RELIABILITY OF THE RESERVOIRS AT THE REGION OF THE FORMER LAKE KARLA IN THESSALY IN MEETING CROP WATER REQUIREMENTS

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Abstract: For the time being, twelve surface reservoirs operate in the area of the former lake Karla in order to supply the sufficient water quantities for irrigation of the nearby cultivated areas mainly during the period June – August when the irrigation water requirements are high while the available water from other resources is negligible. In the present study, monthly climatic data for a period of 43 years (1953-1997), from the meteorological station of the National Meteorological Service (N.M.S.) in Larissa are utilised for the estimation of reservoir evaporation and the crop water requirements in order to evaluate the efficiency of reservoirs in meeting crop water requirements with reference to their technical characteristics and the size of the irrigated areas. The analysis exemplifies that the reliability among the various reservoirs of the study area is not the same. Reservoirs usually do not cover the total crop water requirements of the areas they serve. On average, they cover only part of them (48 – 83%), depending on their characteristics and the cropping pattern of the sub-area they serve.

Key words: Evaporation, evapotranspiration, FAO 56 Penman-Monteith, reliability, reservoir.

1. INTRODUCTION

The Thessaly plain, dominated by the Pinios river watershed, is the largest agricultural area in Greece. Under the present water management regime, the available water provides only 40-70% of the crop water needs over much of the area and extensive droughts occur during critical periods of the growing season (July-August) with adverse effects on crop yield and quality. In order to alleviate these effects a number of irrigation related structures have been planned and constructed. For that purpose, twelve surface reservoirs operate in the area of the former lake Karla in order to supply the sufficient water quantities for irrigation of the nearby cultivated areas.

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 on floods and draughts in urban and rural areas of Thessaly and their environmental impacts", the above region has been selected as study area.

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

In the study area there are twelve (12) reservoirs (Land Reclamation 2005; Goumas 2006) in total that supply irrigation water into nine sub-areas, as shown in Figure 1. These reservoirs are filled up with water, through pumping, early in the spring from Pinios river. This water is then used to irrigate the local cultivations during the dry period (mainly June and July).

In the study area, sprinkler and trickle irrigation is applied on 70% of the cultivations while the rest 30%, mainly serials, are rain fed. From those irrigated areas cotton covers about 85%, while the rest is cultivated by maize, alfalfa and processed tomatoes.

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 meeting the irrigation water needs, taking 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 (Kotsopoulos 1989; Kotsopoulos and Svehlik 1995). 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 water balance of each sub-region for a certain number of years.

