# Combining hydro-economic and water quality modeling for optimal management of a degraded watershed

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## ABSTRACT

Increase of economic and productivity efficiencies intensifies environmental pressures, too. Agriculture is one of the most common examples of this phenomenon. The sector is lacking proper management, which is especially prominent in Mediterranean areas. To address the situation, a holistic modeling approach, combining hydrological, economic and water quality aspects, is recommended for implementation in a Greek watershed. The broader area is degraded regarding its water availability, quality, and management. The model provides insights into water balance, net profit from agricultural activities, presents water quality data from simulations, and introduces two useful parameters informing the decision-maker's knowledge and understanding: the deficit irrigation water's value and a hydro-economic index which estimates (socio-)economic benefits over environmental balance. A combined demand-management plan is also examined considering the above outputs in investigating the multiple effects of the suggested policy measures. Furthermore, to discuss the optimal approach depending on data availability and scope, we compare two different settings of the proposed model. The results of the study confirmed the continuous quantitative and qualitative water resources' deterioration and economic overexploitation of the watershed. The study reveals the immediate need for management actions, integrated modeling approaches, and provides future recommendations on hydro-economic modeling.

**Key words** | hydro-economic modeling, integrated water resources management, irrigation water management, overexploitation index, water quality

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## INTRODUCTION

Today, water is not only a vital resource, but also a significant factor for socioeconomic growth. In most European countries it is a confirmed fact that the scarcity of fresh water has been increasing significantly, and in the last few decades the efficient use of water in agriculture has become necessary (Brouwer & Hofkes 2008; Medellín-Azuara *et al.* 2011; Kim *et al.* 2018). Agriculture has been increasingly intensifying over time, contributing to farmers' income and food provisioning but also causing important environmental problems (Gatabazi *et al.* 2019). The main environmental issues of intensified agriculture are related to land use changes, resources depletion, resources qualitative degradation, and greenhouse gas emissions. Recently, the research has been more and more focused on an integrated agricultural management (Blagojevic *et al.* 2016), which includes the achievement of economic goals under environmental constraints (World Bank 2006; Kahil *et al.* 2016). Hydro-economic models (HEMs) are increasingly

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used for these purposes, as they present a holistic way to illustrate the situation while considering multiple factors and identifying their potential. HEMs have been successfully implemented, mainly to address agricultural concerns and for optimum water allocation and efficiency (Cai *et al.* 2003; Ward & Pulido-Velázquez 2008; Peña-Haro *et al.* 2009; Divakar *et al.* 2011; Varela-Ortega *et al.* 2011; Gutierrez *et al.* 2013; Kamali & Niksokhan 2017; Alamanos *et al.* 2019). However, fewer studies have combined quantitative, economic, and qualitative management in a single hydro-economic modeling framework (Bekchanov *et al.* 2015).

This study addresses the problem of quantitative degradation of irrigation water, the impacts on its quality, and the mismanagement in economic terms. It also proposes an integrated management approach through hydro-economic and water quality modeling. Lake Karla watershed in Central Greece is chosen as the study area. This watershed faces problems of water scarcity and inadequate management, while due to its rural development, economic objectives (e.g., productivity, efficiency, and agricultural income) are considered very important. The proposed modeling approach focuses on water balance, the local economy (profits, costs, irrigation water value, hydro-economic indices, etc.), and the quality of surface and groundwater resources. It also examines a water conservation management plan to introduce demand management to local authorities and support water use efficiency initiatives. The outcomes of the study set the basis for a more systematic and complete monitoring, strengthen the local management, and prepare the ground for the successful implementation of the European Framework Directive 2000/60 (WFD 2000) in this degraded watershed. As a discussion, we compare the presented model with another hydro-economic approach, developed in our previous studies (Alamanos *et al.* 2016, 2017), in terms of data availability, modeling settings, scopes, results, and possible policy measures. This comparison is a new element, as only a few studies have compared the performance of different versions of one HEM under different output criteria. The most relevant studies are those of Krause *et al.* (2005), who investigated the utility of several efficiency criteria for the comparison of (different) HEMs, and the study of Cornelissen *et al.* (2013), who assessed the suitability of different model types for simulating scenarios of future discharge behavior in the context of climate and land use change.

