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# SUSTAINABLE WATER RESOURCES MANAGEMENT IN NEOTECTONIC BASIN SYSTEMS

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## EXTENDED ABSTRACT

Facing the threat of water scarcity, numerous techniques and methods have been introduced, aiming at more effective water resources exploitation. A well promising way to cope with water shortage is to develop and apply combined management techniques for the existing surface water and groundwater resources. Natural resources management requires thorough **understanding** of the **natural processes** controlling each resource and **human activities** affecting and being affected by it. Vital for the success of this approach is a comprehensive knowledge of the hydrological budget and the geometrical and physical properties of the aquifer systems under investigation. It is very important to examine the interaction between surface water and groundwater, present in every natural or artificial physiographic setting, determining the system's biological health and ecological function, including urbanization and agriculture. The regional **social** and **financial infrastructure** are human induced factors which affect water demand and hence resource availability. Especially in neotectonic active regions, the hydraulic relations between hydrological basins can be very complex, because the aquifer geometry is controlled by tectonic surfaces (faults and thrusts).

A prerequisite in realizing management programs is the assessment of the overall capacity of the groundwater system under study. To achieve this goal, first the aquifer geometry must be modelled, using 3D-CAD techniques. This step is extremely important in the case of tectonically controlled geometry. In the next step, the aquifer properties can be estimated by employing methods of spatial statistics. The basis for the development of realistic management scenarios is the thorough knowledge of all social, economical and geoenvironmental attributes of the area, integrated in a dynamic temporal and spatial model. At this time, this knowledge is only partial and fragmented.

In this work we investigate the hydrogeological system of two hydraulically connected hydrogeological basins, the Ano Messinia basin and the Kato Messinia basin. In this interactive hydrogeological – urban – agricultural regime, water needs are met by exploitation of the porous aquifer and discharge of the major karstic aquifers either by major karstic springs or pumping (see Figure 5). Exploitation of the porous aquifer has lead to degradation of its properties, while pumping of the karstic aquifers may also lead to such problems, or even hazard the spring function – not to mention the disturbance of the dynamic balance between these two water bodies.

**Key words**: water shortage, sustainable management, hydrogeology, neotectonic basins, 3D-CAD, GIS, Messinia.

## 1. UNDERSTANDING OF THE NATURAL PROCESSES

A multi-parametric approach of water management demands the collection and analysis of a large volume of data, required for the efficient water resources management, in relation to the natural and human environment. As far as physical properties and processes are concerned, hydrogeological research and simulation, representation of the geometry of the hydrogeological structure of the aquifer and 3D simulation, evaluation of the quality and quantity attributes of the aquifers and relation between surface and groundwater (quality - quantity), are only the first part of the research and monitoring activities to be scheduled in such a project [5], [7].

It has been often noted that in areas with recent tectonic activity, neotectonic structure of an area dominates the distribution and geometry of its aquifers [2], [4], [6], [10].

Neotectonic activity is the primary cause for the creation of smaller or greater tectonic horsts and troughs. Neotectonic grabens evolve gradually into sedimentary basins; such as Megalopolis Basin, a relatively simple structure, or Thessaly Basin, with a complex structure and evolution, evolving into two separate minor basins (eastern and western) [6]. Neotectonic horsts finally form smaller or greater mountains around the basins. Because of the fact that they are highly eroded, karstification is intensified, creating horsts suitable for artificial recharge. In Greece, large poljes, such as the Upper Messinia basin, Megalopolis basin, the basin of Tripoli, etc., are formed in areas where great fault zones intersect. This way, poljes are formed along the line, where great fault zones with a general NNW – SSE direction cross the ones with E–W direction (see Figure1).