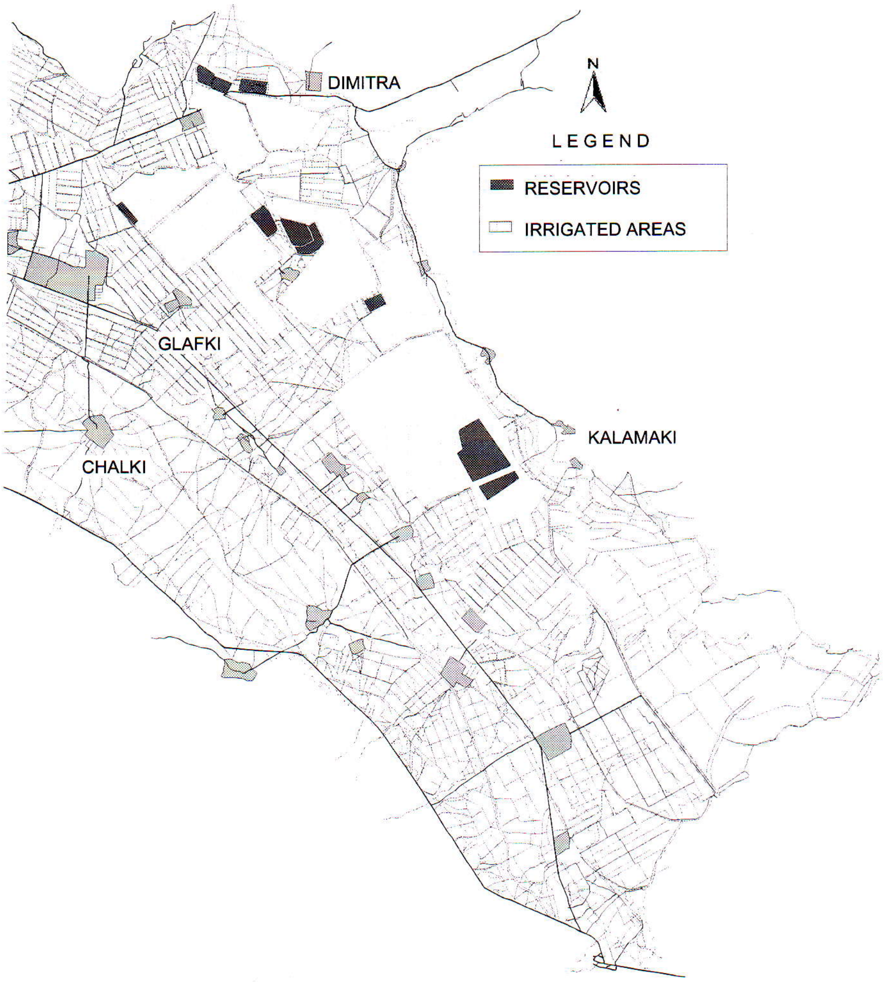

Figure 1: Reservoirs and irrigated by them areas in the region of former Lake Karla

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 (Kalfountzos et al. 1999) 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. MATERIALS AND METHODS

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 consider. 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.

2.1 Calculation of evaporation and evapotranspiration

Nowadays, the most reliable method for the calculation of evaporation and evapotranspiration is considered the modified Penman-Monteith equation, as described in FAO-56 (Allen et al. 1998; Kotsopoulos et al. 2003).

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:

$$ET_c = K_c \cdot ET_o \tag{2.1}$$

where ET_c is the daily evapotranspiration (mm/d), K_c the crop coefficient which is dependant on the crop development stage (Allen et al. 1998), and ET_o the evapotranspiration of the reference crop (mm/d).

Evaporation can be calculated in a similar way through the equation:

$$E = K_c \cdot ET_o \tag{2.2}$$

where E is the daily evaporation (mm/d) and K_c the surface coefficient, which, for shallow water surfaces takes the value of 1.05 (Allen et al. 1998).

The evapotranspiration of reference crop is determined through the modified Penman-Monteith method as described in FAO-56 (Allen et al. 1998; Kotsopoulos 2006) and is expressed through the equation:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma \cdot (1 + 0.34 \cdot u_2)} \tag{2.3}$$

where ET_o reference evapotranspiration (mm/d), R_n net radiation at the crop surface($MJm^{-2}d^{-1}$), 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_a actual vapour pressure (kPa), Δ slope of saturation vapour curve at temperature T (kPa $^oC^{-1}$) and γ psychrometric constant (kPa$^oC^{-1}$). For the evaluation of R_n, the estimation of extra terrestrial radiation (R_a) is essential along with the maximum sunshine duration (N) which can be realised through periodic functions (Kotsopoulos and Babajimopoulos 1997).

Through equations (2.1) and (2.3) 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 years is calculated. These results are presented in Figure 2 for the period 1990-94.

2.2 Calculation of water balance

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

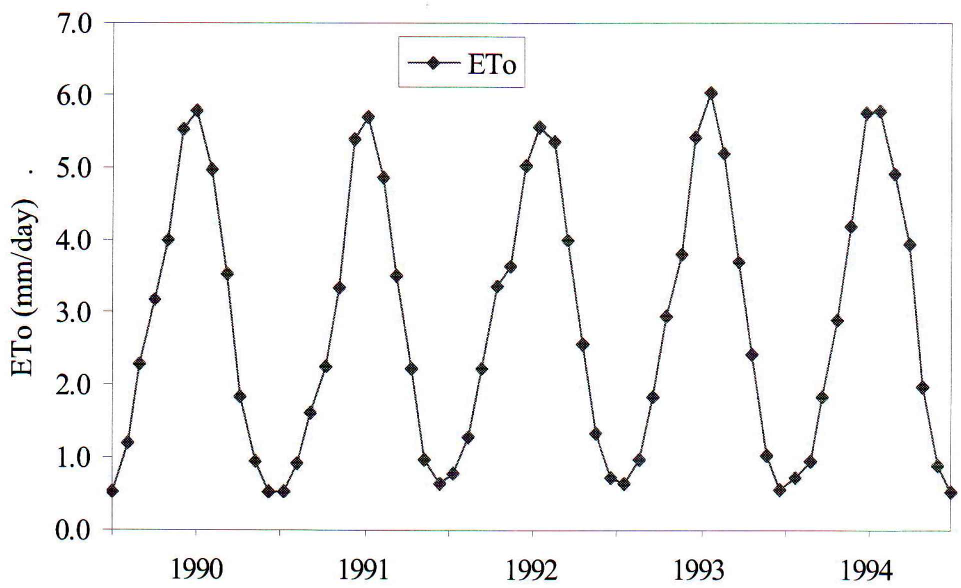

Figure 2: Calculated values of reference crop evapotranspiration (mm/d) at Larissa for the years 1990-94

The water balance is estimated per year and takes into account the technical characteristics of reservoirs (capacity, water surface) along with the evaporation rate (Kotsopoulos et al. 2006), the size of irrigation areas the cropping pattern 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 (Goumas 2006) along with the characteristics of their irrigated sub-areas (Kotsopoulos et al. 2007).

