European Territorial Cooperation Programme
Greece - Italy
2007-2013
INVESTING IN OUR FUTURE
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Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

IRMA

Irrigation Systems Audits in Epirus and Western Greece

WP5, Action 5.2.

Deliverable 3

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IRMA info

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Introduction

General

Greece is a country in South-Eastern Europe, situated on the southern end of the Balkan Peninsula. The surface area of Greece is 130,100 km^2 of which 20% is distributed to its 3,000 islands, whereas, two thirds of the Greek territory is mountainous, making the country one of the most mountainous in Europe. The population reaches 11 million with a density of 84 inhabitants km^{-2} (one of the lowest densities in Europe). About one third of Greek population concentrates along the coastline (Lazarou, 2006).

Greece is dependent on groundwater resources for its water supply. The main aquifers are within carbonate rocks (karstic aquifers) and coarse grained Neogene and Quaternary deposits (porous aquifers). The use of groundwater resources has become particularly intensive in coastal areas during the last decades with the intense urbanization, touristic development and irrigated land expansion. Sources of groundwater pollution are:

- the seawater intrusion due to overexploitation of coastal aquifers
- the fertilizers from agricultural activities and
- the disposal of wastewater.

Greece is characterized by long coastline that favours hydraulic communication between coastal aquifers and seawater, also a non-homogeneous distribution of rainfalls and water resources. Water resources are characterized by high water requirements for agricultural activities and tourism during the dry period (April-late October) when water availability is low. Greece is 31st in top 50 countries with severe water stress. The major water user is agriculture which absorbs 86% of the total consumption. The irrigated land increased greatly in last decades, as indicated by the number of boreholes.

Water needs are mainly covered by groundwater abstracted from the aquifers via numerous wells and boreholes (approximately 300,000 for the whole of Greece). As a result, a negative water balance is established in the coastal aquifer systems triggering sea water intrusion which has negative consequences in the socioeconomic development of these areas. Many aquifer systems are reported to be affected by quality deterioration (salinisation and nitrate pollution) due to irrational management (Daskalaki et al., 2006).

In Greece, the mean annual surface run-off of mainland rivers is 35 billion m^3. More than 80% of the surface flows originates in eight major river basins: the Acheloos (Central Greece), Axios, Strimonas and Aliakmonas (Macedonia), Evros and Nestos (Thrace) Arachtos and Kalamas (Epirus). Nine rivers flow over 100 kilometers within Greece. Four major rivers originate in neighboring countries: Evros (Turkey), Nestos and Strymonas (Bulgaria) and Axios (FYROM). Total inflow from upstream neighboring countries amounts to 12 billion cubic meters. Some 41 natural lakes (19 with an area over 5 km2) occupy more than 600,000 ha or 0.5% of the country's total area. The largest are lakes Trichonida, Volvi and Vegoritida. Lake Prespa is on the borders with Albania and FYROM. The number of Greek wetlands according to the inventory of Greek Biotope/Wetland Centre (or EKBY by its Greek initials), rises to about 400 with 10 of them designated as Ramsar wetlands of international importance. The 14 artificial lakes (ten with an area over 5 km^2) occupy 26, 000 ha. Some 80-85% of freshwater resources are in the form of surface water and the rest are groundwater. Per capita consumption of water is around 830 m^3 with peaks recorded during heat wave days and days of intensive snow fall.

