Spatio-temporal variability of nutrients in irrigation waters and its contribution on fertilization of olive groves in Crete island, Grece

Andreas Panagopoulos1, George Arampatzis1, Evangelos Hatzigiannakis1, Theodore Karyotis2, Sofia Stathaki1 & Evangelos Tziritis1

***1*** *General Directorate for Agricultural Research, Land Reclamation Institute, Sindos, 57400, Greece, panagopoulosa@gmail.com*

***2*** *General Directorate for Agricultural Research, Institute for Soil Mapping and Classification, 1 Theophrastou Str., 41335 Larissa, Greece, theodorekaryotis@gmail.com*

**Abstract.** Irrigation water is essential for crop yield and its quality affects both soil productivity and the environment. The main aim of this study was to assess the spatial and temporal variability of nutrients inputs from groundwater used for irrigation. Another objective was to assess their contribution on rational fertilization of olive groves in two semi arid rural areas of Crete island (Peza and Merambelo), Greece. Hydrochemical parameters were determined in 33 samples collected from irrigation water production facilities (boreholes, wells, reservoirs) at different periods in 2011 and 2012. Also, thematic maps of the distribution of the examined nutrients were compiled. Groundwater is the dominant source of water and originates from different aquifer systems that can be grouped in three distinct categories: (1) karstic aquifers of average to high potential, open to the sea and subject to salinization due to over abstraction and also due to the karst's conduits geometry, (2) sedimentary aquifer systems that are shallow and of average to low productivity, often subject to pollution from point and diffuse anthropogenic sources, (3) marl systems of considerable productivity due to the contained travertine and sandstone intercalations. Lithological structure, controlling hydrodynamic evolution mechanisms and anthropogenic activities reflect on the hydrochemical signatures of the analysed water samples. Significant differences were observed for all water variables assessed among seasons for the studied water samples. The CV% was to the following decreasing order: NO3>SO4>NH4>Ca>Mg>K>Cl>Na and Cl>Na>K> SO4> Mg > NO3 >NH4>Ca for the areas of Peza and Merambelo, respectively. It can be argued that agricultural activities have not affected strongly water quality. However, attention must be paid to increased content of certain ions and metals in the examined water samples in order to assess the impact of anthropogenic and geochemical factors on irrigation water quality. The use of Good Agricultural Practices (GAPs) to reduce agriculture’s impact on water quality is proposed. Attention must be paid on proper soil and water management by ensuring utilization of appropriate quality of water resources in the study area and blending of water from different sources where and when this is necessary and feasible. In addition, appropriate farming practices are required to control water quality and nutrients inputs from irrigation to olive groves, to decrease the amount of applied fertilizers and protect aquifers.

**Keywords.** Nutrients, hydrochemistry, water resources, fertilisation, olive groves, Crete

**1 Introduction**

Physico-chemical characteristics of water are essential to assess the suitability for various uses like domestic, irrigation and industrial. Water quality may vary and is affected by climatic factors, geology and anthropogenic activities. In rural areas, especially under dry climatic conditions is influenced by over exploitation for irrigation. Its degradation is recognized as an emerging problem in Greece and in some regions where agriculture is very intensive, such as in Central Greece, 94% of groundwater is used for irrigation. Groundwater salinity can gradually increase especially in the phreatic aquifers, due to recycling of irrigation water, which then drains back to aquifer (Leaney et al., 1999). Although groundwater salinization and salt accumulation are often natural processes, they can cause serious environmental problems that threaten human’s health, biodiversity and agricultural productivity (Ghassemi et al., 1995).

Nutrient content and concentration of heavy metals in waters are very important due to their adverse effects on human health and the environment. Amongst others, their concentration depends on the inherent geological background and exhibit spatio-temporal variations. Elevated concentrations in water bodies may originate from weathered minerals and leaching, or from anthropogenic activities (i.e. fertilization and plant protection, waste disposal, industrial activities or domestic effluents) and can have adverse environmental effects. Nitrate pollution of agricultural origin is a major source of groundwater degradation, due to nitrogen over fertilization and application of non proper agricultural practices. Water requirements in Greece increase progressively over the last decades due to urbanization, living standards, industrialization and intensification of agricultural activities.

Extensive Neogene deposits dominate geology in the area of Peza where marls and intercalations of sandstones and marly limestones prevail (Figure 1). Water levels are relatively shallow and the aquifers are not open to the sea.

