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# IRRIGATION SYSTEMS PERFORMANCE IN GREECE

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**SUMMARY** – The participatory irrigation projects cover about 40% (572,000 ha) and the private projects 60% (858,000 ha) of irrigated land. The transportation of water in the case of public networks is done by surface irrigation (36%), sprinkler irrigation (52%) and drip irrigation (10%). In private networks the water is applied by surface irrigation, sprinkler irrigation and drip irrigation at rates of 7%, 49% and 44% respectively. The authorities responsible for water management of the public irrigation projects are the Local Organization of Land Reclamation and the General Organization of Land Reclamation. The water and energy consumptions are increasing in the public projects where consumptions of 10,000 $m^3$/ha are usual with water losses up to 50%. In the case of private projects the cost of irrigation water is significant and it is totally chargeable to the farmers. In this way both the losses and consumptions are reduced by 10-20% and 5,000 $m^3$/ha respectively. Regarding the economic parameters, it can be pointed out that by converting a dry land to an irrigated one the family income is increased by more than 70%. For social parameters, it can be said that the conversion increases the employment at a rate of 20%. The environmental impacts from the developments of irrigation networks there are positive (as creation of artificial wetlands) and negative (as draining of wetlands, salinization of coastal aquifers, increasing of agricultural inputs) effects. Recent observations and research showed that the construction of storage dams is increasing and the nitrate problem in ground water remains at low levels. The amelioration of saline aquifers in coastal areas is achieved in many cases by recharging the aquifers with water during the winter.

**Key words:** Irrigation systems, participatory irrigation projects, private irrigation projects, organization of land reclamation, environmental impacts.

## INTRODUCTION

In Greece the main user/consumer of water is agriculture. For irrigation purposes 80-85% of the total water consumption is used (Papazafiriou et al., 2000).

The cultivated land covers 3,470,000 ha from which 1,430,000 ha are irrigated (National Statistical Service of Greece). The participatory irrigation projects cover approximately 40% of the irrigated land and the private projects 60% respectively (Papazafiriou et al., 2000).

A significant variety of irrigation systems exist with characteristic advantages for certain soil/climatic conditions as well as for crop requirements.

## EVOLUTION OF IRRIGATION SYSTEMS

The decisive role, which land improvement projects play in the increase of soil productivity and more generally, in the development of the country's national economy, has been the cause of the interest expressed by the Government in the performance of such works, almost immediately after Greece's liberation from the Turkish yoke and her constitution as a free Nation.

At that time the country was ravaged by malaria, the torrential rivers were destroying the few plains with erosion and with deposits of sterile sediments and agricultural production was suffering a lot from winter floods and summer droughts.

The first land improvement projects performed in Greece were for flood protection, swamp reclamation and drainage, scattered over the country. Among them, we can cite the flood protection works of Acheloos River (1856) and some draining works in different regions of Peloponnesus (1857). The year 1856 marks the starting point of the reclamation of the Kopais periodical lake, having a surface of 20,000 ha (Papadopoulos and Salapas, 1978).

However, a systematic effort of carrying out land reclamation projects on a nation-wide scale started after the inflow in Greece of 1.5 million refugees from Asia Minor (1922-1923), which caused a very acute socioeconomic and demographic problem. The solution of this problem would be impossible without taking radical measures for increasing the cultivated land and soil productivity, in combination with intensive land exploitation (Papadopoulos and Salapas, 1978).

The effort of the Governments was focused at performing broader schemes of land improvement projects, giving priority to flood protection works in large plains (especially in Macedonia, Thessaly and Epirus), draining of swamps and lakes, reclamation of low lands, watershed stabilization works in mountainous areas and, of course, irrigation. This effort started in 1925 and continued uninterruptedly since then, the only exception being the Second World War years (1940-1944) and the years of internal conflicts (1946-1949) (Papadopoulos and Salapas, 1978). As a result, both cultivated and irrigated lands were impressively increased from the beginning of $20^{th}$ century (Fig. 1) (National Statistical Service of Greece).

