population, stable irrigation demand), and constant, average availability conditions. Planned and already decided interventions were also taken into consideration.

Evaluation results regarding the effectiveness and cost of the two approaches are presented in Figure 4 and Table 2. In terms of effectiveness, both strategies can meet more than 95% of domestic needs; set targets are also met for irrigation water supply. However, in terms of the latter, the soft-path approach has a slightly better performance, especially after the full introduction of measures that target the agricultural sector, i.e. irrigation method improvements and measures that limit domestic consumption. Therefore, it becomes evident that agricultural activities can be sustained more effectively through the introduction of measures that improve the efficiency of water usage.

*Table 1: Measures incorporated in the two alternative water management strategies*

| **Hard-path approach** | **Soft-path approach** |
|---|---|
| | **Network Unifications** |
| **Groundwater Exploitation**<br>A total of 4 additional boreholes, yielding 204,000 $m^3$/yr | **Groundwater Exploitation**<br>1 additional borehole, yielding 75,000 $m^3$/yr |
| **Surface water exploitation**<br>Interception dam for aquifer enhancement<br>Capacity of 98,000 $m^3$ | **Surface water exploitation**<br>Interception dam for aquifer enhancement<br>Capacity of 98,000 $m^3$ |
| **Reduction of Network Losses**<br>From 25 to 20 % | **Reduction of Network Losses**<br>From 25 to 20 % |
| | **Conservation measures in the hotel sector**<br>10% reduction of consumption |
| | **Irrigation Method Improvement**<br>Substitution of current methods with drip irrigation |
| **Desalination**<br>Additional capacity of:<br>1300 $m^3$/d in 2010<br>2000 $m^3$/d in 2020<br>2700 $m^3$/d in 2030 | **Desalination**<br>Additional capacity of 600 $m^3$/d |




(a) (b)

*Figure 4: Effectiveness of the proposed strategies in meeting the set targets (a) domestic use (b) irrigation water provision*

Estimated costs for the two strategies and the reference case are outlined in Table 2. Financial costs include capital and operational costs for measure implementation, and costs associated with the operation of the water system (e.g. pumping costs for irrigation and domestic supply, network costs, administrative costs etc). Environmental cost is associated with the cost of preventive/mitigation measures and includes two components: one incurred from groundwater over-abstractions, and one dealing with pollution generation from inadequately treated urban return flows.

*Table 2: Comparison of strategy costs*

| | **Financial Cost** | **Resource Cost** | **Environmental Cost** | **Groundwater over-abstractions ($hm^3$-2015)** |
|---|---|---|---|---|
| | **(PV, 4%, 2004-2030, million €)** | | | |
| Reference | 27.59 | 5.07 | 36.07 | 0.63 |
| Hard-path | 33.99 | 3.88 | 35.89 | 0.58 |
| Soft-path | 30.33 | 0.87 | 33.84 | 0.45 |

The soft-path approach appears more advantageous, presenting lower values for financial, environmental and resource costs. The reduction of financial costs is primarily due to the introduction of efficiency improvements, which limit the required desalination capacity (i.e. 600 vs. 2,700 $m^3$/d). Similar results are obtained for environmental costs, since in most aquifers the abstractions considered "unsustainable" (exceeding the safe yield) are significantly lower.

Therefore, a preliminary conclusion that can be drawn from this analysis is that soft-path approaches can be effective in mitigating water stress, while at the same time incurring lower costs to consumers. This issue is further elaborated in the following section.

## 3.2. Addressing Cost Recovery Issues

An additional step in the process of defining appropriate strategies is the development of cost recovery scenarios that could ensure the financial sustainability of water services. These scenarios are formulated for each water use sector and service by setting appropriate cost recovery targets to be achieved within a set timeframe, and taking into account the present institutional and administrative framework.

Domestic water supplies in Paros have been under the administration and management of a municipal water utility company (DEYAP) since 1999. Increasing block tariffs (IBTs) set by the DEYAP recover operation and maintenance costs for water supply and wastewater collection and treatment, and part of the capital costs. Although maintenance and control follow a centralized and better-organised decision-making path than before, there are still remnants of the past administrational structure, when each municipal department used to develop its own water resources. One of these remnants is the differentiation of block tariffs per municipal department. Irrigation water supplies in the northern part of the island are managed by a Local Board for Land Improvement (TOEV); however, most agricultural needs are met through private boreholes and crop irrigation relies solely on groundwater. In this case there is no recovery of any kind of neither environmental nor resource costs.