The detailed knowledge of the specific type of the hydrogeological – physical-geographical system, in which the aquifer is located, is crucial for the study of groundwater flow and the resulting karstification. Areas of interest, i.e. cultivated plains and urban areas, are usually located in neotectonic grabens, consisting of many smaller ones and surrounded partially or totally by mountains, where the alpine basement outcrops. Within the tectonic grabens, clastic sediments, either marine or lacustrine, of great thickness can be found overlaying the alpine basement. The physical-geographical-hydrogeological systems are usually divided into closed and open systems. The neotectonic grabens-basins are complicated systems and they can be divided into the four following categories:

- Hydrologically and hydrogeologically closed, when there are neither surface nor underground water losses. In such cases the basin may turn into a lake.
- Hydrologically closed, with no water run-off outside the basin, but open hydrogeologically, when the ground water escapes through permeable formations of the basement. These usually form temporary lakes, such as in the Argon Pedion, a small field on Tripolis Highland (Peloponnesus, Greece), as vividly described by the ancient Greek writer, Pausanias.
- Hydrologically and hydrogeologically open, when both superficial and underground water may run off easily, the way it happens at the Argolic field or at the Thriassio field.
- Hydrologically open and hydrogeologically closed, such as the Ano Messinia basin.

It has been pointed out that the Pamissos river basin (areas 6 and 7 in Figure 1) consists of two different hydrogeological basins, the ones of Ano Messinia and Kato Messinia, whose aquifers communicate only under extreme conditions [1]. Thereafter, the attributes of these two basins have been simulated and studied, and calculations of their water budgets have been made [2], [3].