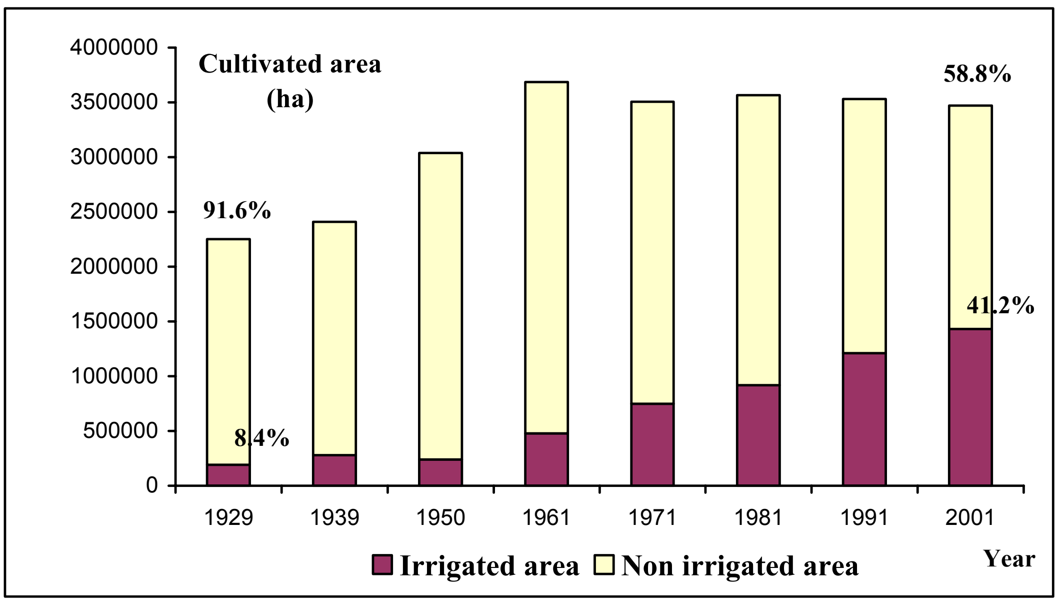


Fig. 1. Total cultivated area (irrigated and non irrigated) in Greece from 1929 to 2001.

The increase in irrigated lands was observed in all levels of altitude and especially in flat areas (Fig. 2), where the percentage is as high as 71% of the total irrigated area (National Statistical Service of Greece).

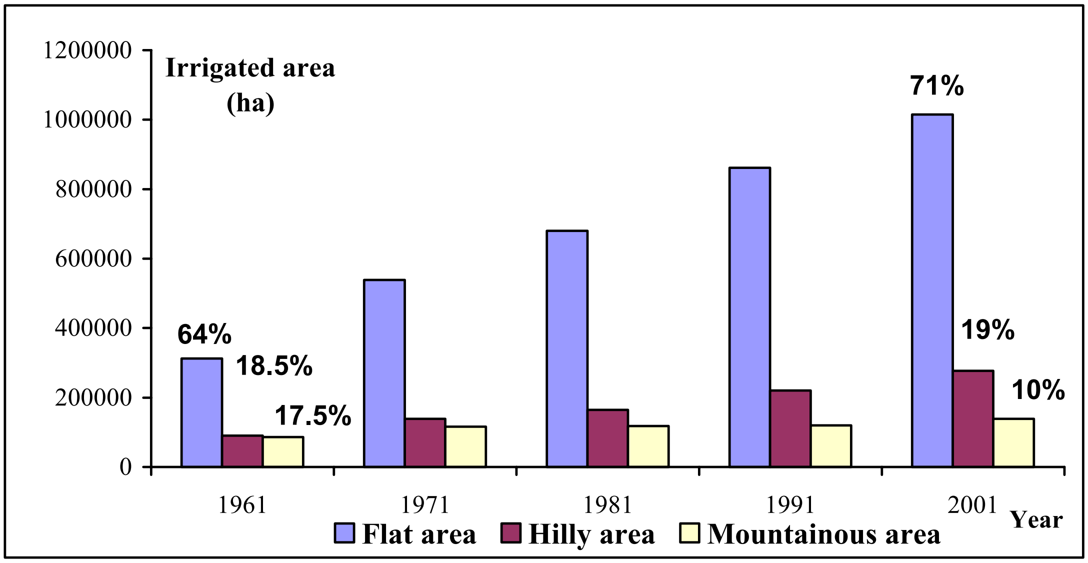


Fig. 2. Irrigated areas distribution into flat, hilly and mountainous ones.

Both private and public sectors contributed to the increase of irrigated lands. As regards the public sector, it has the tendency to cover 44% of the irrigated land instead of 26% thirty years ago (Fig. 3) (Agricultural Policy Council, 2000).

Arable crops exhibit the highest irrigated percentage, followed by fruit trees, vegetables and the vines in a decline order. As it is shown in Fig. 4 for the year 2001, the percentage of arable crops cover 65% (931,000 ha) of the irrigated land, fruit trees 24% (346,000 ha), vegetables 8% (113,500 ha) and vines 3% (40,000 ha) (Agricultural Policy Council, 2000).

