The efficiency of water reservoirs at the region of the former Lake Karla in Thessaly to meet irrigation requirements

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Abstract: - In the region of Thessaly, at the area where the former lake Karla extended, before it was drained, a number of surface reservoirs operate and supply the sufficient water quantities for irrigation of nearby cultivated areas mainly during the period between June and August, when the irrigation water requirements are high, while the available water from other resources is negligible. In the present study, monthly climatic data taken from the meteorological station of the National Meteorological Service (N.M.S.) in Larissa, Greece are utilised for the estimation of both the reservoir's evaporation and the crop water requirements in order to evaluate the efficiency of reservoirs in meeting these crop water requirements, with reference to their technical characteristics and the size of the irrigated areas.

Key-Words: - Irrigation, evaporation, reservoir, cultivation, evapotranspiration.

1 Introduction

Thessaly, from agricultural point of view, is the most important part of central Greece, not only because it is a non mountainous area, but also because the Pinios River, which crosses the region, makes the plain highly fruitful.

Since the ancient times (period of Herodotus), at the foothills of Pelion, there existed a lake named Viviis, which was considered to be the place where part of the surface waters of Thessaly plain were concentrated. This lake, today known as Karla, has been drained, since the last five decades.

The cultivations at the *region where the former lake of Karla existed* are irrigated mainly by water that is stored into nearby reservoirs, which have been constructed for this purpose.

In the frame of the research programme "Archimedes – EPEAEK II", co-funded by the European Social Fund & National Resources and realised by the Dept. of Civil Engineering of TEI of Larissa, Greece, under the title "Spatial mapping and estimation of hydrological risk, emphasising the floods and draughts in urban and non urban areas of Thessaly and their environmental impacts", the above region has been selected as a study area.

The research aims at estimating the reliability of the above structures, i.e. water reservoirs, covering the essential water quantities for irrigation.

In the study region there are totally eleven (11) reservoirs [1, 2] that supply specific areas (totally eight sub-regions) with irrigation water, as shown in Fig. 1.

These reservoirs are filled up with water, through pumping, early in the springtime from Pinios River. This water is then used to irrigate the local cultivations during the water shortage period (mainly June and July).

In the study area the cultivations irrigated by sprinkler and trickle consist 70% of the total area, leaving the rest 30% to non-irrigated, which are mainly serials. From the irrigated areas cotton covers about 85%, while the rest is cultivated by maize, alfalfa and processed tomato.

Given the size of reservoirs along with the corresponding irrigated area and the distribution of crops, it is considered more than necessary to evaluate the reliability of each reservoir in covering the irrigation water needs, taking always into account the variability of climatic conditions from year to year.

Methodologies for validating irrigation networks have been proposed in the past for specific crop species [3, 4]. This work necessitates mainly the estimation of both the evaporation of reservoirs and the evapotranspiration of crops on a monthly basis. These estimations are then utilised to calculate the