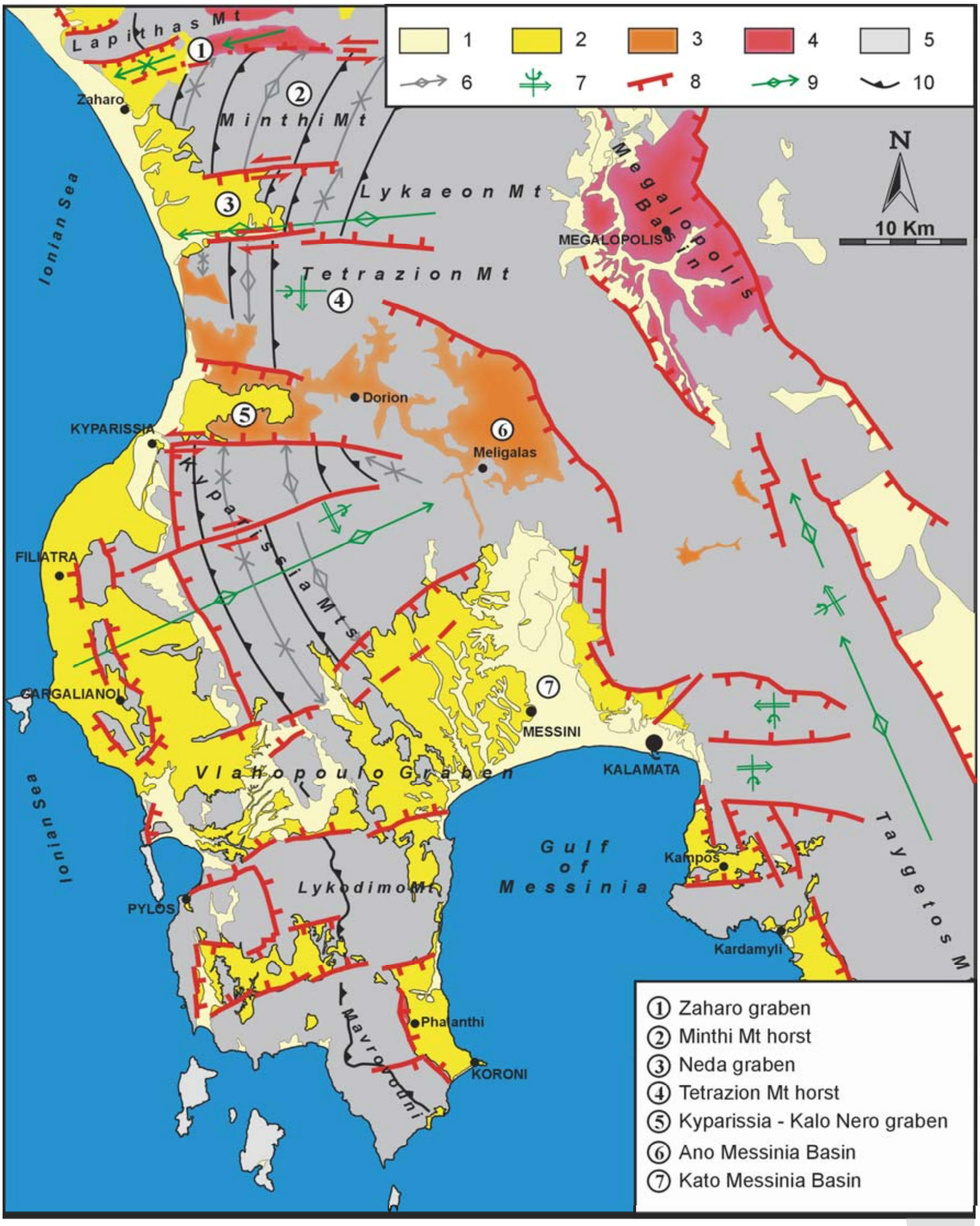



**Figure 1:** Schematic map showing the neotectonic regime of Central-Western Peloponnessos. 1: Holocene deposits, 2: E. Pleistocene marine deposits, 3: Plio-Pleistocene continental deposits, 4: Plio-Pleistocene lacustrine deposits, 5. Alpine basement, 6: Dominant plunge of alpine fold axes, 7: Rotational axis, 8: Neotectonic fault zone, 9: Neotectonic fold axis, 10: Thrust (After Mariolakos, Fountoulis, Ladas 2001 [4], modified).

## 2. HUMAN ACTIVITIES

The agricultural development profile of Messinia Prefecture, along with the increased water demand during summer season when tourism is highly increased, has caused certain pressures on the water bodies of the area (see Figures 2,3). In both Ano Messinia and Kato Messinia hydrogeological basins, water demands are satisfied by exploitation of the aquifers that are developed within the basin sediments, of the major karstic springs that discharge in the area, and of the surface water of the drainage network (for irrigation purposes). Nevertheless, spatial and temporal distribution of water needs does not match water supply. As a result, overexploitation of aquifers has resulted in salinization effects in the porous aquifers of Kato Messinia basin, apart from the pollution effects caused mainly by fertilizers in all plains and urban use in Kalamata and Messini towns [3].