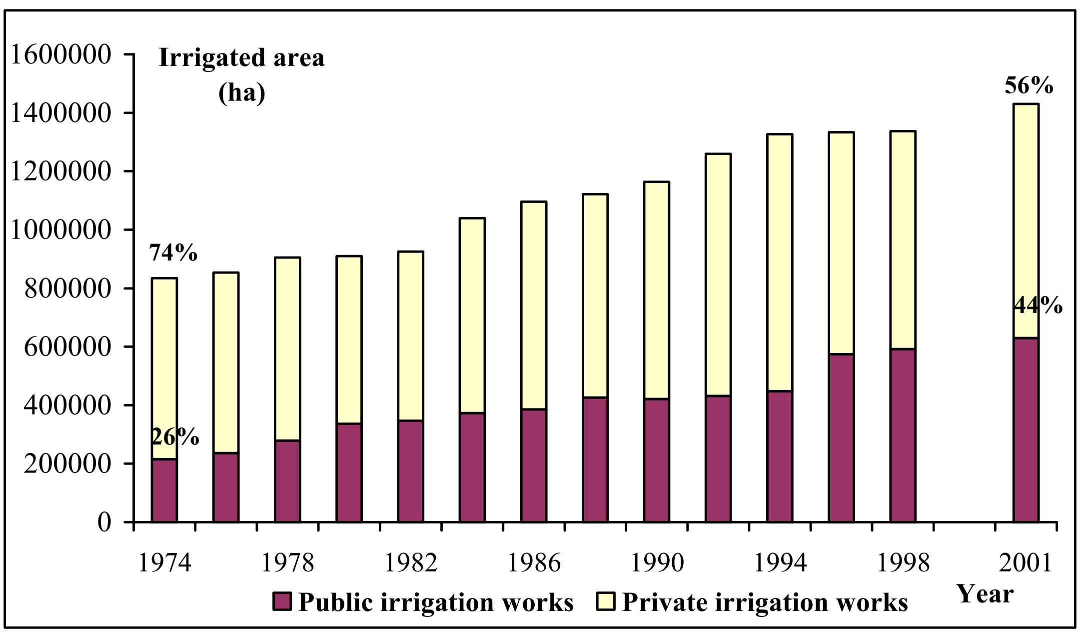


Fig. 3. Total irrigated area in Greece from 1974 to 2001.

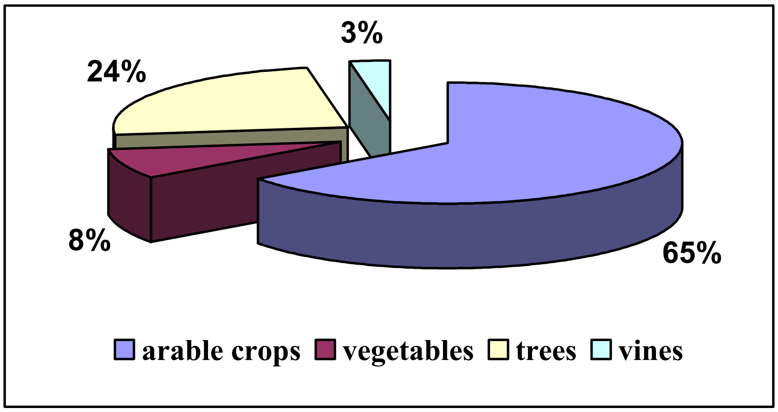


Fig. 4. Proportions of irrigated crops (data 2001).

## IRRIGATION SYSTEMS MANAGEMENT

The authorities responsible for water management of the public irrigation projects are the Local Organization of Land Reclamation (LOLR) for projects of local importance and the General Organization of Land Reclamation (GOLR) for projects of general importance. The GOLR are actually second in the rank surveying the LOLR and both are under the supervision and scientific support of the Land Reclamation Directions in the Prefectural Services. There are 10 GOLRs and 382 LOLRs in total (Pergialiotis, 2003).

### Planning and operation parameters of irrigation systems

#### *A - Technical Parameters*

The irrigation networks constructed before the year 1959 are generally inferior, from a technical point of view, to those constructed afterwards. Prior to 1959, the dominant idea was to construct main canals for the conveyance of water from the supply source to the fields. All other subsidiary structures, i.e. water distribution canals, small technical structures on the canals, land leveling and land forming, etc. were left to the interested farmers. Thus, the irrigation networks constructed before 1959 – a great number of which have subsequently been improved – consisted primarily of disorderly arranged ditches (most of which were unlined), whose tracing followed the boundaries of the irrigated land properties. The consequences of this attitude were: a waste of irrigation water, low irrigation efficiency, small percentage of irrigated lands, high operation and maintenance cost and a quick deterioration of the constructed networks (Papadopoulos and Salapas, 1978).

The irrigation projects constructed during the decade 1960-1969 have been studied on a quite different basis. Almost all of them consist of concrete-lined canals which are generally classified in three categories: primary, secondary and tertiary. The layout of the tertiary canals (forming the distribution networks) is such that they are parallel and equidistant to each other. Such a layout is obtained by neglecting, during the tracing of the network, the existing boundaries of the land properties. This results in a compulsory land consolidation and such a consolidation has, in turn, the result that each agricultural property takes finally the shape of a rectangle whose one side coincides with the tertiary canal where the water is supplied, while the opposite side coincides with the corresponding drainage tertiary channel (Papadopoulos and Salapas, 1978).

During the same period 1960-1969 the competent State Services started studying the construction of collective sprinkler irrigation networks with water distribution “on demand”, according to the system applied in Southern France. However, the works in these projects proceeded at slow rates and it is only in 1969 that two small collective sprinkler irrigation networks (at Litochoro and at Polder Messolonghi) started operating for the first time on an area of 750 ha (Papadopoulos and Salapas, 1978).

The construction, on a large scale, of collective sprinkler irrigation networks started in 1970 in the districts of Acheloos, Ioannina, Alfios, Kavassila (Thessaloniki) and Messara (Crete). Sprinkler irrigation was applied in Greece even before 1970, but only in the cases of private and properties (Papadopoulos and Salapas, 1978).