Table 1: Technical characteristics of reservoirs and their irrigated sub-areas

	Technical characteristics of reservoirs			Characteristics of the irrigated sub-areas				
	Reservoir	**Capacity $10^6 m^3$**	**Water surface $10^3 m^2$**	**Irrigated Area $10^3 m^2$**	**Cotton %**	**Maize %**	**Alfalfa %**	**Processed Tomato %**
1	Eleftherio I, II	1.70	600	4000	85		15	
2	Glafki	2.10	550	5415	85	10	5	
3	Kalamaki I, II	8.00	2750	20000	85		15	
4	Dimitra	1.00	400	2600	85		15	
5	Platikampos II	1.45	500	4560	85	10	5	
6	Platikampos I	0.50	250	1500	85	10	5	
7	Namata I, II	2.90	983	10000	80	10	5	5
8	Omorfochori	1.25	350	5000	80	20		
9	Kastri	1.10	350	4900	85		15	

3. Results and discussion

Results refer to the average reliability of reservoirs, R_m, its standard deviation, SD_R and the variation coefficient, CV_R. These values come from a simulation period of 43 years. As reliability of a reservoir is defined, the ratio of its capacity over the total crop water requirements of the sub-area it serves. The value 1.0 for reliability (maximum value) means that water requirements of all crops irrigated in a certain sub-area are completely satisfied. These results are shown in Table 2.

Table 2: Reliability parameters of reservoirs for the study area

	Reservoir	Average rate, R_m	Standard Deviation, SD_R	Variation Coefficient, CV_R, %
1	Eleftherio I, II	0.832	0.113	13.6
2	Glafki	0.816	0.115	14.1
3	Kalamaki I, II	0.800	0.111	13.9
4	Dimitra	0.758	0.116	15.3
5	Platikampos II	0.667	0.105	15.8
6	Platikampos I	0.660	0.109	16.5
7	Namata I, II	0.610	0.099	16.3
8	Omorfochori	0.543	0.091	16.7
9	Kastri	0.483	0.082	17.0

For the cropping pattern assumed under the existing agricultural conditions (Table 2), the average reliability, R_m and its standard deviation, SD_R, vary significantly from area to area. Average reliability, R_m, maybe as low as ~48% (Kastri) while its maximum value slightly exceeds 83% (Eleftherio). On the contrary, the variation coefficients of reliability, CV_R, vary slightly from area to area and are in the range of 13.5-17.0%.

Taking into account the values of the above parameters and the assumptions of the Central Limit Theorem (Haan 1977; Kite 1985; Yevjevich 1982; Chatfield 1983), 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 various planning periods and risk levels. These reliability results are presented in Table 3.

Table 3: Estimated reliability of reservoirs for the study area

	Reservoir	Mean R_m for a period of 10 years and a 10% risk level	Mean R_m for a period of 10 years and a 5% risk level	Mean R_m for a period of 5 years and a 5% risk level
1	Eleftherio I, II	0.787	0.766	0.749
2	Glafki	0.769	0.749	0.732
3	Kalamaki I, II	0.755	0.735	0.718
4	Dimitra	0.711	0.690	0.673
5	Platikampos II	0.625	0.606	0.590
6	Platikampos I	0.616	0.597	0.580
7	Namata I, II	0.570	0.552	0.537
8	Omorfochori	0.506	0.490	0.476
9	Kastri	0.449	0.435	0.422

In general, the most reliable reservoirs are those of Eleftherio I & II followed by Glafki, Kalamaki I & II, Dimitra, Platikampos II, Platikampos I, Namata, Omorfochori and Kastri.

More specifically, for a planning period of 10 years and a 10% risk level, the reservoirs are classified according to their average reliability as follows: 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%), Omorfochori (50.6%) and Kastri (44.9%). These results are depicted in Figure 3.