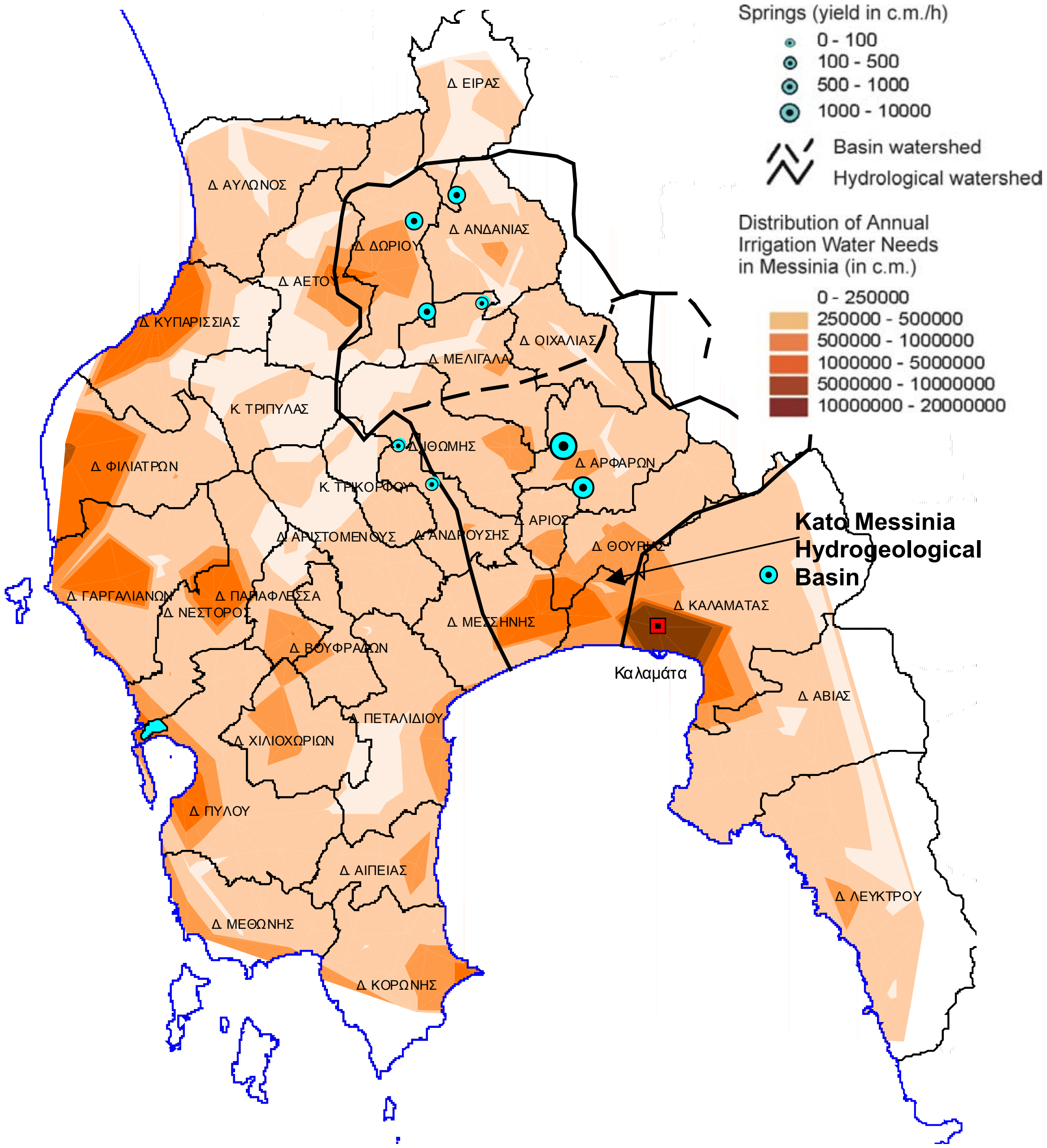



**Figure 2:** Distribution of drinking water needs throughout Messinia Prefecture based on distribution of population by town and village and on the accepted daily consumption of 200lt per person (Data from National Statistical Service of Greece, 2001).

Thus, it is well evident that, effective water resources management cannot be applied unless human induced factors are thoroughly studied and combined with spatial and temporal data concerning water availability. The processing of statistical data in a GIS environment can show a realistic view of the distribution of water demands, but can only be useful if combined with a reliable hydrogeological model. For example, in the Kato Messinia hydrogeological basin, 9 municipalities are exploiting the same water resources. It is very clear that urban use (mainly drinking water needs) is only a small percentage of the total needs, mainly concerning agricultural use (see Figure 4).