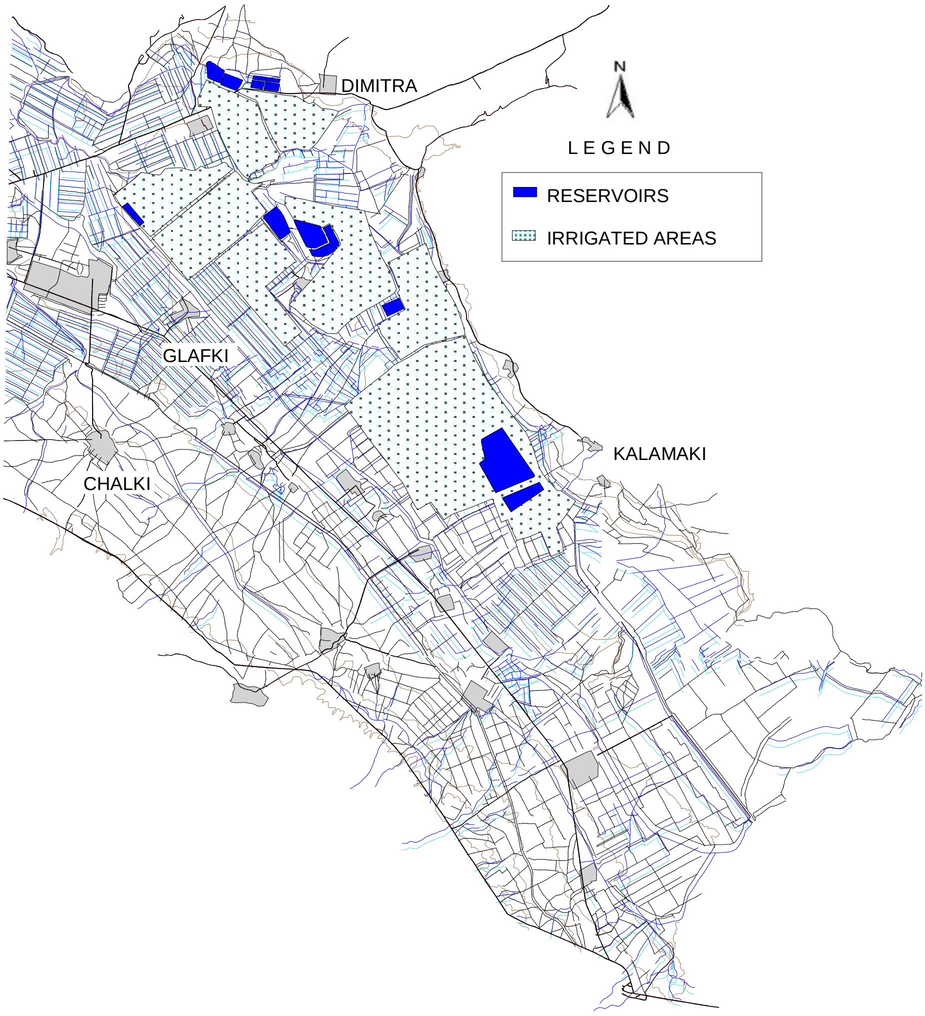

Fig. 1: Reservoirs and irrigated by them areas in the region of former Lake Karla

water balance of each sub-region for a certain number of years.

This project considers monthly climate data taken from the meteorological station of the National Meteorological Service (N.M.S.) of Larissa along with soil data [5] and crop species data of the study area, with the aim at estimating the water balance of each sub-region which is irrigated from a certain reservoir. These estimations are then utilised to evaluate the reliability of reservoirs in order to cover sufficiently the local irrigation water needs.

2 Procedures - Methodology

Each region of cultivation is characterised by a number of parameters, such as water evaporation from reservoirs, crop water needs, rainfalls and reduction of soil moisture, which have to be considered. All these features have to be taken into account in order to estimate the water shortage during each year and consequently the risk of failure in water supply for irrigation.

The study area is close to the city of Larissa, where a meteorological station of the N.M.S. is already in operation. The greater Larissa area is suffering by warm and dry summers. This period is crucial for crop growth, demanding for irrigation great quantities of water. At the plain part of the county and especially at the region of the former Lake Karla, the prevailing temperatures along with other climatic parameters which determine the level of evaporation and evapotranspiration of crop species (solar radiation, sunshine duration, relative humidity, wind speed) are practically considered to be the same to those recorded by the N.M.S. of Larissa.

3 Calculation of evaporation and evapotranspiration

The most reliable method for the calculation of evaporation and evapotranspiration in our days is the modified method of Penman-Monteith, as described in FAO-56 [6, 7, 8].

The method is applied in two stages. Initially the evapotranspiration of the reference crop is calculated and then crop evapotranspiration is estimated using the corresponding crop coefficient as shown in the following relation

$$ET_C = K_C \cdot ET_O, \tag{3.1}$$

where are: ET_C the daily evapotranspiration (mm/d), K_C the crop coefficient which is dependant on the stage of the crop development [6], and ET_O the evapotranspiration of the reference crop (mm/d).

Evaporation can be calculated in a similar way through the equation

$$E = K_C \cdot ET_O, \tag{3.2}$$

where are: E the daily evaporation (mm/d) and K_C the surface coefficient, which, for shallow water surfaces takes the value of 1.05 [6].