On a preliminary basis, cost recovery scenarios were formulated through the definition of flat-rate volumetric prices and charges, re-adjusted every five years in order to achieve a set recovery of financial and environmental costs. For this purpose, costs were allocated to each use according to the *'polluter pays'* principle through the DSS. More specifically, financial and environmental costs associated with supply provision were allocated proportionally to the volume supplied to each use(r) from each supply source, whereas environmental costs from pollution generation were allocated according to the loads generated from each use.

For irrigation water, where financial costs are fully covered by the users, environmental cost recovery is effected through charges for over-abstraction. It should be noted that the actual implementation of such an instrument would involve the specification of abstraction limits per borehole, and the metering of extracted quantities at the end of the irrigation season. The definition of the maximum charge per 5-year period is based on the consideration that the private welfare surplus (i.e. the difference between benefits and the water costs charged to the consumers) from agricultural activities should be positive. This limited the maximum possible recovery of environmental costs to 50%. On the other hand, tariffs for the Water Utility were formulated to achieve a 100% recovery of financial costs for the entire planning period. The targeted recovery of environmental costs for 2005 was set at 50%, and was gradually increased, reaching 70% in 2030.

The estimation of prices and charges to be eventually applied was based on an iterative process, whereby demand and allocated volumes were re-estimated according to assumed demand elasticities. Resulting prices and charges are presented in Table 3.

*Table 3: Prices and charges estimated for the two strategies, in €/m³*

| | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| **Domestic Use** | | | | | | |
| Hard path | 2.19 | 2.19 | 2.19 | 2.27 | 2.32 | 2.32 |
| Soft path | 2.14 | 2.14 | 2.18 | 2.27 | 2.32 | 2.32 |
| **Irrigation** | | | | | | |
| Hard path | 0.09 | 0.12 | 0.12 | 0.12 | 0.13 | 0.13 |
| Soft path | 0.07 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 |

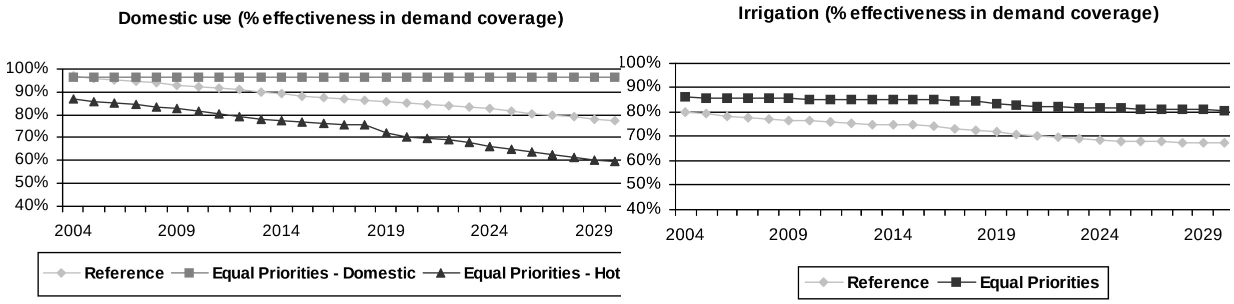
It becomes therefore evident that in principle, and at until the year 2010, the adoption of soft approaches can also result in lower costs charged to consumers. After 2020 both strategies result in similar prices and charges. Although costs for non-structural solutions are lower, due to the reduction of consumption, the volume of water sales is also smaller and therefore higher prices are required in order to attain the same cost recovery targets.

### 3.3. An alternative water allocation scenario

Water resource planning, as presented in the previous paragraphs, was based on the assumption that supply enhancement and demand management are financed through public funds, which are afterwards recovered through the water bill. In addition, strategies were developed taking into account the Greek Law 3199/2003 with regard to priorities for supply provision. Accordingly, the provision of water for domestic purposes, which also includes tertiary sector activities such as tourism, was considered of first priority, to be guaranteed under all circumstances.

This section outlines the development of an alternative model, where users develop supplies required for sustaining economic activities through private initiatives. Water supply for households is of the highest priority, and provided by the public authorities. Free competition over scarce resources is promoted between tourism and agriculture, which both receive water at a lower and equal allocation priority.