After the seventies, sprinkler irrigation networks have become popular in both the public and private sectors. In Figs. 5 and 6, the trends of the irrigation techniques for both public and private networks are shown. Nowadays, the situation is formed as described below.

Field water in the case of public networks is applied by means of surface irrigation, sprinkler irrigation and drip irrigation in proportions of 37%, 53% and 10% respectively, with a distinct falling tendency of surface irrigation (Agricultural Policy Council, 2000). Water in the private networks is applied by means of surface irrigation, sprinkler irrigation and drip irrigation at rates of 7%, 49% and 44% respectively (Ministry of Agriculture, 2000).

The way of irrigation water conveyance is given in figures 7 and 8. The conveyance proportion of pumping water is increased in public networks in relation to the water flow in open ditches (Agricultural Policy Council, 2000). In the private networks the proportion of pumping water remains at a high level (Ministry of Agriculture, 2000). In public networks the conveyance of water is done mainly by means of earthen or concrete channels with a tendency to be replaced by pipelines.

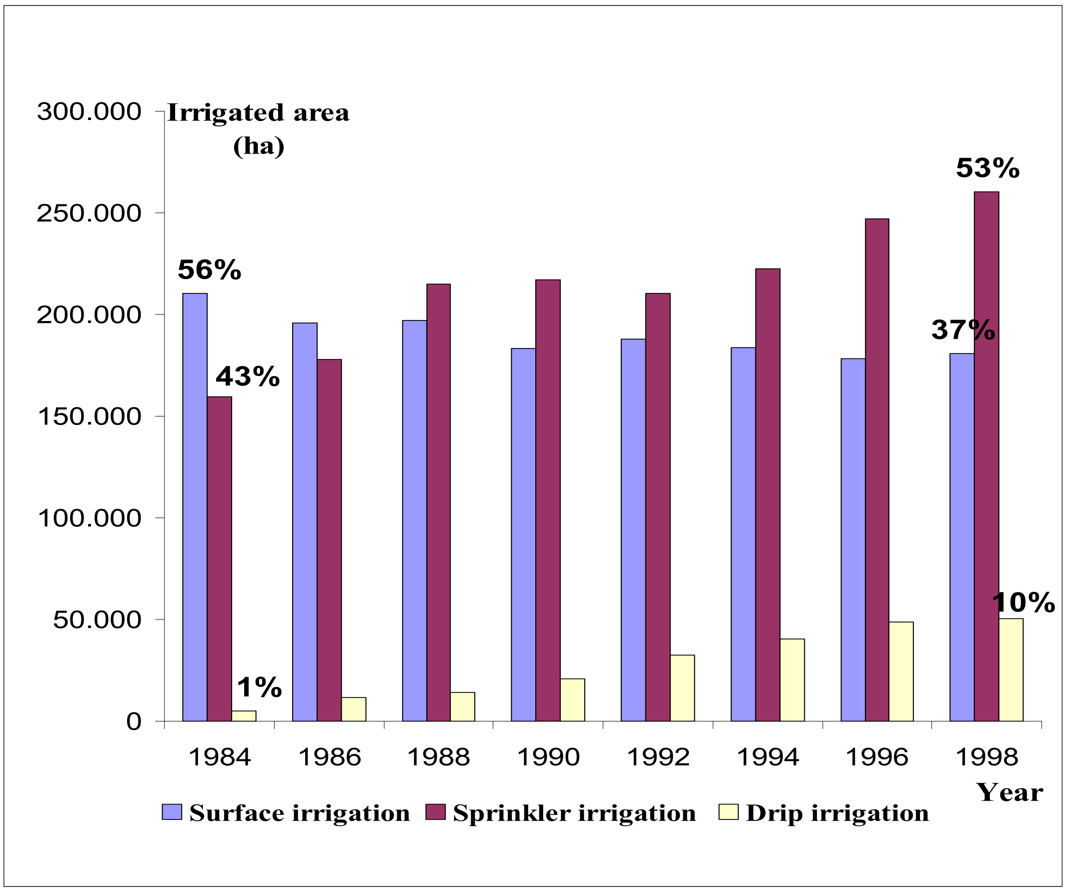


Fig. 5. The trends of irrigation techniques used in public networks.

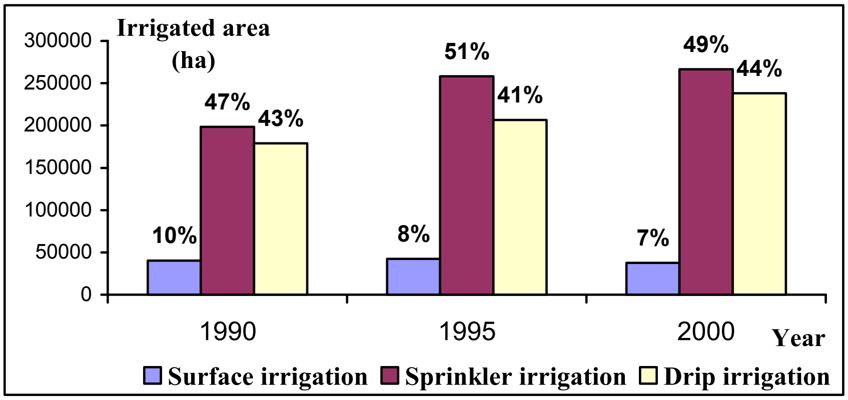


Fig. 6. The trends of irrigation methods used in private networks.