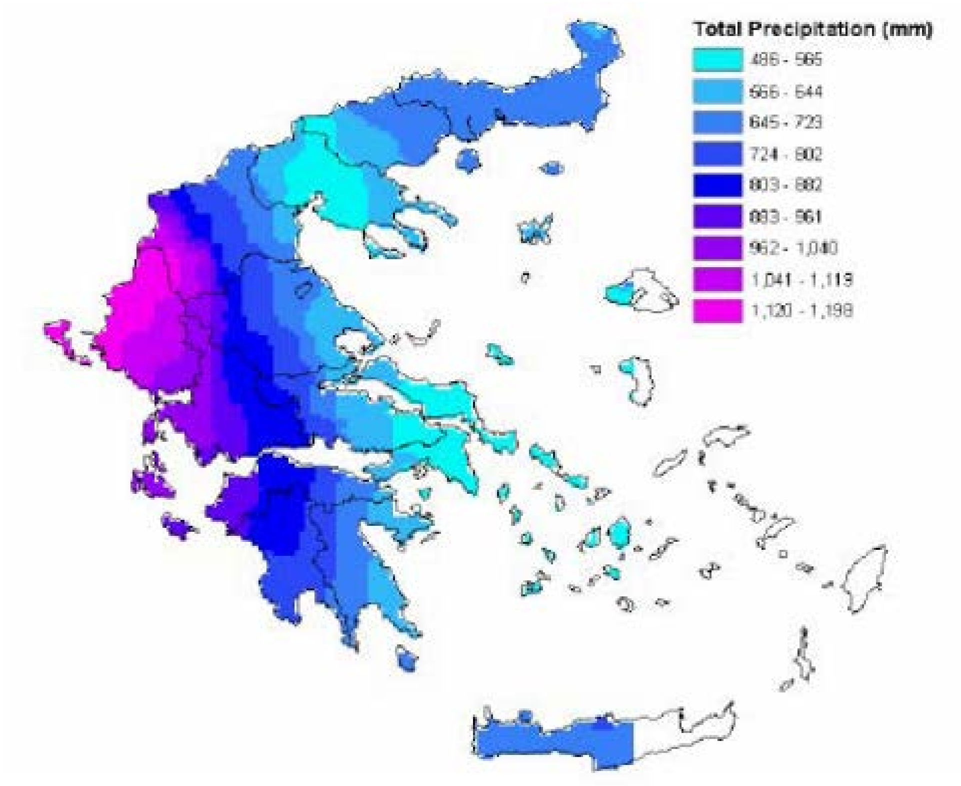


Fig. 1 Distribution of total precipitation in Greece (mm year^{-1})

The rainfall in Greece is variable in space, increasing from the south to the north (Fig. 1), due to the change of climatic conditions varying from dryer and warmer to humid and cooler conditions because of the increase in latitude, and also increasing from the east to west due to the separation of the country to two different climatic unities, brought by the Pindos range and its extension to Peloponnesus and Crete. Western Greece accepts the majority of rainfalls, more than 1500 mm year^{-1}, while Eastern Greece, along with the islands of Aegean and Crete, have considerably smaller rainfalls e.g. Attica's mean inter-annual precipitation is approximately 400 mm year^{-1}.

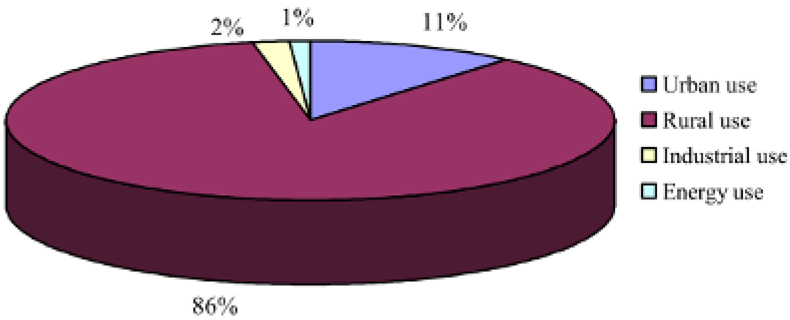


Fig. 2 Water use in Greece

The shortage of water (drought) in a region is not only related to the availability of the water resources, but also to the water utilization. Unfortunately, as previously mentioned, the major users of water in Greece are mainly located in the Eastern and Southern regions of the country, which is rather disadvantageous as compared to the natural enrichment. As it results from Fig. 2, Greece does not present a balanced scheme of water uses, as the rural usage takes the lion's share of 86% (Lazarou, 2006).