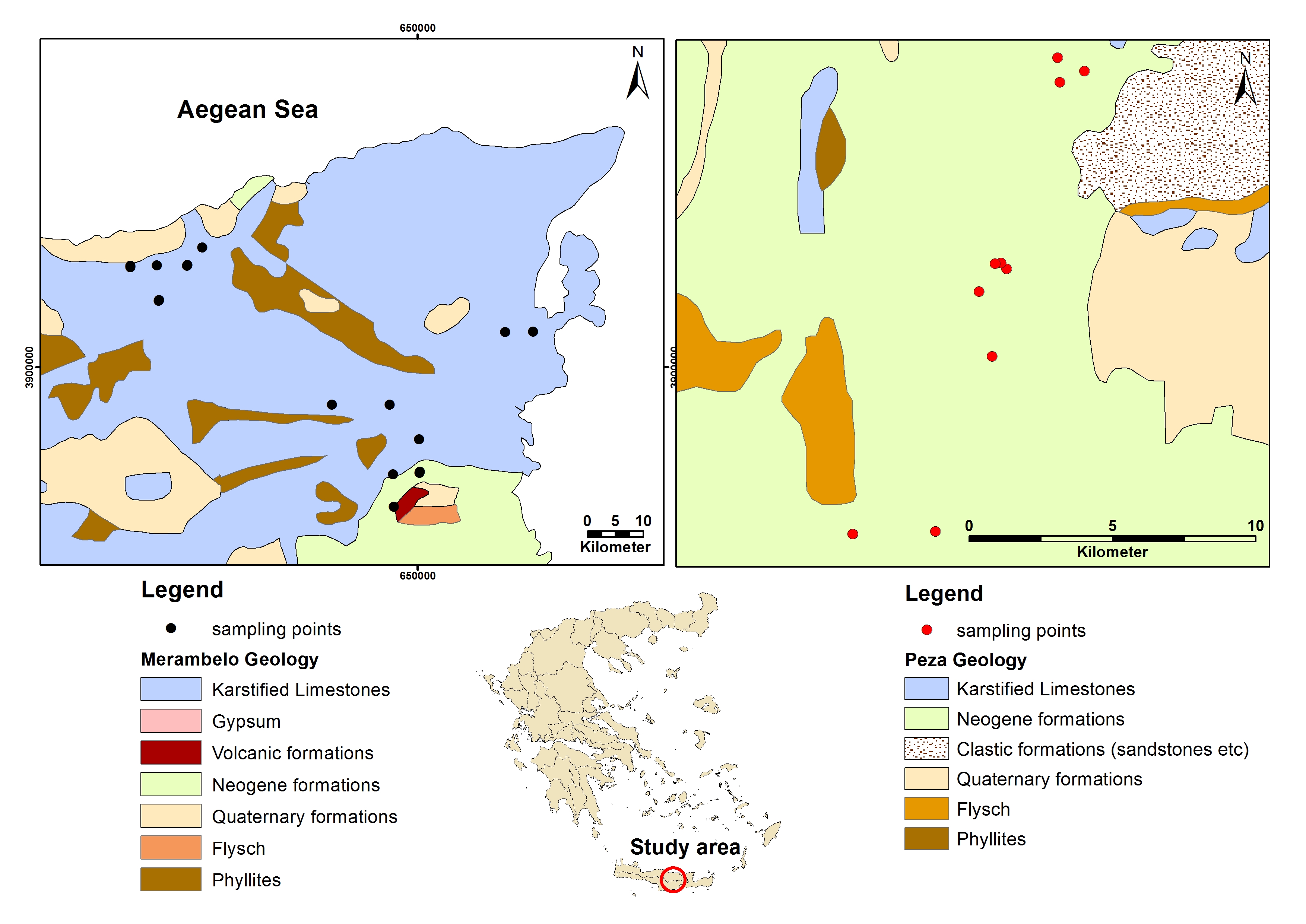


Figure 1: Simplified geological map of the study areas depicting locations of sampling net

On the contrary, Merambelo is dominated by extensive karstic aquifers that are characterised by deep water levels, are subject to sea water intrusion and are generally located in remote areas, thus are protected to some extend from anthropogenic pollution (Figure 1). On the other hand, a number of wells are tapping a sedimentary aquifer system characterised of shallow water table, subject to diffuse and point anthropogenic pollution sources, but normally not subject to salinization. In the arid regions of Greece groundwater is the dominant water source and is often abstracted from deep boreholes. In the study areas of Crete were olive groves are widely spread, water demands for irrigation are covered mostly from groundwater abstractions from the shallow alluvial and Neogene or deep karst aquifers. Most soils originate from alluvial deposits, coluvial formations or fan terraces. They have shallow soil horizons, have been affected by erosion and belong to the soil orders of *Entisols*, *Inceptisols* and/or *Alfisols* (Soil Taxonomy,1999).