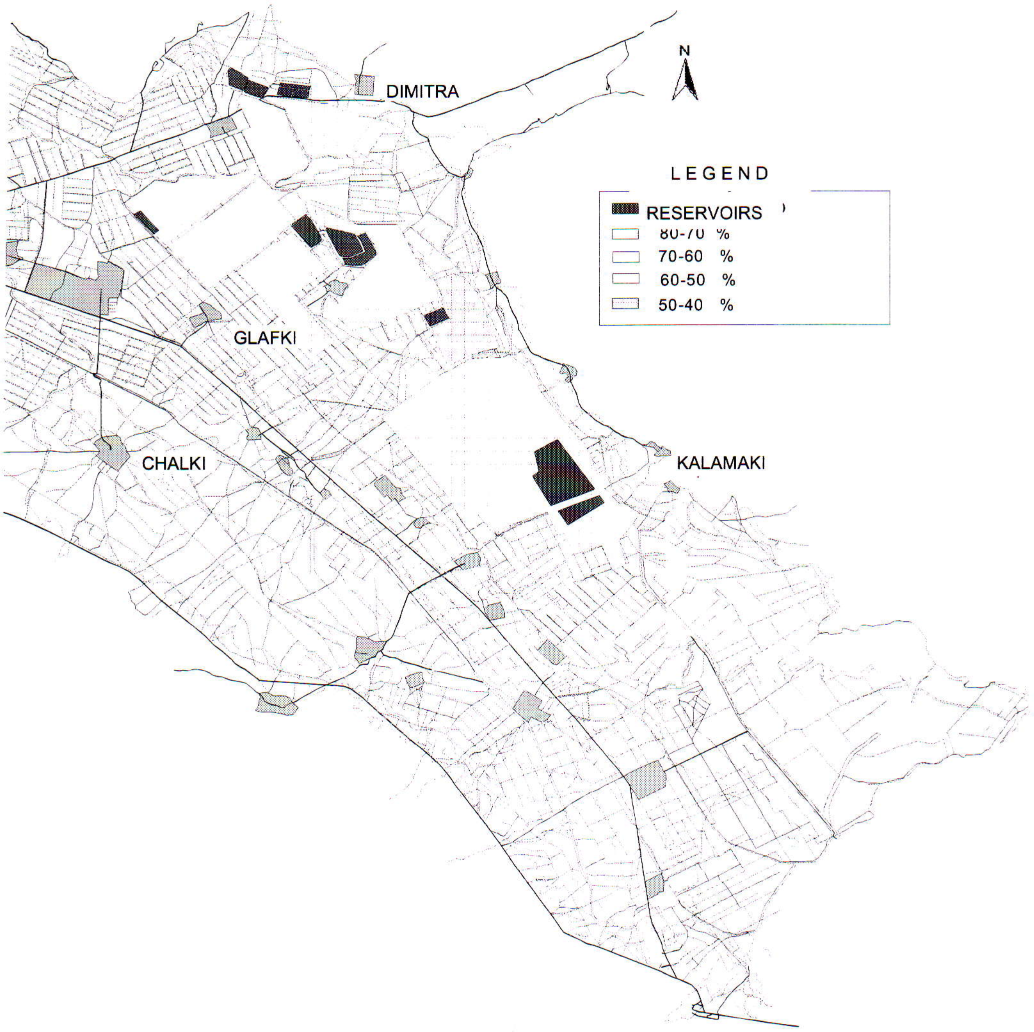

Figure 3: Average reliability of reservoirs in the region of Karla for a decade and a 10% risk level

4. Conclusions

From the calculated values of water shortage related to crop water requirements and the reservoir capacity for each part of the study area (broader area of the former lake Karla) that take into account the stochasticity of climatic conditions for a period of 43 years, the size of reservoirs along with the size of the irrigated areas and the current distribution of crop species, the following conclusions can be drawn:

a) The reliability of the reservoirs within the study area as it is related to irrigation water requirements vary significantly from place to place. Reservoirs usually do not cover the total crop water requirements of the areas they serve. On average, they cover only part of them (48 – 83%), depending on their characteristics and the cropping pattern of the sub-area they serve. The most reliable reservoirs, according to the characteristics presented above, are those of Eleftherio I & II, Glafki, and Kalamaki I & II while the least is the one of Kastri.

b) Reliability values for the cultivated areas served by the same reservoir vary from year to year, due to the discrepancies of the 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 evaluating the efficiency of the existing reservoirs and planning the construction of new ones, so that, they meet the local irrigation water requirements.

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