Water regions of Greece

According to water resources legislation (1739/87 for the management of water resources), Greece has been divided in 14 water regions as follows: West Peloponnese, North Peloponnese, East Peloponnese, West Central Greece, Epirus, Attiki, Central Greece and Evia, Thessaly, West Macedonia, Central Macedonia, East Macedonia, Thrace, Crete and Aegean Islands (Ministry of Development, 1987). The fourteen water regions of Greece are illustrated geographically in Fig. 3.

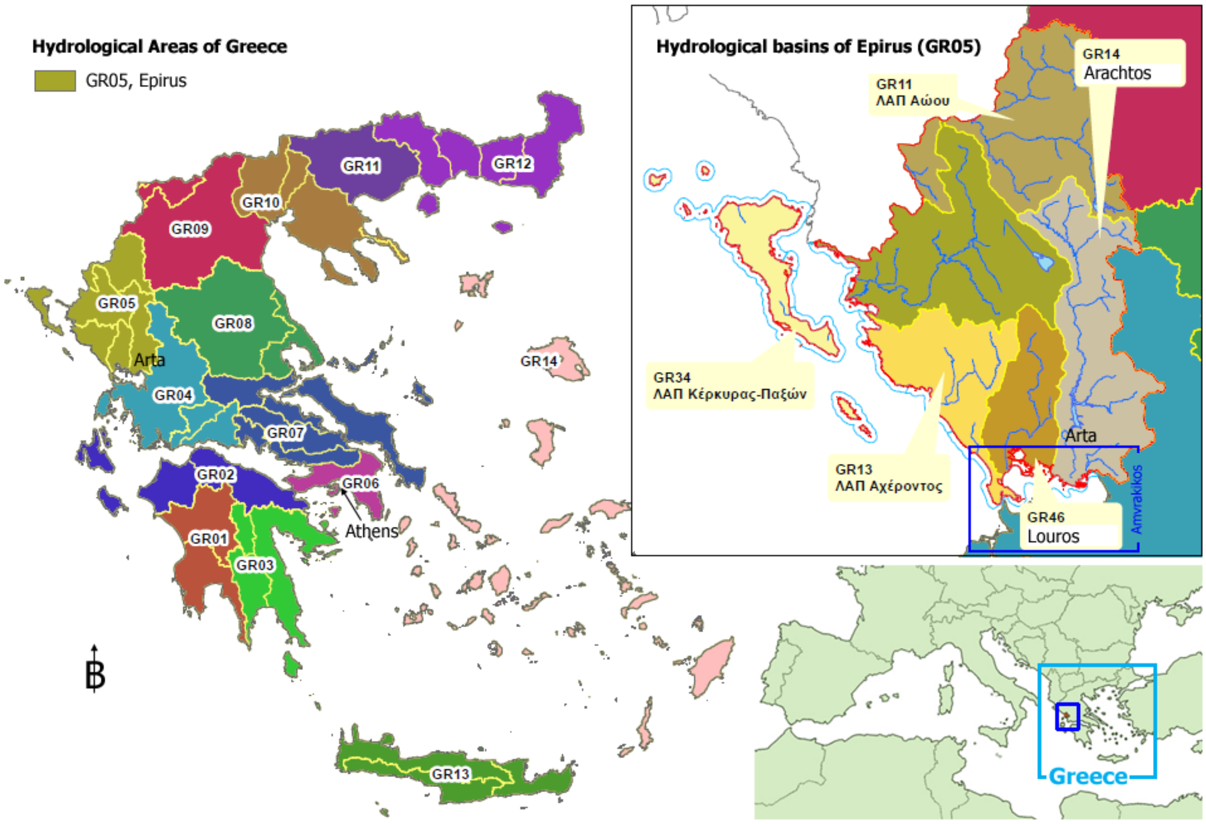


Fig. 3 The 14 hydrological districts of Greece

According to recent studies and the "National Programme for the Development and Protection of Water Resources" that was prepared in 2007, by the Technical. University of Athens for the Central Water Agency (http://www.itia.ntua.gr/g/docinfo/782/) the following results are derived:

- Precipitation: 116,330 hm^3 $year^{-1}$
- Evapotranspiration: 59,236 hm^3 $year^{-1}$
- Total renewable water resources: 57,100 hm^3 $year^{-1}$ (including the water resources originated from neighboring countries: 12,953 hm^3 $year^{-1}$)
- Total water withdrawal: 8.243 hm^3 $year^{-1}$
- Water withdrawal for irrigation: 6,859.5 hm^3 $year^{-1}$ (as percentage of total renewable water resources: 84%)
- Water withdrawal for stock farming: 106.8 hm^3 $year^{-1}$ (as percentage of total renewable water resources: 1%)
- Water withdrawal for households: 956.6 hm^3 $year^{-1}$ (as percentage of total renewable water resources: 12%)

- Water withdrawal for industry and energy: 161.4 hm^3 $year^{-1}$ (as percentage of total renewable water resources: 3%)

Irrigation Systems Performance in Greece

In Greece the main user/consumer of water is agriculture. For irrigation purposes 80-85% of the total water consumption is used. The cultivated land covers 3,470,000 ha from which 1,430,000 ha are irrigated (Fig. 4). The participatory irrigation projects cover approximately 40% of the irrigated land and the private projects 60% respectively. A significant variety of irrigation systems exist with characteristic advantages for certain soil/climatic conditions as well as for crop requirements (EASAC, 2007).

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).