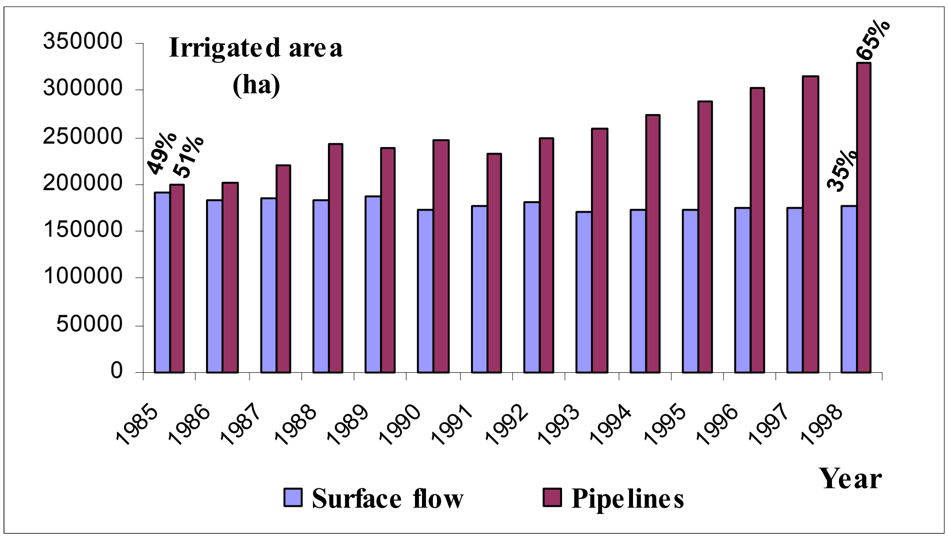


Fig. 7. Conveyance of irrigation water in public networks.

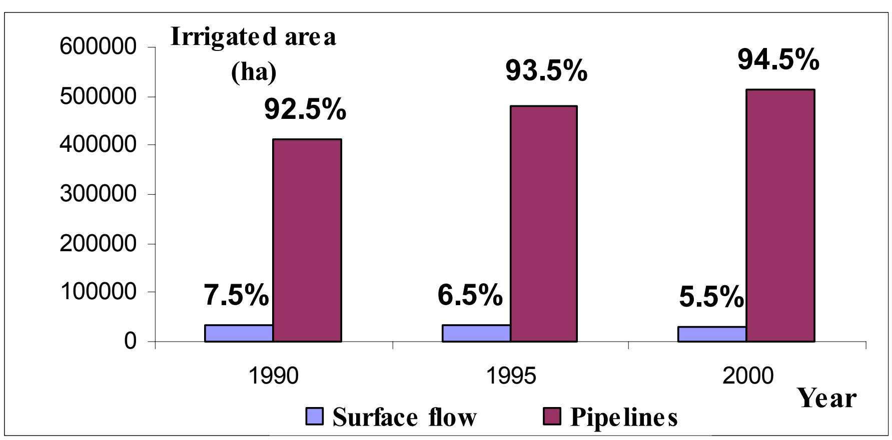


Fig. 8. Conveyance of irrigation water in private networks.

Finally, the water sources differ radically between public and private networks. The public networks, mainly use surface water, while the private ones use underground water (Figs 9, 10). The water used in public participatory irrigation networks originates from rivers and springs (42%), artificial lakes (25%), drilled wells and wells (24%), natural lakes (5%), drainage ditches (4%) (Agricultural Policy Council, 2000). There is a rising interest for artificial water reservoirs. The water used in private irrigation networks comes from drilled wells (82%), rivers and springs (13%), drainage ditches (3%) and artificial lakes (2%) (Ministry of Agriculture, 2000).