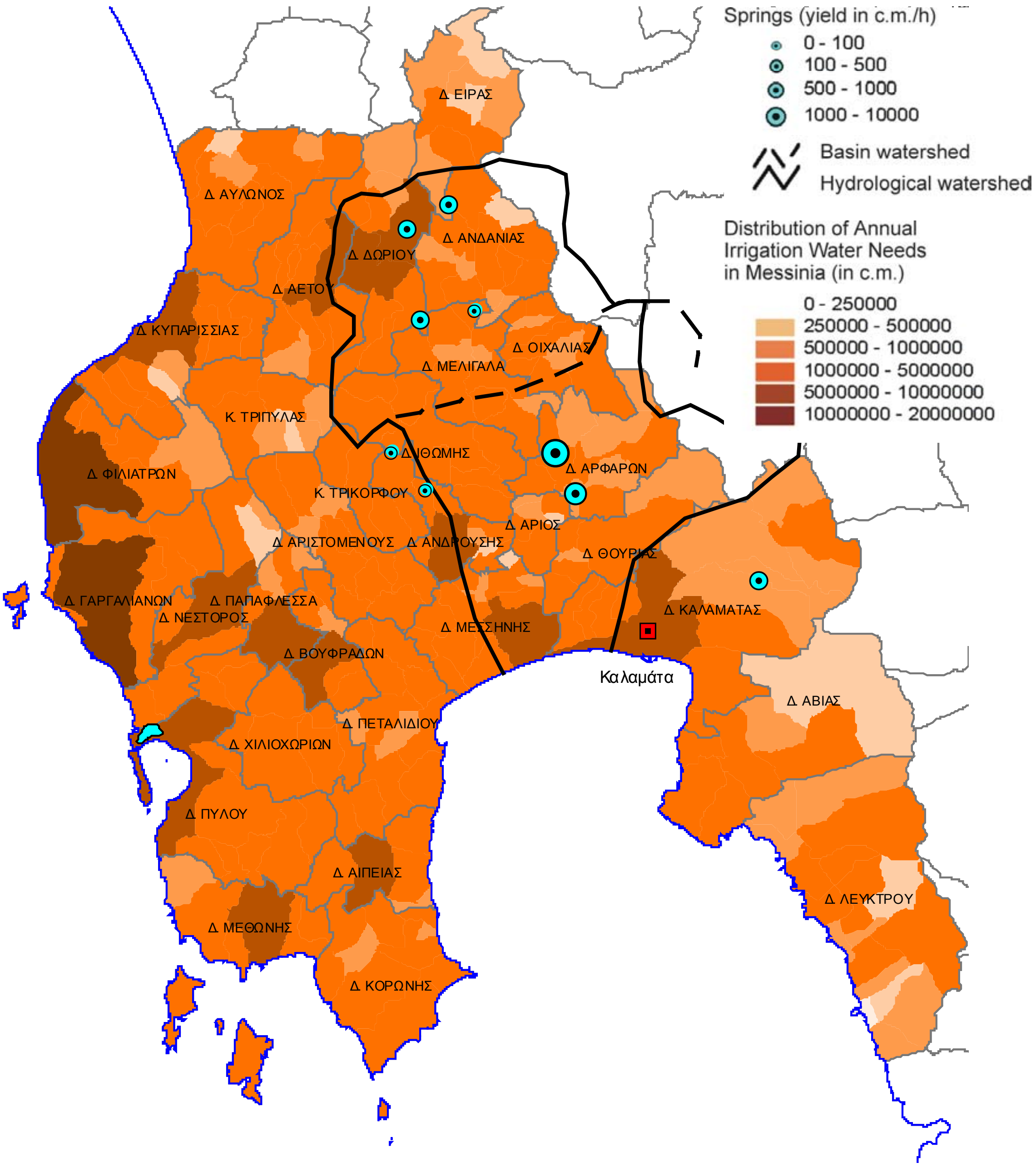
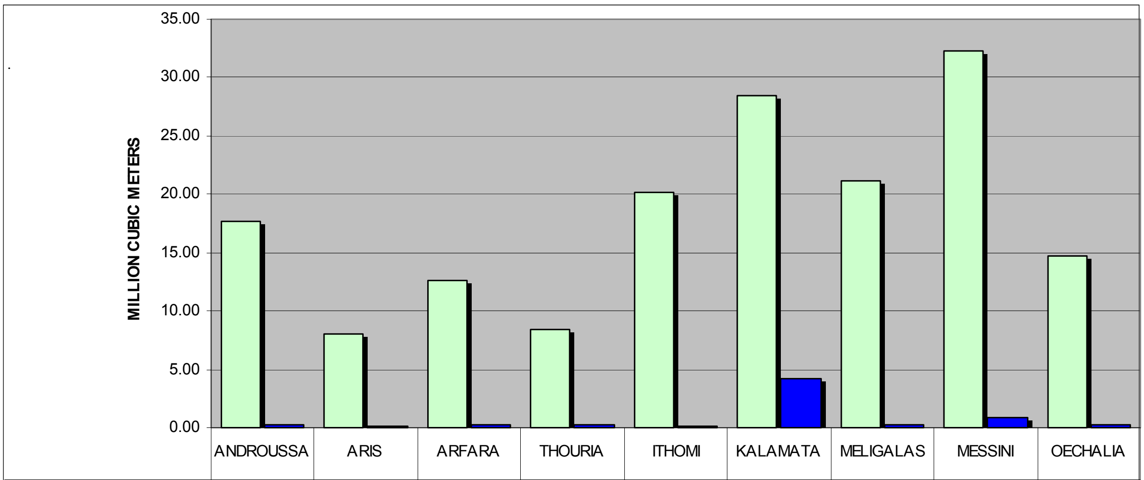