The overall aim of our work is to provide a more integrated modeling approach, in order to facilitate the understanding of the situation in environmental and economic terms. After this stage, every management plan would be examined from a different and more complete perspective, and the decision-making process would become less risky. The proposed HEM is simple and aims to help the local authorities to broaden their current knowledge of complex water resources management problems. In this context, our model takes into account hydrological, economic, and water quality factors and examines their status under various environmentally-friendly measures. The novelty of this work is the simulation of all these factors together in a model designed to simplify the outcomes (or to express them in a more understandable way) and to orient policy-making towards more sustainable paths.

## STUDY AREA

Lake Karla watershed, covering an area of 1,663 km$^2$, is located in central Greece, in the southeast part of the water district of Thessaly. The local climate is characterized as Mediterranean with dry and hot summers and cold and humid winters (Tzabiras *et al.* 2016). It can be considered as an agricultural watershed since 94% of water is used in irrigated agriculture (Alamanos *et al.* 2016; Tzabiras *et al.* 2016). Subsequently, residents' income is mainly generated by agricultural production. It should also be noted that irrigation water demand is mainly covered by the groundwater aquifer and by the Pinios River.

The Local Agency of Land Reclamation (LALR) of Pinios River uses open irrigation canals, which results in great losses, while at the same time in the aquifer area there are several illegal and uncontrolled wells (Sentas *et al.* 2018). The former Lake Karla was drained in 1964 but the devastating environmental consequences led to its reconstruction, which was completed in 2012. Although the works have been finished, the new Karla reservoir is not operating yet, thus causing further environmental problems (Papanikos *et al.* 2009; Sidiropoulos *et al.* 2019). As a result, areas that were planned to be irrigated from

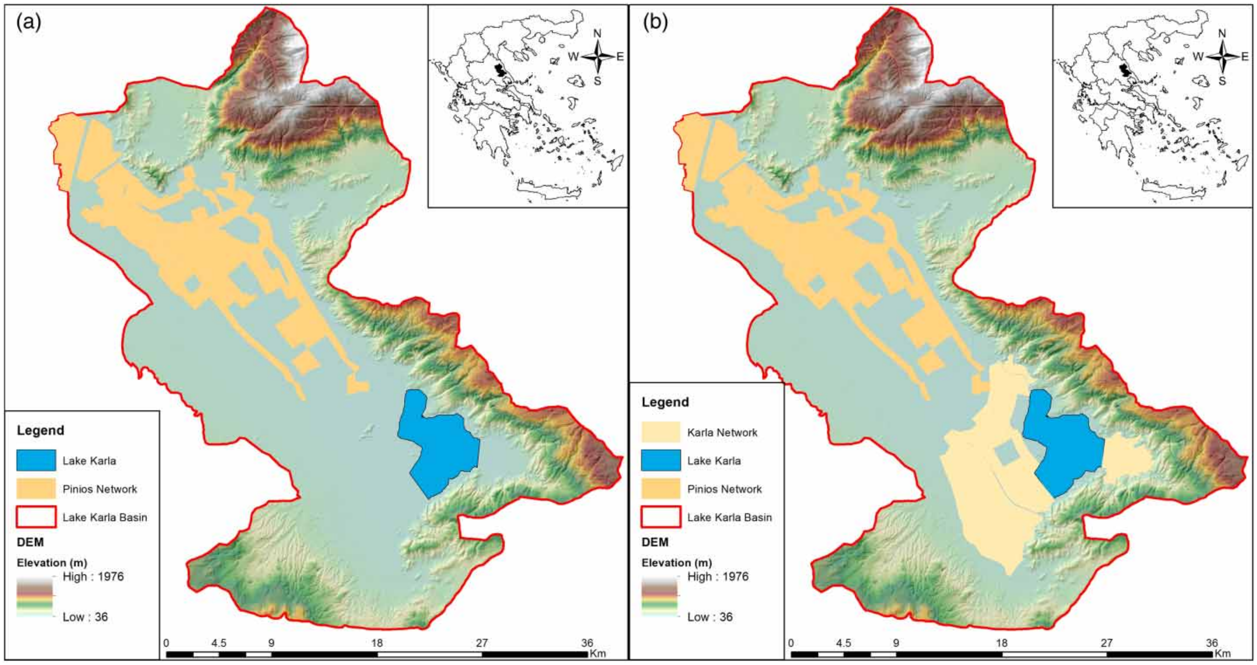

**Figure 1** | Lake Karla watershed: (a) in the current state, (b) in the future state of reservoir operation (*Source*: Alamanos *et al.* 2019).

the lake's surface water are still irrigated from groundwater resources, thus continuing to overexploit them (Figure 1). Pinios LALR (which serves an area of 154 km$^2$) and Karla LALR (which serves an area of about 10 km$^2$) are the two irrigation management authorities of the watershed. They are not in cooperation with each other and irrigation water management is still at a very primitive stage.