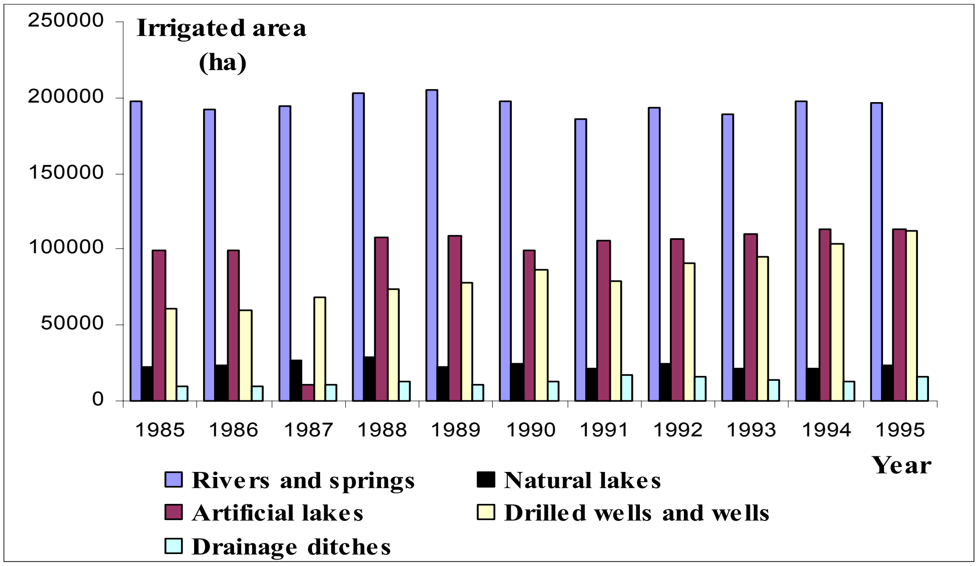


Fig. 9. Source of irrigation water in public networks.

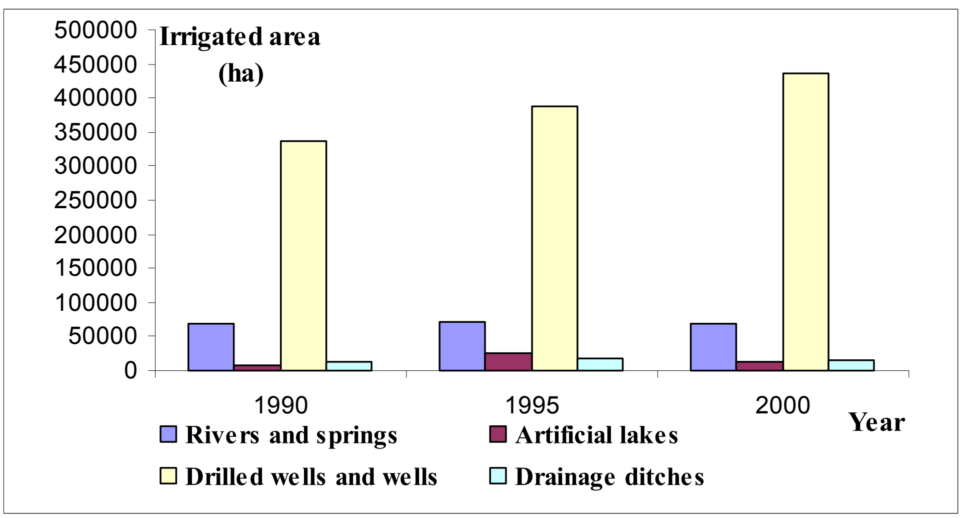


Fig. 10. Source of irrigation water in private networks.

It is worth pointing out that in Greece there are about 200,000 drilled wells and wells for irrigation purposes, 13 rivers with a summer discharge bigger than 3 $m^3$/sec, 21 large lakes covering an area bigger than 320 ha, 52 big carstik springs (and thousands minor ones) and more than 70 artificial lakes with a total effective volume bigger than 9.5 billion $m^3$. The total annual water potential is estimated about 70 billion $m^3$, including the rivers water flowing from neighboring countries (Pergialiotis, 2003).

In the course of time the hydraulic pressure and the discharge of the irrigation networks were decreased as a result of accumulated experience and know-how. The agro-technical plans, as a necessary component of an irrigation network project, were used systematically since the fifties. However, irrigation works have constructed without technical plans up to the late eighties.

For the public works the method of estimating water demands was done using the classic equation of Blaney-Criddle (Ministry of Public Works and Ministry of Agriculture, 1976), with a reduced crop coefficient up to 30%. This was accomplished following experimentation over different parts of Greece. In spite of the weakness of the equation, it is obvious that the possibility of overestimating the needs of the networks has been minimized and in this way more land was irrigated using relative small quantities of water (Papazafiriou et al., 2000).

Also, some effort was spent to modernize the planning of irrigation networks towards better servicing of the consumers (one outlet for each parcel with ensured pressure head and discharge) (SCP-GERSAR/Hydrosystem, 1997).

It is evident that a sociological approach is needed in planning irrigation networks. A bottom-up approach starting from the actual field requirements of final utilizers (farmers) and going up to the top, calculating the needs at the head of the networks and, in this way, finding the appropriate water supplies for the satisfaction of the total demands. This necessity followed the pilot actions of modernization-reforms of irrigation networks in the region of Peneus (Eleia) (SCP-GERSAR/Hydrosystem, 1997).

As regards the water and energy consumptions of the irrigation networks of the country, the following applies:

➢ In the private networks, where one or a few farmers are involved, irrigation networks with capital intensity are usual as a result of lacking easy available water resources. In this case dominates the model: pumping from drilled wells in the parcel (farm) -conveyance through pipelines - application with sprinkler or drip irrigation. In spite of the progress to a large extent in rural electrification and the reduced rates of electricity for farmers, the operational cost of the system remains considerable high in comparison to the cost in public networks, where users pay only a token payment. Furthermore, the water sources are mostly of reduced quantity and quality. Therefore, strong incentives exist for saving groundwater. In these systems losses are 10-20% and they are due to the wrong water application. Water consumption does not exceed 5,000-6,000 m$^3$/ha, even in high water consuming crops such as alfalfa, maize etc.