**Figure 3:** Distribution of irrigation water needs throughout Messinia Prefecture based on distribution of cultivated areas (Data from National Statistical Service of Greece, [8]).

In this interactive hydrogeological – urban – agricultural regime, water needs are met by exploitation of the porous aquifer and discharge of the major karstic aquifers either by major karstic springs or pumping (see Figure 5). Exploitation of the porous aquifer has lead to degradation of its properties, while pumping of the karstic aquifers may also lead to such problems, or even hazard the spring function – not to mention the disturbance of the dynamic balance between these two water bodies.




| | ANDROUSSA | ARIS | ARFARA | THOURIA | ITHOMI | KALAMATA | MELIGALAS | MESSINI | OECHALIA |
|---|---|---|---|---|---|---|---|---|---|
| MAX. IRRIGATION NEEDS | 17.69 | 8.10 | 12.60 | 8.46 | 20.21 | 28.49 | 21.20 | 32.27 | 14.72 |
| DRINIKING WATER NEEDS | 0.21 | 0.16 | 0.23 | 0.30 | 0.18 | 4.21 | 0.29 | 0.81 | 0.20 |

**Figure 4:** Irrigation and Drinking water needs of municipalities throughout Kato Messinia hydrogeological basin (Data from National Statistical Service of Greece [8]).

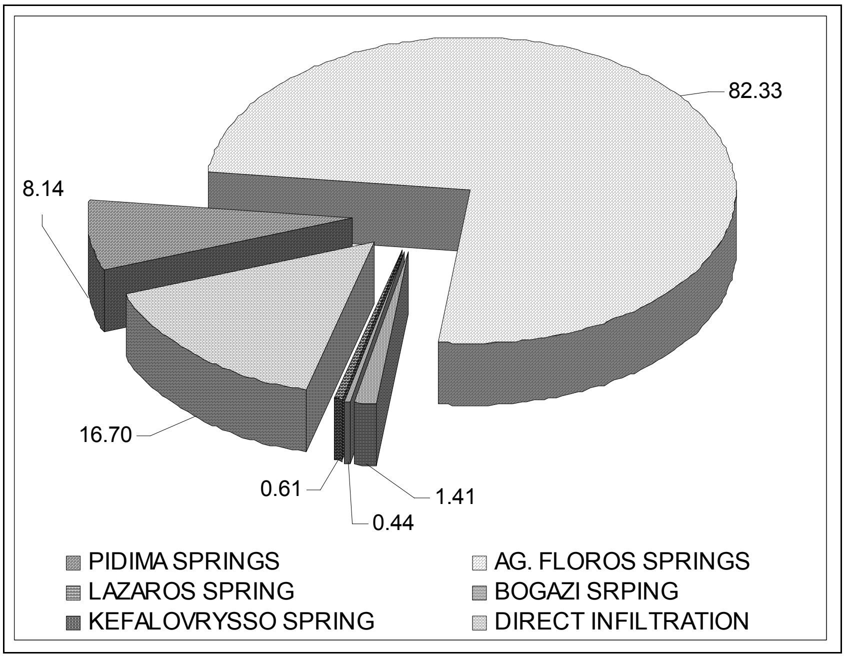



**Figure 5:** Annual groundwater yield (in million cubic meters) in the municipalities throughout Kato Messinia hydrogeological basin (Data from Inventory of karstic springs of Greece [9]).