The limited water resources (water supply), the cultivation of water-demanding crops (high water demand), and the current use of a per-area pricing system of irrigation water have resulted in serious environmental and management problems (Sidiropoulos *et al.* 2013; Alamanos *et al.* 2016). In particular, per-area water charges (tariffs) are generally considered as inefficient pricing mechanisms because the price of water is not connected to water use (consumption). Also, in the study of Alamanos *et al.* (2017), it was revealed that the welfare losses due to the under-pricing of irrigation water are extremely high. Therefore, it is essential to estimate the cost per water body (as recommended by the WFD 2000/60/EC) in order to use it as a better proxy for future pricing mechanisms.

Another interesting and challenging factor concerning Karla's watershed is water quality. Most studies have tended to focus on the water quality of the reservoir (Chamoglou *et al.* 2014) and on the nitrate pollution of the aquifer (Sidiropoulos *et al.* 2019). Despite the interest, nobody, to the best of our knowledge, has examined the qualitative characteristics of the Pinios River, Karla's aquifer, and Karla's new reservoir in the same study (watershed's supply sources) or the opportunities for their improvement. According to official databases the water quality in these three water bodies is poor (Greek Ministry of Agricultural Development and Food 2010). This is a consequence of the intensification of the agriculture and the overexploitation of water resources combined with the excessive use of pesticides and fertilizers (Sidiropoulos *et al.* 2019).

## METHODS

### Description of the hydro-economic model

The proposed model consists of four main outputs as follows.

#### Water balance estimation

The watershed was divided into three zones – serviced areas from each water body (Figure 1): Pinios River, aquifer, and (in the future) Karla reservoir. The estimation of each water body's balance consists of a series of models for which the results are linked according to the following procedure (Figure 2):

- The hydrological model UTHBAL (Loukas *et al.* 2007) calculates the surface runoff and the groundwater recharge, namely, the renewable surface and groundwater resources. Monthly temperature and precipitation time series were used as inputs during the period 1960–2009.
- In order to estimate the water demand for urban, industrial, and animal husbandry water uses, data regarding production, population, and specific consumption per municipality were collected. Each water use's requirements were calculated, as in Alamanos *et al.* (2016).
- The CROPWAT (FAO 2015) model calculates the water requirements of the watershed's crops given meteorological, soil, plant, and agricultural data. The agricultural water demand was then calculated by taking into account the efficiency coefficients of transfer (network) and implementation of irrigation (methods) (Hydromentor 2015).
- The above parameters were incorporated in the WEAP (Water Evaluation And Planning System) (weap21.org) software in order to simulate the supply sources and the demand sites (node-based model) and to calculate the water balance (for the entire watershed and per zone, respectively) (Figure 3(c) and 3(d)).

## Estimation of the total net profits from agricultural activities

A simple and straightforward model was developed. In it, the crop distribution, their average annual yield, the product prices, the subsidies, and the total production cost were used as input data. In further detail, Equation (1) was applied for every studied crop of each zone:

$$NP = GP - TPC \quad (1)$$

where: NP is the net profit, GP is the gross margin, as the sum of total revenue (production multiplied with product prices) plus the subsidies, TPC is the total production cost