The graphs of Figure 5 portray the evolution of effectiveness in demand coverage, assuming that no measures are taken towards supply enhancement. The reference case corresponds to the original priority setting, where no distinction is made between households and the hotel sector. Under the current priority assumptions, the improvement in residential and irrigation demand coverage is evident, while tourism demand is not adequately met. Most importantly however, Figure 5a portrays that no further action is required to guarantee adequate water supply for households.




(a) (b)

*Figure 5: Effectiveness of the two allocation schemes for the coverage of (a) residential and tourist demand and (b) irrigation demand*

The set allocation priorities directly affect total economic output: in present value terms, foregone benefit from tourism reaches 13.11 million €, while benefits accrued from agricultural activities are only equal to 7.54 million €. Similarly, the total social welfare surplus (i.e. the difference between the total value or benefit and the total financial and environmental costs) is also reduced by approximately 8%.

A first response to this income loss could be the enhancement of water supplies by the hotel industry, in order to safeguard tourism revenues. Similar responses, through the installation of small, privately owned desalination units have been considered by hotel and lodging owners in the past in other popular tourist destinations. For Paros, the required total desalination capacity for meeting the peak mid-August tourism demand is estimated at 5,700 $m^3$/d in 2010, and 9,500 $m^3$/d in 2030. Electricity grid constraints limit maximum installed capacity to 5,000 $m^3$/d for the period 2005-2020 and 6,000 $m^3$/d for 2021-2030. The additionally required water supply can originate from surplus of public water supply sources and water purchases from irrigation boreholes. The supply mix for the hotel sector, as estimated through the DSS, is presented in Figure 6.

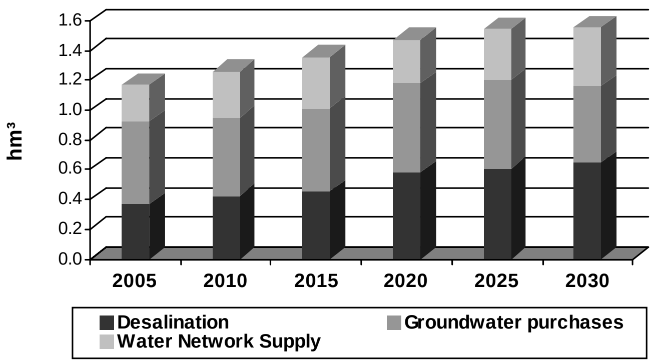
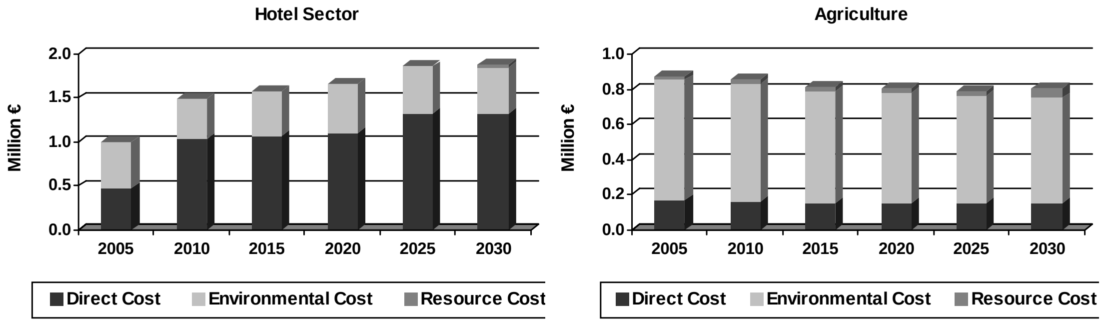



*Figure 6: Supply mix for the hotel sector*

Figure 7 presents the costs allocated to the hotel and agricultural sectors. In the first case, financial costs represent the costs of public water supply provision, the capital and operational costs associated with desalination unit construction and operation, and the cost of groundwater purchases. Prices for the latter are estimated in order to compensate for income loss from agricultural activities, and thus represent a lower limit for this cost.