**2 Materials and Methods**

Water samples were collected in the years 2011 and 2012 from 33 water production facilities (boreholes, wells, reservoirs). The collection, transfer and storage of the samples were done according to the protocol ISO 5667. The samples were stored chilled in portable thermally insulated containers and delivered to the laboratory within 24h of sampling to avoid any alterations to the chemical composition prior to the determinations under the ISO 17025 protocol. For the same reason, a separate sample was prepared for heavy metals determinations that was processed through 45μm membrane filters and acidified to pH 2 using ultrapure acid. In situ measurements of temperature, electrical conductivity (EC) and pH were performed. Determinations were performed as follows: atomic absorption for Ca and Mg, flame photometry for Na and K, graphite furnace for heavy metals, UV-VIS spectrophotometry for nutrients and SO4, and titration for HCO3, CO3 and Cl.

**3 Results**

No prior systematic studies have been elaborated in the two regions with regards to the temporal and spatial variation in groundwater chemistry. Great variation was recorded among chemical properties in the studied water samples. These differences in concentration and distribution may be attributed mainly to the geological structure and human activities in the form of fertilization, irrigation, and tillage practices. Boron, which is toxic to sensitive crops, was not found to harmful concentrations except from three samples.

Table 1 tabulates the average values of selected parameters determined in 2011 (autumn-following the end of the irrigation period) and 2012 (summer-during the peak of irrigation period), respectively. Hydrochemical analyses suggest that groundwater from boreholes and wells of the two study areas is alkaline in nature. Results also indicate a considerable issue that is related to high electrical conductivity with a maximum value of 9.14 mS/cm in 2011 and the respective value of 6.10 mS/cm in 2012. Determinations suggest that nine samples exceeded the limit of 3.00 mS/cm for the period 2011which renders the use of water problematic-unsuitable for sensitive crops (Ayers and Westcot, 1994), and likewise samples with values exceeding the limit of 3.00 mS/cm were also identified in sampling period 2012. It was recorded that most of the water samples presenting high salinity issues originate from wells and boreholes located in the region of Merambelo and tap aquifers of high to average productivity that are open to the coast and thus subject to salinization due to sea water intrusion. Statistical figures regarding mean, minimum, maximum values and STD of the studied water samples are presented in Table 1.

The mean content of macro elements (K, Na, Ca and Mg) did not vary greatly between 2011 and 2012 (Table 1) and calcium was the most abundant element, while lowest concentration was observed for potassium. Calcium abundance is well explained by the geological structure of the regions studied, as presented in previous sections of the paper.

Table 1: Statistics of chemical properties in waters

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** |  | **pH** | **EC** | **K** | **Na** | **Ca** | **Mg** | **Cl** | **SO4** | **NO3** | **NH4** | **P-Olsen** | **B** |
|  |  |  | **mS/cm** | **mg/l** | | | | | | | | | |
| **2011** | **mean** | 7.7 | 2.50 | 10.7 | 258.5 | 157.4 | 49.2 | 481.7 | 253.4 | 8.40 | 0.39 | 0.01 | 0.27 |
| **Min.** | 7.0 | 0.53 | 0.7 | 14.9 | 46.9 | 9.5 | 34.1 | 13.4 | 0.29 | 0.08 | 0.37 | 0.00 |
| **Max.** | 8.4 | 9.14 | 40.0 | 1228.2 | 684.6 | 169.5 | 2256.2 | 1426.4 | 42.70 | 1.52 | 15.95 | 0.02 |
| **STD** | 0.30 | 2.14 | 11.13 | 310.05 | 4406.6 | 1376.65 | 13488.42 | 7094.01 | 235.09 | 10.84 | 127.68 | 0.30 |
|  | | | | | | | | | | | | | |
| **2012** | **mean** | 7.6 | 1.88 | 9.0 | 213.2 | 148.7 | 44.5 | 400.2 | 216.5 | 10.14 | 0.49 | 0.01 | 0.17 |
| **Min.** | 6.8 | 0.52 | 0.6 | 14.7 | 55.0 | 12.5 | 27.9 | 0.5 | 0.32 | 0.04 | 0.37 | 0.00 |
| **Max.** | 8.4 | 6.10 | 39.0 | 898.1 | 700.0 | 151.0 | 1792.1 | 1696.2 | 62.75 | 1.39 | 12.88 | 0.05 |
| **STD** | 0.33 | 1.41 | 9.46 | 237.96 | 156.45 | 29.32 | 459.08 | 400.55 | 13.12 | 0.33 | 3.85 | 0.01 |