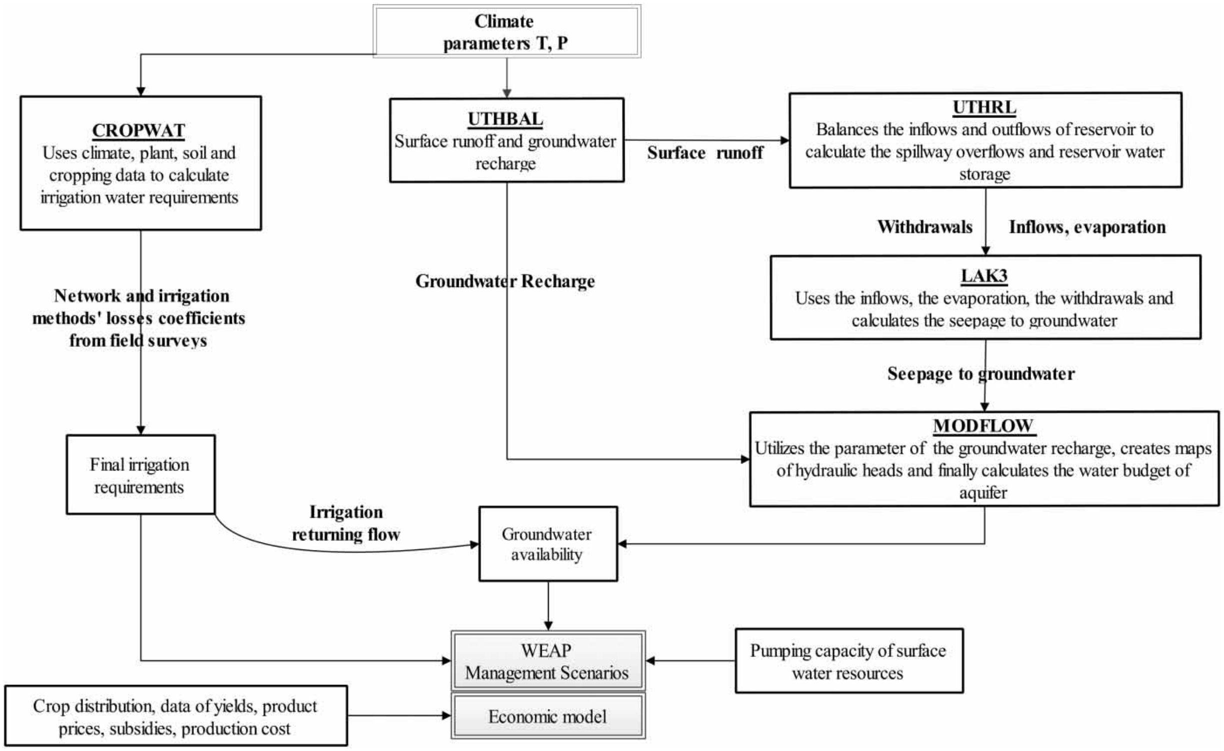

**Figure 2** | The process for the estimation of the basic outputs of the HEM, presented in a flow diagram.

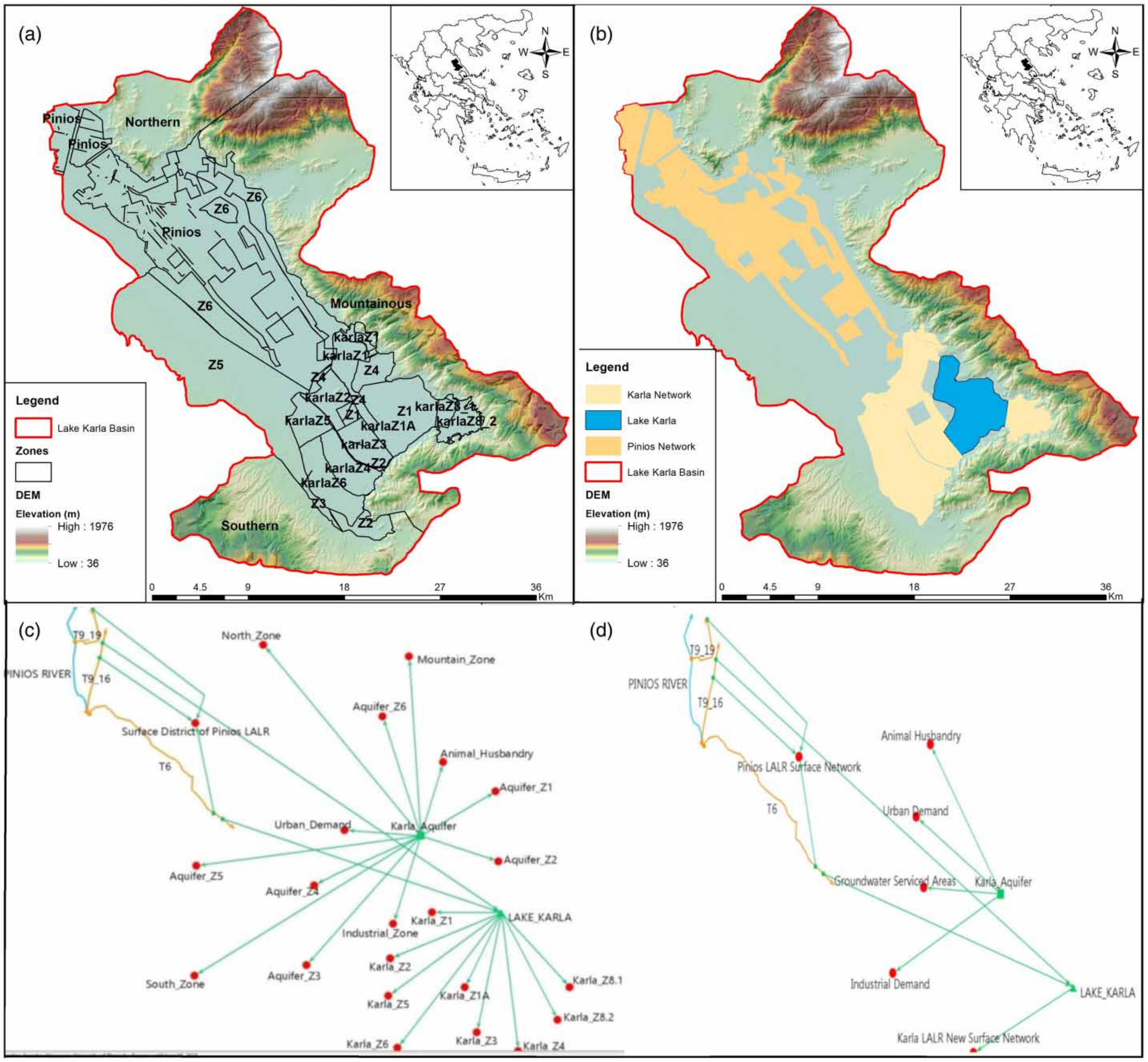

**Figure 3** | The examined watershed: (a) divided into irrigation zones (Version 1) and (b) divided into water body zones (Version 2).

(variable costs), as the sum of the costs of lubrication, herbicides, seed, two sprays, defoliants, harvesting cost, pumping costs, oil, labor, planting cost, mechanical operations, and agricultural deductions.

## Calculation of the deficit water value

This parameter is useful for decision-makers to comprehend the magnitude of negative water balance in understandable-to-them terms. The value of the deficit water shows to the responsible authorities the size of profits occurring from use of water that should not be used as a means to avoid negative water balance. This value estimates the profit that occurs from the theoretical usage of the deficit irrigation water in the agricultural production (Alamanos *et al.* 2019). Given the water needs and the crops' areas, the water requirements were converted in $m^3/km^2$ for each crop. The water balance and hence the deficit irrigation water for each supply source are also known. The deficit water was allocated in the studied crops and this way we found the actual areas that can be serviced by it. The total net profit of agricultural production in these areas, as calculated in step 2, expresses the value of water. The advantages of this approach are as follows:

- The deficit irrigation water has been shared with the existing crop distribution in order to avoid overestimation or underestimation of this value. This method represents an innovative and practical way to illustrate the actual 'environmental' costs of the farmers' current cropping preferences.
- The shares of the deficit water in relation to each crop were percentage-based. They were not calculated based on the most beneficial spatial way in order to avoid any subjectivity that could arise from a spatial optimization method, which is sensitive to crop changes.

## Economic overexploitation index

An overexploitation index was used mainly in order for the stakeholders to understand the magnitude of impact of the environmental degradation for the sake of their profits. It should be noted that indices about deficit water in irrigated agriculture are increasingly becoming a vital factor in water resources management (Koksal 2008; Argyrokastritis *et al.* 2015; Martínez-Fernández *et al.* 2016; Verma 2017). Traditionally, the focus has been on water scarcity (NETGREEN 2012). Most of these indices aim to simplify the concerned parameters so that they become manageable (Wang *et al.* 2012). The index presented herein expresses the possible profit (value) of deficit water as compared to the existing profits.

The ratio of the deficit water value (calculated in step 3) to the total profits from the agricultural activities (step 2), is suggested as an index of farmers' profits against environmental balance. The bigger this index is, the more negative is the water balance and the higher is the conservation potential. It is a simple way that provides a useful measure for decision-makers to understand the quantitative deterioration of water resources in economic terms, with which they are more familiar.