➢ In public networks water and energy consumptions are generally increased as a result of considerable water losses in the course of water conveyance from the source up to the final application. Consumptions about 10,000 m$^3$/ha are usual, whereas rates up to 17,000 m$^3$/ha are occasionally observed. Data from relevant research pointed out that the effective (actual) needs of the crops do not exceed the 5,000 m$^3$/ha. Therefore, losses exceed 50% (SCP-GERSAR/Hydrosystem, 1997).

It must be pointed out that differences are very large in time and place. It is possible large differences to be observed from year to year even in neighbouring irrigation networks belonging to the same LOLR. These deviations are due to:

- Inefficient maintenance
- Extraordinary damaging events
- Unorthodox methods of water application
- Wrong use of network
- Ageing of the networks
- Earthen delivery canals
- Wrong water charging
- Lack of personnel and efficient control techniques.

A lot of canals in the networks for surface methods of irrigation are earthen, although this situation is being improved. However, there are cases where water shortage has positively activated the involved users and losses have been reduced to the normal range of 15-20% (Economical Chamber of Greece-West Crete Department and Geo-technical Chamber of Greece-Crete Department, 1998). A consequence of the water losses is the large consumption of energy in the public irrigation networks. This over-consumption of energy rises the operational cost of the network, which result in a negative attitude of the consumers to settle their dues and concomitant power-cuts (SCP-GERSAR/Hydrosystem, 1997).

The power-cut of electricity induces a cessation of the cathode protection of the steel pipes viz. an acceleration of their ageing and a creation of water hammers during a sudden start of the operation.

In this way, a vicious circle is created which brings about a continuous deterioration and shortening of network's life (the contractual life is supposed to be 50 years) (SCP-GERSAR/Hydrosystem, 1997).

Another example of the picture of public networks is the irrigation intensity factor, namely the ratio of the irrigated to the covered area of the network. The satisfactory values of this factor are above 70-80%. In our case, values of 30-40% are not rare (SCP-GERSAR/Hydrosystem, 1997). The reasons for these low values are:

- Wrong planning of networks
- Abandoned fields
- Field holders with other employments than farming
- Wrong operation of network
- Low quality of water
- Low quality of service

### *B - Economical Parameters*

In a country like Greece with a semiarid climate, water resources management demands large amounts of money from the State and the EU budget. In recent years, the major reclamation works were constructions of dams and ponds as well as further development of networks.

In order to take full advantages of the works, attempts have been done to use the projects to not only for irrigation but also for domestic use and energy. Thus, multiple benefits arise that justify the construction cost.

In Greece, the economical stability of the works in the planning stage is examined simultaneously for the followed criteria (Ministry of Coordination, 1976):

a) The net present value of the work must be positive. Usual values in Greece are many tens of millions of euros.
b) The ratio of present benefit value for the present cost value of the work (cost/benefit ratio) must be bigger than unity. Usual values are between 1.1 and 1.5.
c) The internal rate of return is the most important criterion concerning the "efficiency" of the work. It must take values higher than the rate of lending interest of Hellenic state from international financial-credit organizations (e.g. World Bank). As it is obvious, the values of the rate of lending interest are changed with today's rate to be about 5.5%.

These criteria follow the guidelines of the Organization for Economic Cooperation and Development (OECD) for the validation to these types of Reclamation Works (Bergmann and Boussard, 1976). From the same projects it is concluded that the family income is increased more than 70% inside the work district as well as in the wider work district, after the conversion of an arid area to an irrigated one. It can be said that similar principles are followed by the Ministry of Finance for the estimation of the presumptive income of farmers. In this case for the same region, the income in an irrigated area of one stremma (1,000 $m^2$) is double in comparison to the same arid area (Naftemporiki Newspaper, 2004).

The construction of public irrigation works are almost accompanied by compulsory redistribution of land properties in the perimeter of the work. This means that each farmer finally receives one or more parcels of large size, suitable for applying automations for a business type of farming. In this way three fundamental structural problems of greek agriculture were solved (Karamanos, 1998).

1. The small holding
2. The multiparcelling
3. The concomitant high cost of production

The process of land redistribution has been carried out systematically in Greece since 1959 and up to now an area of 900,000 ha has been redistributed. Obligatory and voluntary land redistributions cover 63% of the irrigated land and 26% of the total cultivated land (Vlachos et al., 2000).

The costing of the tendering services as well as the pricing policy of water use are problematic in Greece.

A. In the public reclamation works the operational costs (administrative-operational-maintenance) are estimated; then, the distribution of proportional expenses is based on an area-basis of the irrigated land. This way of distributing expenses has the following disadvantages (Dercas, 2003).

1. The estimation of the cost for each organization (LOLR) is different and it is based more on the operational expenses (energy for pumping, etc.) and less on the salaries of administrative staff. For the most of the cases, the analogous cost for maintenance and depreciation of the works is not included.
2. The pricing of water based on the size of parcel is in a way obligatory and sufficient for surface networks but it is particularly problematic in irrigation networks under pressure. It does not create motives for saving water and energy. A usual characteristic of greek irrigation networks is that the energy cost is higher than the personnel cost. This fact is opposite to the rational management according to the international standards.