A significant limiting factor is the concentration of Cl-. Twelve and fifteen samples for the years 1011 and 2012, respectively, presented concentrations higher than 355 mg/l, which is considered the value above which considerable limitations exist with regards to water utilization for irrigation purposes (Panoras and Ilias, 1999). As expected, this limiting factor is apparent in the same water samples that present high electric conductivity values. All of the samples that present high salinities originate from the area of Merambelo and are related to boreholes that tap the karstified aquifer systems that are open to the sea and subject to salinisation, partly as a result of the hydrogeological setup of the region, but also due to the irrational management of water resources.

However, according to Council Directive 98/83 (EC, 1998) regarding water quality intended for human consumption, it is obvious that only in one sample nitrates concentration was higher than maximum admissible levels of 50 mg/l. Finally, ammonium was low with a mean concentration less than 1 mg/l in the examined samples.

Olive groves require irrigation especially during the dry period of summer. Taking into account the water requirements of olive trees, the elaboration of data revealed the following order concerning the maximum inputs of elements in irrigation water applied to the olive groves (kg/ha): Cl (6072.5) > Na (3189.5) > Ca (2076.9) > S (1561.3) > Mg (448.5) > K (118.5) >N (29.5).

Results suggest that application of nitrogenous fertilizers have affected groundwater quality. It can also be concluded that the applied quantity of nitrogen per hectare was not higher than crop demands. A rational fertilization policy should be implemented according to the rules set in the Nitrates Directive 676/91/EC (EEC, 1991). Moreover, a part of nitrates in the shallow aquifer can be attributed to leaching of the mineralized nitrogen originated from the decomposition of soil organic matter. Based on afore discussed findings, it is suggested that the established monitoring network is further expanded and operate systematically to enable study of the level and fluctuation of inorganic nutrients. To safeguard water quality, measures should be suggested aiming at preservation and rational exploitation of water resources.

**4 Conclusions**

This study suggests that both natural and anthropogenic processes contributed to chemical composition of groundwater in the studied areas of Crete island. The content, variability and transport of soil nutrients to aquifers is controlled by chemical, geological and biological factors and by human activities. According to findings of this investigation, the general water quality for irrigation is not very good in several samples and certain restrictions exist for the usage to crops. Fertilization, irrigation and land management play a dominant role in protecting groundwater from deterioration by adopting farming systems that receive lower application of agro chemical inputs.

Water management in Crete island needs to be sustained in order to reduce the negative impact which causes water pollution. The potential areas for future research in the study area include: assessment of the effectiveness of fertilizer use for olive groves, impact of nitrogenous fertilizer loss and water pollution, impact of future land use change on water quality at sub-catchment level, modeling nutrients loss by runoff and adoption of a specific Code for Good Agricultural Practices

**5 Acknowledgements**

Data used in this study were produced as part of the activities elaborated in the framework of the LIFE09 ENV/GR/000302 SAGE10 titled “Establishment of Impact Assessment Procedure as a tool for the sustainability of agro-ecosystem: The case of Mediterranean olives”.

**References**

[1] Ayers, R.S. and Westcot, D.W. (1994), Water quality for agriculture, *FAO Irrigation and Drainage Paper, 29 Rev. 1.*

[2] EC, (1998), Council Directive 98/83 about water quality intended for human consumption, *Official paper of the European Communities,* V. L330, pp. 32-54.

[3] EEC, (1991), *Council Directive 91/676 on the protection of waters from nitrates pollution of agricultural origin, Official paper of the European Communities,* V. L375, pp. 1-8*.*

[4] Ghassemi, F., Jakeman, A.J. and Nix, H.A., (1995), *Salinisation of land and water resources: human causes, extent management and case studies*, University of New South Wales Press, Sydney.

[5] Leaney, F., Walker, G., Knight, J., Dawes, W., Bradford, A., Barnett, S. and Stadter, F., (1999), *Potential for Groundwater Salinisation in the Tintinara area of SA: Impacts of planned irrigation allocations*, CSIRO Land and Water, Technical Reports 33/99.

[6] Panoras, A., and Ilias, A., (1999), *Irrigation with treated domestic effluent*, Giahoudis-Giapoulis, Thessaloniki.

[7] Soil Survey Staff. (1999), *Keys of soil taxonomy: A basic system of soil classiﬁcation for making and interpreting soil survey,* USDA Agricultural Handbook 436 2nd ed., Washington, D.C.: U.S. Government Printing Ofﬁce.