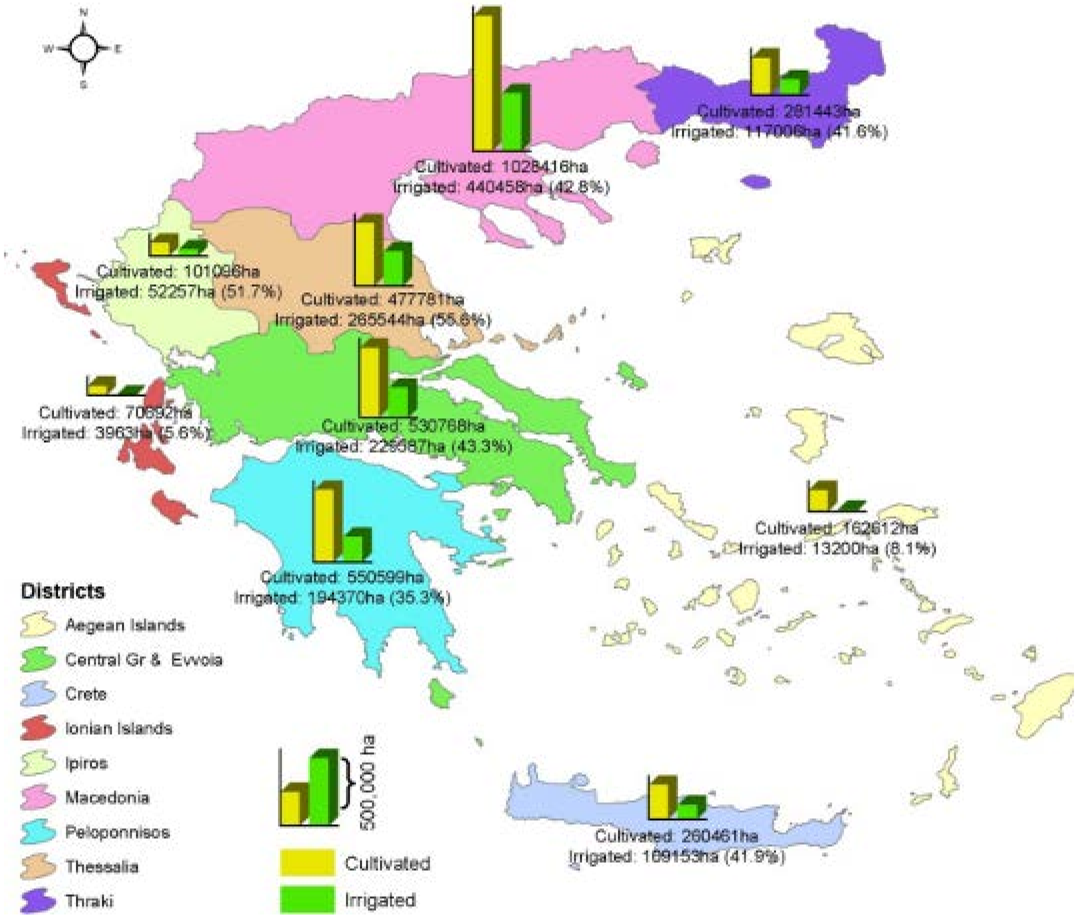


Fig. 4 Cultivated and irrigated land in Greece

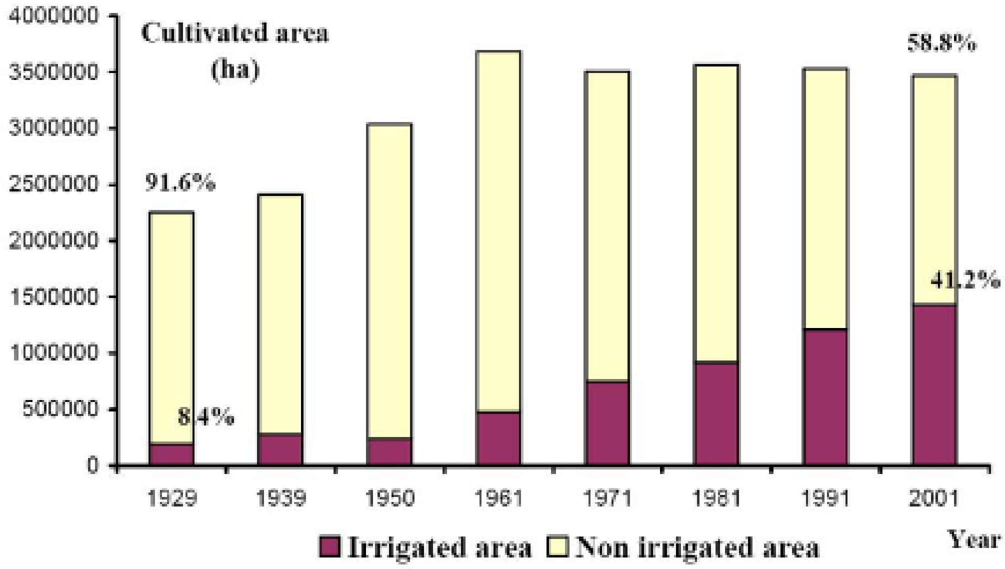


Fig. 5 Total cultivated area (irrigated and non-irrigated) in Greece from 1929 to 2001.

As a result, both cultivated and irrigated lands were impressively increased from the beginning of 20th century (Fig. 5). 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. 6). 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. 7 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).