## Water quality

The present study also examines water quality and its improvement possibilities through different irrigation water conservation measures/policies. As mentioned in the study area section, water quality data were collected for the three water bodies of the watershed. The Greek Ministry of Agricultural Development and Food assesses Pinios River water quality from 21 sampling stations in order to use it for covering irrigation purposes (Greek Ministry of Agricultural Development and Food 2015). As far as the aquifer is concerned, the groundwater quality monitoring is examined by the Institute of Geological and Mineral Exploration (IGME 2010) from a large number of wells. The Management Body of Karla-Mavrovouni-Kefalovriso-Velestino-Pinios Delta (M.B.K.M.K.V.P 2014) is responsible for the observation of Karla's reservoir water quality using five stations. In all three water bodies, the examined water quality parameters included physicochemical parameters, the main inorganic compounds such as nitrates ($NO^{3-}$), nitrites ($NO^{2-}$), sulfate ($SO_4^{2-}$), chloride ($SO_4^{2-}$), iron (Fe), calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), conductivity, as well as the pesticides which are the major organic pollutants in the study area. It was checked where and in which of these parameters their concentrations exceed the allowable limits. The guidelines, standards, and regulations about the urban supply, irrigation, industrial supply, ecological use, and ecosystem sustainability, tourist use, etc. were used as established by the World Health Organization and the European Union (Loukas 2010).

## Scenario analysis

All the above parameters were simulated under two scenario situations: Scenario I – the current state – (Figure 1(a)) and Scenario II – management plan. Considering the negative water balance due to increased water demand and high losses, the 'economic' overexploitation of the limited available water resources, and their poor water quality, a combination of demand management measures is proposed. This plan (Scenario II) aims to present overall improvement of the watershed's situation:

- Operation of Karla reservoir. The main difference when comparing the baseline Scenario I and the suggested Scenario II is the new irrigation areas that will be served by the reservoir. In Scenario I, they were served by the underlying aquifer (Figure 1(b)). The suggested plan would allow for the aquifer to recover, and it would give the farmers opportunities to cultivate more land using surface renewable water resources.

- Reduction of the irrigation losses, by using higher transfer coefficient for the irrigation efficiency of the open channels of the Pinios network and for the pipeline network, considering proper cleaning and maintenance.
- Using drip irrigation instead of sprinklers, in order to achieve a more efficient irrigation water use.
- Replacement of 20% of cotton crops with 10% winter wheat and 10% maize, which is in agreement with the last decade's crop distribution trends and the objectives set by the new Common Agricultural Policy (Ministry of Agricultural Development & Food 2015). CAP provides more opportunities for management of water saving measures (e.g., financial incentives for cultivating less water-consuming crops).

### Calculating the benefits of Scenario II

The water balance and the net profits from agricultural activities were confirmed and compared with those of Scenario I, as well as with the deficit's water value. Furthermore, the contribution of the quantitative replenishment of the water quality was evaluated, by the dilution of the water pollutants in each water body, with the volume of the water saved by the implementation of Scenario II. The dilution is mainly a natural process, which reduces water pollution, often associated with increased water availability (Antonakos & Lambrakis 2000; Paragahawewa *et al.* 2015; Alamanos 2019). Dilution is used mainly for reducing the concentration of conservative substances (e.g., organic compounds) rather than for non-conservative substances (e.g., some organic substances) (Pantazidou 2016). The new (reduced) concentrations of the pollutants were compared with their initial concentrations (of Scenario I).

## RESULTS

The results of the two aforementioned management scenarios are presented in Table 1. According to these results, Scenario I exhibits high unmet demand, especially in the aquifer, and slightly higher profits compared to Scenario II. Furthermore, Scenario I's deficit water value is high compared to the respective overall agricultural incomes and this proves the quantitative degradation of the water over the renewable resources. The overexploitation index illustrates the same phenomenon, not only in hydrological, but also in economic terms.

**Table 1** | Annual results of the integrated hydro-economic model for the two examined scenarios, per zone and for the entire watershed

| | Scenario I | Scenario II |
|---|---|---|
| **Annual water balance (hm³)** | | |
| Pinios | −10.801 | 55.065 |
| Aquifer | −149.603 | −67.397 |
| Karla | – | 21.767 |
| **Total** | −160.404 | 9.436 |
| **Annual net profit (mil.€)** | | |
| Pinios | 9.146 | 8.945 |
| Aquifer | 38.167 | 30.639 |
| Karla | – | 9.098 |
| **Total** | 47.313 | 48.682 |
| **Deficit water value (mil.€)** | | |
| Pinios | 1.335 | – |
| Aquifer | 22.433 | 10.106 |
| Karla | – | – |
| **Total** | 23.768 | 10.106 |
| **Water overexploitation index** (–) | | |
| Pinios | 0.15 | 0 |
| Aquifer | 0.59 | 0.21 |
| Karla | – | 0 |