(a) (b)

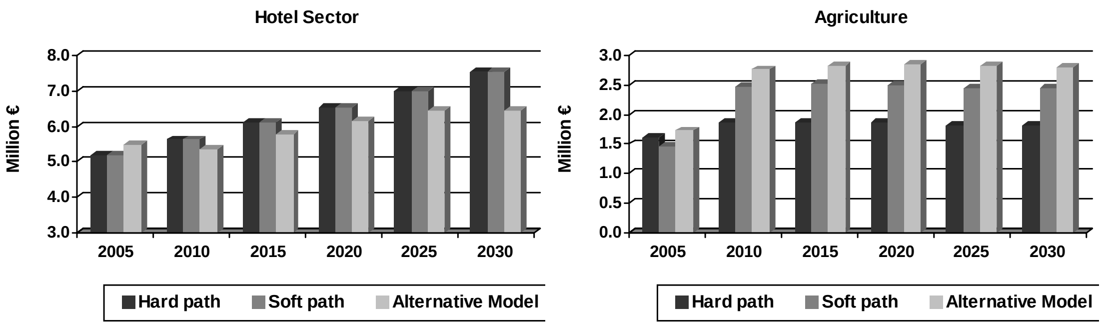
*Figure 7: Incurred financial, environmental and resource costs to the hotel and agricultural sectors under the alternative development model*

Flat-rate tariffs for supply from the public water system are estimated by assuming the same cost recovery targets. Table 4 presents the resulting unit costs incurred to users for 2015. The most important difference is observed in prices incurred to households, which are even lower than the current weighted average tariff of 1.47 €/m$^3$. On the other hand, the economic burden imposed on the hotel sector is almost insignificant, with the average unit cost being only 6% higher than that of the hard-path approach.

*Table 4: Costs incurred to consumers under different management plans (2015, €/m$^3$)*

| | Households | Hotel Sector | Agriculture |
|---|---|---|---|
| Hard-Path | 2.19 | | 0.12 |
| Soft-Path | 2.18 | | 0.11 |
| Alternative Model | 1.29 | 2.32 | 0.08 |

Finally, Figure 8 presents a comparison of the private welfare surplus for the two economic sectors and for each examined planning scheme.




(a) (b)

*Figure 8: Incurred financial, environmental and resource costs to the hotel and agricultural sectors under the alternative development model*

In line with the estimated costs, in the short run the economic impact of the alternative allocation scheme does not influence much the total net benefit accrued to users; the difference becomes larger at the end of the simulation period, when the installed desalination capacity is considerably higher and costs incurred to consumers increase.

## 4. Concluding Remarks

Integrated modelling can play an important role in the evaluation of the effectiveness of different management options and instruments for meeting the targets of the WFD. The development of a comprehensive framework which assesses environmental, economic, and social impacts of alternative policies can be considered a distant, data-intensive target to achieve. The combination of hydrologic and economic models can however, in some cases yield meaningful results in case study applications, which can in their turn be used for studying policy alternatives towards water resource planning and development.

The development of strategic plans following the principles of Integrated Water Resources Management and the Water Framework Directive should be based on a thorough examination of the existing institutional and administrative frameworks, and of the regional development patterns and user expectations. Regardless of the model used – public or private water supply development – strong regulatory frameworks are necessary in order to ensure the sustainable management of water supplies and the preservation of traditional economic activities, vital to the social structure. This however should not compromise the decentralisation of decision-making, which can help at addressing emerging water management issues locally.

Following the final evaluation of the two Strategies against each other and the reference case, it can be inferred that pricing will not influence the size of the infrastructure needed for the coverage of demand. The total water consumption (including both domestic use and irrigation) remains the same, as the demand decrease in the domestic sector only means that the water volumes available to irrigation are increased. Due to the current institutional framework, pricing of irrigation water is an instrument that cannot be implemented, although for private supplies it could take the form of abstraction charges for overabstraction; a subsidy is therefore always present between the domestic and agricultural use of water. The evaluation results for the "soft-path" approach (Strategy 2) compared to the reference case and the "hard-path" approach (Strategy 1) emphasise that the high temporal water imbalance in the island can best be solved through a combination of small-scale decentralised structural measures and soft interventions aiming to increase the efficiency and productivity of water use. Such a conclusion is further strengthened by the lower costs incurred to consumers in to the adoption of "soft" responses to mitigate water stress.

This example further serves to illustrate that under suitable supply management and allocation schemes the recovery of water-service related costs can result in the more equitable allocation of available resources, while at the same time incurring lower costs for water service provision, both to the users and to the utility, and thus promoting the financial sustainability of the water services. Given a strong regulatory framework that ensures the sustainable management of available water resources and that the local economic activities and general public well-being are safeguarded, these conditions apply both to public and private water supply providers. Finally, it should be stressed that the development of a visionary and successful programme of measures should always be a participatory process; only then can all social concerns and conflicts be addressed in a satisfactory manner, providing solutions that will be to the best interest of both society and the environment.

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