In order to make a safe estimation of the present total water needs of this area (9 municipalities), it has been accepted that all agricultural areas are cultivated and irrigated (taking into account the needs of the present types of cultivations by percentage of the cultivated area) [8], [11]. The comparison of the total water needs to the annual groundwater yield in the area points out the size of the hazard the area is facing (see Figure 6). It has to be noted that, the statistic data concerning water needs are calculated for the most extreme conditions, which nevertheless are not too rare.

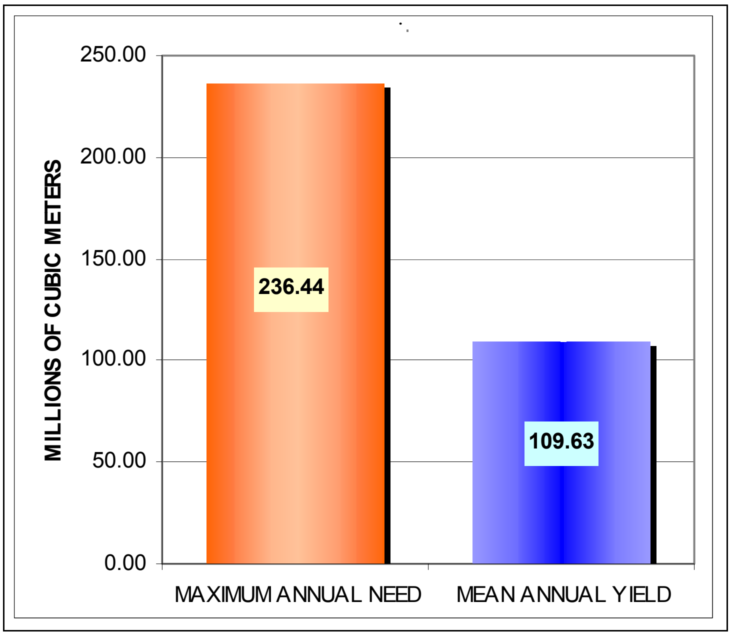



**Figure 6:** Comparison of maximum annual irrigation and drinking water needs to the mean annual groundwater yield in the municipalities throughout Kato Messinia hydrogeological basin (Data from [2], [8], [9], [11]).

## 3. SUSTAINABLE MANAGEMENT

Sustainable water resources management, as it is strictly and in detail defined by the Directive 2000/60 of the E.U., includes not only protection of the quality and quantity of both surface and groundwater bodies, but also restoration of their normal attributes in due time [7]. This means that administration should not only insure that water needs will be met in the present and future times, but at the same time the negative consequences of overexploitation should be reversed. The previously presented shortage in groundwater quantities does not necessarily mean that water resources cannot meet human needs in the area. It simply points out that groundwater bodies cannot sustain any amount of consumption by themselves. We can already mention the partly coverage of irrigation needs by surface drainage as an alternative method of reserving groundwater, which nevertheless, has not proved adequate in semi arid areas such as Greece.

We believe that the basis for the development of realistic management scenarios is the thorough knowledge of all social, economical and geoenvironmental attributes of the area, integrated in a dynamic temporal and spatial model. At this time, this knowledge is only partial and fragmented, and, in any case, not continuously updated (not to say obsolete). In order to achieve this goal, the following actions are necessary:

- Continuous monitoring of physical properties, enrichment and revision of the dynamic models of the hydrogeological systems.