Considering the water quality results, it is crucial to mention that Karla reservoir is an extremely vulnerable water body, as the water from Pinios and most of the surface runoff ends in it. As long the reservoir remains inactive, all the pollutants gathered from the inflows remain in it. The aquifer is also polluted, as fertilizers and pesticides are being transferred to the groundwater through infiltration. The above are the consequences of the intensive cultivation and production requirements of the study area. Agriculture is the primary occupation and the main source of income for the majority of the local population. Therefore, water resources management is vital for the region's sustainable future in terms of economic, social, and natural environment. Table 2 contains a summary of

**Table 2** | Number of pollutants in dangerous concentrations compared to the number of total pollutants found in each water body in Scenario I

| | Groundwater | Pinios surface water | Karla reservoir |
|---|---|---|---|
| Pollutants over the thresholds/ Pollutants found | 15/41 | 13/36 | 7/20 |

the number of chemical elements – pollutants and indices (C.E.), and pesticides (P.), whose concentrations are found to exceed the allowable limits, according to the relevant guidelines and legislations.

As proved above, Scenario II decreases the unmet demand, this way producing a larger water volume (storage), which will not be used. Subsequently, the detected pollutants are naturally diluted with this volume. The results of the (theoretical) implementation of Scenario II are shown in Table 3, as reduction percentages compared to Scenario I.

The results of Scenario II are very encouraging as they show potential short-term improvements in all examined factors, if a demand management plan is implemented.

## DISCUSSION

It is worth mentioning that in our previous studies (Alamanos *et al.* 2016, 2017) we developed a different hydro-economic approach (Version 1), in an attempt to start monitoring Lake Karla watershed for the first time from this perspective. In Version 1, the main difficulties were lack of data and incomplete recordings. The scopes of the two versions (the previous one and the one presented herein – Version 2) are different. This is illustrated in the settings of the two models. In this section, a comparison between these two versions is made, in order to provide some useful insights for hydro-economic modeling settings and approaches, depending on the data availability and scope of each study. Table 4 summarizes the features of the two HEMs' versions in a comparative way.

In Version 1, due to limited data, the water availability data from previous design studies were used, while in Version 2, the hydrological water balance was simulated (Figure 2).

Version 1's division of irrigation zones gave an advantage for spatial illustration of the outputs (per zone). The irrigation water value was evaluated with the 'Net Income Change' method, allowing us to produce the corresponding demand curves (Alamanos *et al.* 2017). Net profits, water requirements, and water value were then connected through a geographical information system (GIS) model in order to provide a spatial distribution of these parameters to the various watershed zones. It is clear that the simulation of the above outputs is better, easier, and more useful by dividing the watershed into irrigation zones. In addition, this approach highlights the results' importance and removes significant data weaknesses. In contrast, a significant advantage of Verson 2's division in water bodies – zones, is the ability to use the overexploitation index. The role of the proposed overexploitation index is to express in a simple way the vague term 'size of the negative water balance'. The economic indices, and especially profits, are more understandable, and thus, have become major management priorities. If it is clear to the decision-makers, for example, that 59% of the total profit comes from the aquifer's overexploitation, then they can recognize the environmental damage and turn to more sustainable solutions. The WFD's goals can be gradually achieved, by 'translating' confusing terms into commonly accepted terms that will, at the same time, prepare the ground for its proper implementation.

**Table 3** | Reduction percentages of concentrations of C.E. and P., achieved by each measure included in Scenario II

| | Groundwater | | Pinios surface water | | Karla reservoir | |
|---|---|---|---|---|---|---|
| **Comparison of reduction (%)** | **C.E.** | **P.** | **C.E.** | **P.** | **C.E.** | **P.** |
| Scen. I → Reservoir operation | 23 | 23 | 1.15 | 0 | – | – |
| Scen. I →Losses reduction | 27 | 27 | 68 | 18 | 39 | 6 |
| Scen. I → Drip irrigation | 24 | 24 | 19 | 2.3 | 22 | 2.7 |
| Scen. I → Crop replacement | 27 | 26 | 1.15 | 0 | 31 | 4.3 |