The problem of pricing according to the consumed water volume is difficult to be solved as many technical problems exist.

- Many farmers use the same inlet as a result of the small holdings.
- A lot of inlets are out of order for different reasons (acts of vandalism, inefficient maintenance).

The costing on a water volume consumption basis is not popular to farmers, who think that they will pay more than they pay today. Of course, there are also exceptions where each consumer has its private inlet and its private water meter (e.g. networks of ODWEC in Chania-Crete).

In addition the pricing in certain networks (e.g. Peneus, Alfios) depends on the method of water application. When farmers use gravity irrigation methods in networks under pressure (this incident leads to over-consumptions), it is obvious that the administrator of the organization will try to prevent such behavior and to charge these farmers with increased rate per water volume (Dercas, 2003).

Also, it must be emphasized than even in healthy administrative organizations, like ODWEC where projects are operative for both domestic and irrigation purposes, there are cases where actual charges are not attributed to farmers and the cost is transferred with increased value to domestic water. In this case the farmers are subsidized for social policy reasons.

In private networks, users seem to pay the total amount of cost of the water supply. However, they are not charged for the environmental effects cost caused by over- pumping and they are also strongly subsidized for buying irrigation equipment as well as for using energy appropriate for operation of the networks (oil, electricity) (Dercas, 2003).

To face this situation the Ministry of Agriculture moves to the framework of the EU-Directive 60/2000. According to this Directive, it is expected during 2004 to formulate proposals for costing the irrigation water on the following principles (Dercas, 2003).

- The financial cost includes the cost of water supply and the relevant services. It is included the total cost of operation and maintenance as well as the capital cost (return of capital and payment of interest and possibly the profit of shares).
- Environmental cost is included, which represents the cost of environment and ecosystems deterioration from the use of water resources (e.g. degradation of the water ecosystems, salinization and degradation of productive soils).
- Water resources cost representing the cost of losses, for other uses, because of the reduction of water resources (excessive pumping).

### *C - Social Parameters*

The conversion of an area from arid to irrigated one creates an increasing in local employment by at least 20%, according to relevant economic-technical data. It is also observed a reduction in working ours as a result of automations. In this way there is a tendency to keep rural population at their home and to avoid their emigration to urban areas. In addition, the creation of parallel activities, as agro-tourism, is feasible in the case of water sufficiency after the construction of mixed hydro-irrigation works. This has been already achieved in some arid Aegean islands, where a lot of reservoirs have been constructed from the Ministry of Agriculture to collect the winter runoff water in the last decade.

Thus, during the summer both domestic water needs are served and fresh vegetables are produced for local markets.

It is important that the management of public works is governed through transparent democratic procedures, following the public approval through the Environmental-Impact Assessment (EIA) of the work and the regular operation of the LOLR where basic component is the general assembly of water users.

Finally, there are and some negative elements in planning and operating public networks: Planning does not contain special research for investigation of social structures and the potential of users in relation to the specifications of the project. Accordingly, it is possible that users may be unable to use the capabilities when the work will operate (SCP-GERSAR/Hydrosystem, 1997).

### *D - Environmental Parameters*

Environmental aspects are both positively and negatively affected by the water development projects.

- The Environmental-Impact assessment (EIA) as a necessary and essential part of a water development project. This is a relatively new requirement (it is being used for the last ten years) and it helps avoid the more significant negative impact to environment (Skordas and Anagnostopoulou, 1995).
- The creation of artificial wetlands, as ponds, canals and paddy fields. On many occasions the wetlands are so significant that they are included in wetlands of international importance (RAMSAR), as the artificial lake Kerkini, or equally important as critical stations of migration of birds, like the ponds in Crete and in the islands of Aegean (Zalidis and Mantzavelas, 1994).
- The reductions in groundwater pumping through drilled wells, in the case of existing water reservoirs, give the opportunity to stop the salinization of water where there is the phenomenon of seawater-intrusion.
- The draining of wetlands for cultivation has been abandoned.
- The salinization of groundwater from the excessive water pumping and the consequent sea-water intrusion to the land (plains of Argos, Komotini, Xanthi, Marathon etc.). It must be noted the case of groundwater salinization due to geological effects (North coastline of Crete) (Pergialiotis, 2003).
- The degradation of land resources by means of oxidation of organic soils (former Lake of Agoulinitsa) or the salinization of soils. In both cases the wrong operation of drainage systems is responsible.
- The pollution of surface and underground waters caused from the excess use of fertilizers and pesticides after an intensive form of farming (e.g. nitrites in the plain of Thessaly, pesticides in the waters of Axios). The State has established a network for monitoring water quality, carrying out systematic samplings in sensitive regions, and, when necessary, introducing artificial water recharging or reservoir constructions (Pergialiotis, 2003).

## CONCLUSIONS

There is a strong tendency towards a sustainable irrigated agriculture: winter runoffs are stored, distribution and application losses are reduced, farmers' incomes are raising and unemployment is falling down, environmental benefits from a rational development of water works are realized.

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