- Detailed mapping of land-use.
- Monitoring of water consumption, and its spatial and temporal distribution.
- Mapping and recording of all existing water transportation networks and all private and public, legal or illegal wells, and monitoring of their function.
- Short and mid- term cost accounting of water.
- Control of licensing and re-evaluation of previous licences.
- Strong motivation in favour of public networks (i.e. low pricing) and against private (and especially illegal) direct access to water bodies.
- Implementation of the politic "the pollutant pays", preferably not in the form of a penalty after pollution, but in the form of preventive measures.
- Implementation of alternative methods of water management (i.e. alternative methods of irrigation, transportation from other areas instead of direct pumping from the aquifer, recycling, artificial recharge of karstic aquifers, change of land use, etc.)

## REFERENCES

1. MARIOLAKOS, I. (1988). The application of Darcy's law in closed geomorphological and hydrogeological systems, Example: The basin of Ano Messinia, SW Peloponnesus. *Bull. Geol. Soc. Greece,* v.**XX/3**, pp 77-96.
2. MARIOLAKOS, I., FOUNTOULIS, I., SPYRIDONOS, E., LOGOS, E., THEOCHARIS, D., (1997). – Quantitative investigation of the hydrogeological system of Kato Messinia basin. *Proc. 4th Hydrogeological Congr. Hell. Comm. Hydrogeology of the Geol. Soc. Of Greece,* November 1997, pp 259-269, Thessaloniki, Greece..
3. MARIOLAKOS, I., FOUNTOULIS, I., SPYRIDONOS, E., LOGOS, E., THEOCHARIS, D., (1997). – Qualitative investigation of the hydrogeological system of Kato Messinia basin. *Proc. 4th Hydrogeological Congr. Hell. Comm. Hydrogeology of the Geol. Soc. Of Greece,* November 1997, pp 270-284, Thessaloniki, Greece.
4. MARIOLAKOS, I., FOUNTOULIS, I., LADAS, I, (2001). Paleogeographic evolution of SW Peloponnesus during Quaternary. *Proc. 9th Intern Congr. of the Geol. Soc. Of Greece, Bull. Geol. Soc. Greece, v.* **XXXIV/1** pp. 37-45.
5. MARIOLAKOS, I., FOUNTOULIS, I., SPYRIDONOS, E., DRITSA, C., KAPOURANI, E., ANDREADAKIS, EMM. (2001). Holistic Methodology for Water Resources Management in Semi-Arid Regions. Case Study in Mani (S Peloponnesus, Greece). In proc*. Of 10th Biennial Symposium on Artificial Recharge of Groundwater "Artificial Recharge and Intgrated water management"* Arizona USA, p.31-40.
6. MARIOLAKOS, I., FOUNTOULIS, I., SPYRIDONOS, E., ANDREADAKIS, EMM. (2001). Artificial Recharge of the Underground Karstic Aquifer of Farsala Area, Thessaly, Central Greece. In proc*. Of 10th Biennial Symposium on Artificial Recharge of Groundwater "Artificial Recharge and Integrated water management"* Arizona USA, p.71-80.
7. MARIOLAKOS, I., FOUNTOULIS, I., SPYRIDONOS, E., ANDREADAKIS, EMM., KAPOURANI, E. (2002). A multi parametric approach of water management in the frame of sustainable development. In proc. *3rd International Forum "Integrated Water Management", HYDRORAMA 2002.* p.390-401.
8. NATIONAL STATISTICAL SERVICE OF GREECE, (2001). URL:http://www.statistics.gr.
9. SKAYIAS, S., (1978). Inventory Of Karstic Springs of Greece, v.**I** *Peloponnesus – Zakynthos – Kefallinia*, 165p., Inst. Of Geol. Min. Res., Greece.
10. SPYRIDONOS, E., FOUNTOULIS, I., ANDREADAKIS, EMM., MARIOLAKOS, D., MANUTSOGLOU, E. (2002). Using integrated 3D geological modeling for planning artificial recharge of karstic aquifer groundwater. Case study in the Enipefs River basin, Thessaly, Greece. In proc. *8th Annual Conference of the International Association for Mathematical Geology, Berlin Sept.2002, Terra Nostra* **4/2002** p.493-498.
11. URL: http://www.messinia.gr