**Table 4** | Comparison of the two versions of Lake Karla watershed hydro-economic model's characteristics

| Version 1 | Version 2 |
|---|---|
| Incomplete data and recordings (hydrological and economic). As a result, the scope was a preliminary understanding of the system | Complete and reliable official data per farm (Greek Agency of Payments and Control for Community Aid 2014). The aim was to prepare for a complete monitoring and implementation of the economic objectives of the WFD |
| Desirable outputs: water balance, irrigation water cost, farmers' utility, irrigation water value, management scenarios | Desirable outputs: water balance, net profits, deficit water value, overexploitation index, water quality, demand management plan |
| 4 main crops were used, because of limited data. Statistic databases and satellite methods were used | 11 crops were used, as they were classified from the official per-farm data |
| The watershed is divided into 10 (min) and 19 (max) irrigation zones (for baseline and future scenario respectively)<br>This division offered higher precision, spatial integration of the results and 'covered' the weakness of the limited data that were used for the analysis (Figure 3(a)) | The watershed is divided into 3 zones depending on the supply source (water bodies), as it is convenient and useful for the simulation of the quantitative and qualitative degradation of each water body of the watershed (Figure 3(b)) |
| Tools: GIS, CROPWAT, WEAP (weap21.org), economic model | Tools: GIS, CROPWAT, WEAP (weap21.org), economic model |

Table 5 shows the basic comparable outputs of the two HEM versions. For the comparison, Scenarios I and II were simulated in both versions.

It should be noted that Version 1 does not 'cancel' or recant Version II, or vice versa. The weaknesses of one version are strong points in the other. The reason is that with each model's setting we tried to better highlight the outputs of each version, considering the given data. Thus, the HEMs should have flexible or different settings, depending on the needs of the desired results and data availability. The two different divisions of the watershed can also work in a complementary way to each other, in order to show the findings in an even more detailed spatial scale, for example, by analyzing results of the different irrigation zones of the first version, that are included in each zone of the second version. Furthermore, Version 2 cannot be considered as an updated version of Version 1, as it is just a better way to illustrate the corresponding outputs. This approach also sets the basis for calculating other mandatory factors, such as the full water cost, as a sum of monetary, environmental, and natural resource cost per water body, according to the recommendations of the WFD 2000/60/EC. This update on the proposed model is currently being investigated.

**Table 5** | Comparison of the common comparable results of the two HEM versions

| Management scenarios | Annual water demand ($hm^3$) Version 1/Version 2 | Water balance ($hm^3$) Version 1/Version 2 | Farmers' utility (v1)/Net profits (v2) (mil. €) |
|---|---|---|---|
| Scenario I | 343.9/374.1 | 131.9/160.4 | 41. 962/47.313 |
| Scenario II | 228.1/266.3 | −43.3/7.3 | 44. 457/48.681 |

## CONCLUDING REMARKS

The current study attempted to emphasize the role of a hydro-economic simulation, and a way for its better implementation, rather than develop a new hydro-economic methodological framework. An integrated hydro-economic model can provide the necessary elements to facilitate the managerial procedure, as well as to improve important factors such as water balance, quality, and profit. The case of Lake Karla watershed is very similar to the majority of Mediterranean basins – areas facing water and management problems, with no experience with such tools. The new point of view of expressing the quantitative and qualitative deterioration of each water supply source can help inform the stakeholders and the authorities, and as a result, to change the common misconception that water resources are inexhaustible.

The correlation between the improvement in water balance and water quality is a novel and noteworthy element. The new (diluted) pollutants' concentrations in every water body are satisfactorily lower and further support the role of the quantitative replenishment to the water quality. The comparison between the two HEM versions is also a good starting point for further improvement of such approaches. The purpose of each modeling approach, the analyzed scenarios and outputs, as well as the data availability, are the main factors for the HEM's structure.

Our suggestion for future hydro-economic modeling, especially for water-scarce areas, is to take into account as many parameters as possible, including the water value. The sphericity of the problems' perception and the recognition of the water value will sensitize the authorities into necessary managerial policies and socio-economic measures. A theoretical implementation of a demand management plan in a degraded area was proved to be a solution for most of its problems. The appropriate models' methodologies can differ, but some factors are necessary for decision-makers' knowledge (e.g., water value, hydro-economic indices, etc.). The data requirements and specific characteristics mainly determine the modeling approach, the choice of methods and tools. However, by taking into account more parameters that combine environmental and economic objectives, it is easier to provide guidelines for an integrated, efficient, and flexible management, where the water and the economy will be considered together, and not one against the other.

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