The evapotranspiration of reference crop is determined through the modified Penman-Monteith method as described in FAO-56 [6, 8] and is calculated through the equation:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \dfrac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma \cdot (1 + 0.34 \cdot u_2)} \tag{3.3}$$

where the following symbols represent:

- ET_O evapotranspiration of reference crop (mm/d),
- R_n net solar radiation ($MJm^{-2}d^{-1}$),
- G soil heat flux density ($MJm^{-2}d^{-1}$) which here can be considered negligible ($G \approx 0$),
- T mean air temperature at 2m height (^oC),
- u_2 average wind speed at the same height (ms^{-1}),
- e_s saturation vapour pressure (kPa),
- e_α actual vapour pressure (kPa),
- Δ slope of saturation vapour curve at a temperature T (kPa^oC^{-1}) and
- γ the psychrometric constant (kPa^oC^{-1}).

For the evaluation of R_n, the estimation of extra terrestrial radiation (R_α) is essential along with the maximum sunshine duration (N) which can be realised through periodic functions [10].

Through equations (3.1) and (3.3) along with the monthly rates of climatic parameters (temperature, sunshine duration, relative humidity and wind speed) for the years 1955-1997 taken from the N.M.S. of Larissa, the monthly rates of evapotranspiration for the above period of 43 is calculated. These results are presented in Fig. 2 for the period 1990-94.

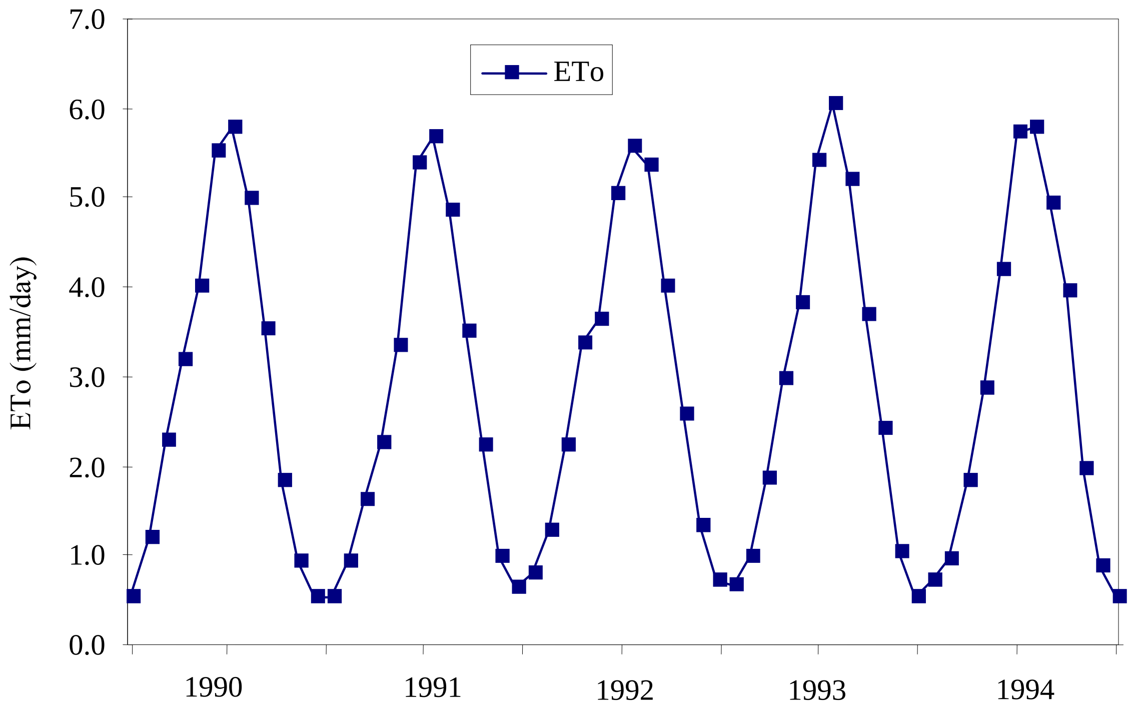

Fig. 2: Calculated values of reference crop evapotranspiration (mm/d) at Larissa for the years 1990-94

Table 1: Technical characteristics of reservoirs along with the sub-regions they serve

	Technical characteristics of reservoirs			**Corresponding served sub-regions**				
	Reservoir	**Capacity 10^6 m^3**	**Water surface $10^3 m^2$**	**Irrigated Area 10^3 m^2**	**Cotton %**	**Maize %**	**Alfalfa %**	**Processed Tomato %**
1	Eleftherion I, II	1.70	600	4000	85		15	
2	Dimitra	1.00	400	2600	85		15	
3	Platikampos I	0.50	250	1500	85	10	5	
4	Platikampos II	1.45	500	4560	85	10	5	
5	Glafki	2.10	550	5415	85	10	5	
6	Namata I, II	2.90	983	10000	80	10	5	5
7	Kastri	1.10	350	4900	85		15	
8	Kalamaki I, II	8.00	2750	20000	85		15	

4 Calculation of water balance

The validation of reservoirs' reliability of the study area necessitates the water balance of each sub-region irrigated by a certain reservoir system.

The water balance is estimated per year and takes into account the technical characteristics of reservoirs (capacity, water surface) along with the evaporation rate [9], the size of irrigation areas and the crop water requirements, the rainfalls and the reduction of soil moisture.

The data used for the calculations are presented on Table 1 and refer to the technical characteristics of reservoirs [2] along with the served by them sub-regions.

5 Results and discussion

The results of calculations are shown in Table 2. They refer to the average reliability of reservoirs R_m, its standard deviation, SD_R and the variation coefficient, CV_R, that come from a simulation period of 43 years.

As reliability of a reservoir is defined the ratio of its capacity over the total water needs of the sub-region which is served. The value 1 of reliability – which is its maximum one – means that the crop water requirements are completely satisfied.

Table 2: Reliability of reservoirs for the study region

	Reservoir	**Average rate, R_m**	**Standard Deviation, SD_R**	**Variation Coefficient, CV_R, %**
1	Eleftherion I, II	0.832	0.113	13.6
2	Dimitra	0.758	0.116	15.3
3	Platikampos I	0.660	0.109	16.5
4	Platikampos II	0.667	0.105	15.8
5	Glafki	0.816	0.115	14.1
6	Namata I, II	0.610	0.099	16.3
7	Kastri	0.483	0.082	17.0
8	Kalamaki I, II	0.800	0.111	13.9

Taking into account the values of the above parameters that refer to the reliability of reservoirs for the study region and the assumptions of the Central Limit Theorem [11, 12, 13, 14], a general classification of those reservoirs is feasible according to their reliability under specific conditions.

The validation is typically realised with respect to the average reliability of reservoirs for a period of 10 years and a probability 10%.

It is estimated that the most reliable reservoirs are those of Eleftherion I & II (78,7%) followed by Glafki (76,9%), Kalamaki I & II (75,5%), Dimitra (71,1%), Platikampos II (62,5%), Platikampos I (61,6%), Namata (57,0%) and Kastri (44,9%).

The above results are depicted in Fig. 3.

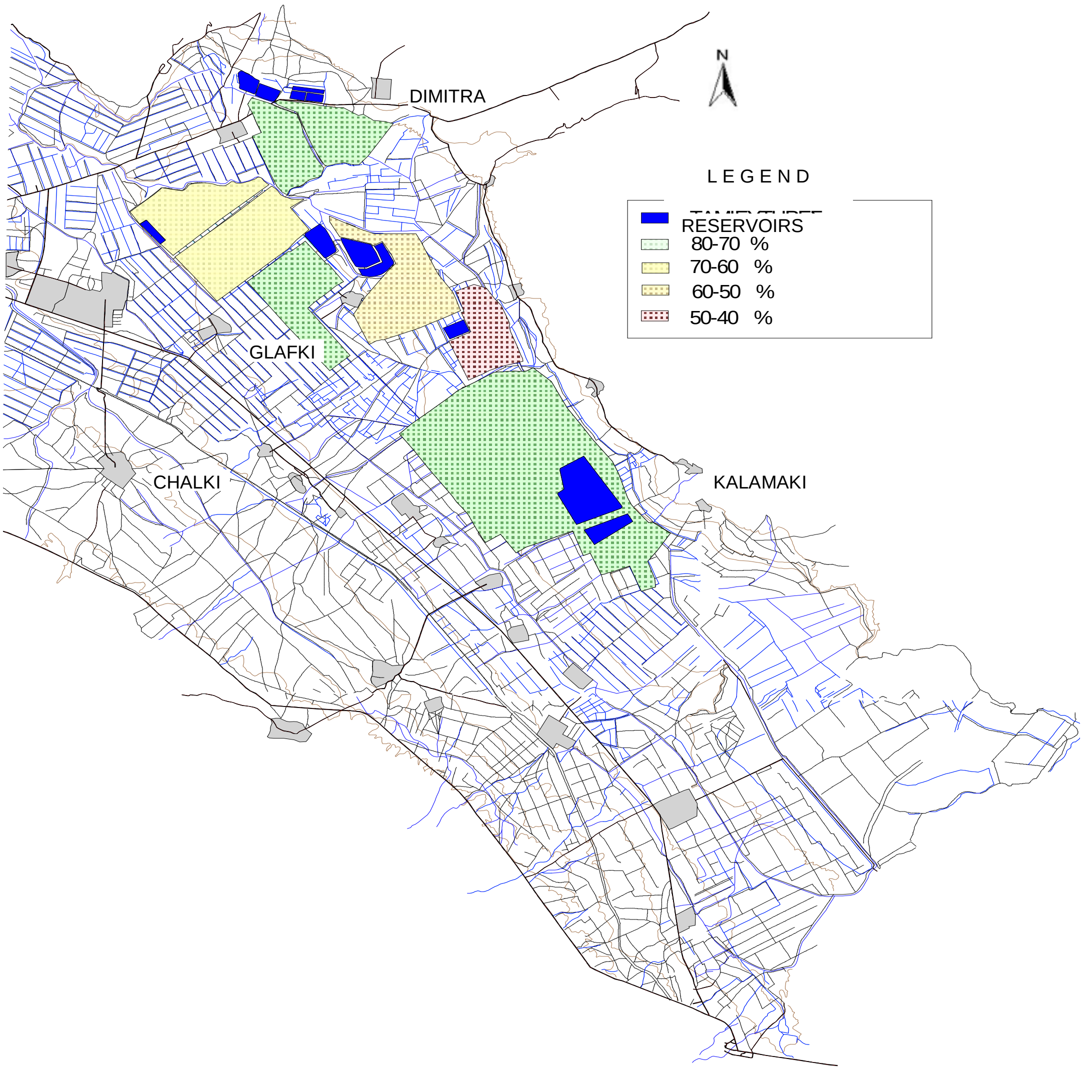

Fig. 3: Average reliability of reservoirs in the region of Karla for a decade and a probability 10%

6 Conclusions

From the calculated values of shortages on the water balance for each sub-region of the study area (part of the former Karla Lake) – that take into account the variability of climatic conditions for a period of 43 years, the size of reservoirs along with the size of the irrigated areas and the distribution of crop species – the following conclusions can be drawn:

a) The reliability among the different reservoirs of the study area may not be the same. Reservoirs usually do not cover the total local crop water requirements. On average they cover only a part of them (48 – 83%), depending on the conditions of the sub-region which is served by each reservoir. The most reliable reservoirs, according to characteristics presented above, are those of Eleftherion I & II, Glafki, and Kalamaki I & II while last comes the one of Kastri.

b) The irrigation needs for the cultivated areas that are served by the same reservoir may not be equally satisfied from year to year, due to different climatic conditions. This variability, expressed through the variation coefficient, fluctuates between ~13,5 - 17%.

The above reliability analysis for the structures used to store water for irrigation, may be a useful tool for a further construction of new ones, so that, at last, they fulfil the corresponding local irrigation water needs.

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