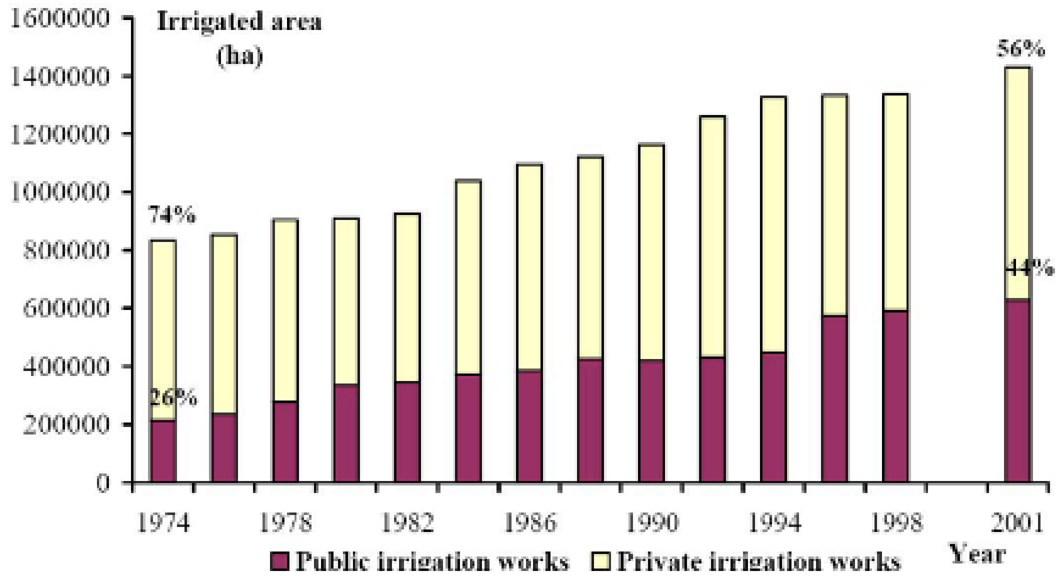


Fig. 6 Total irrigated area in Greece from 1974 to 2001

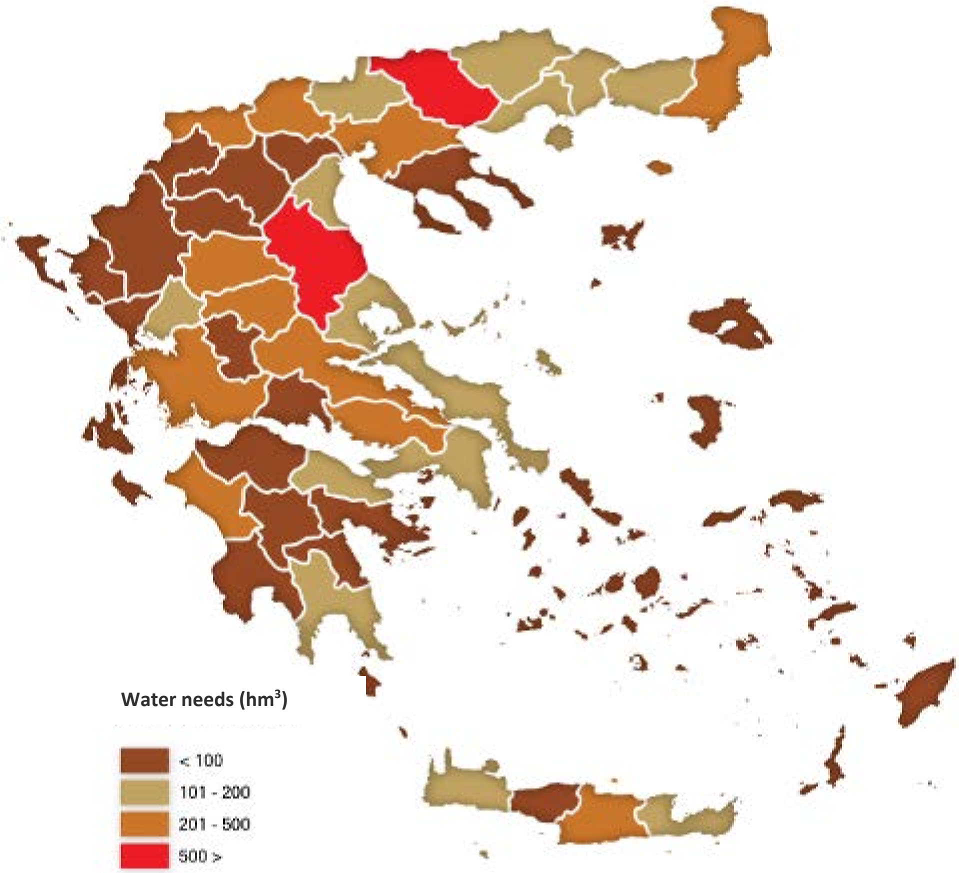


Fig. 7 Water needs for each prefecture in Greece (Migkiros, 2012)

In Fig. 8, a simplified map of the irrigation methods in crops for the region of Epirus, Greece, is presented (I.GM.E., 2000). The main methods that are used are surface irrigation with canals and irrigation with sprinklers.

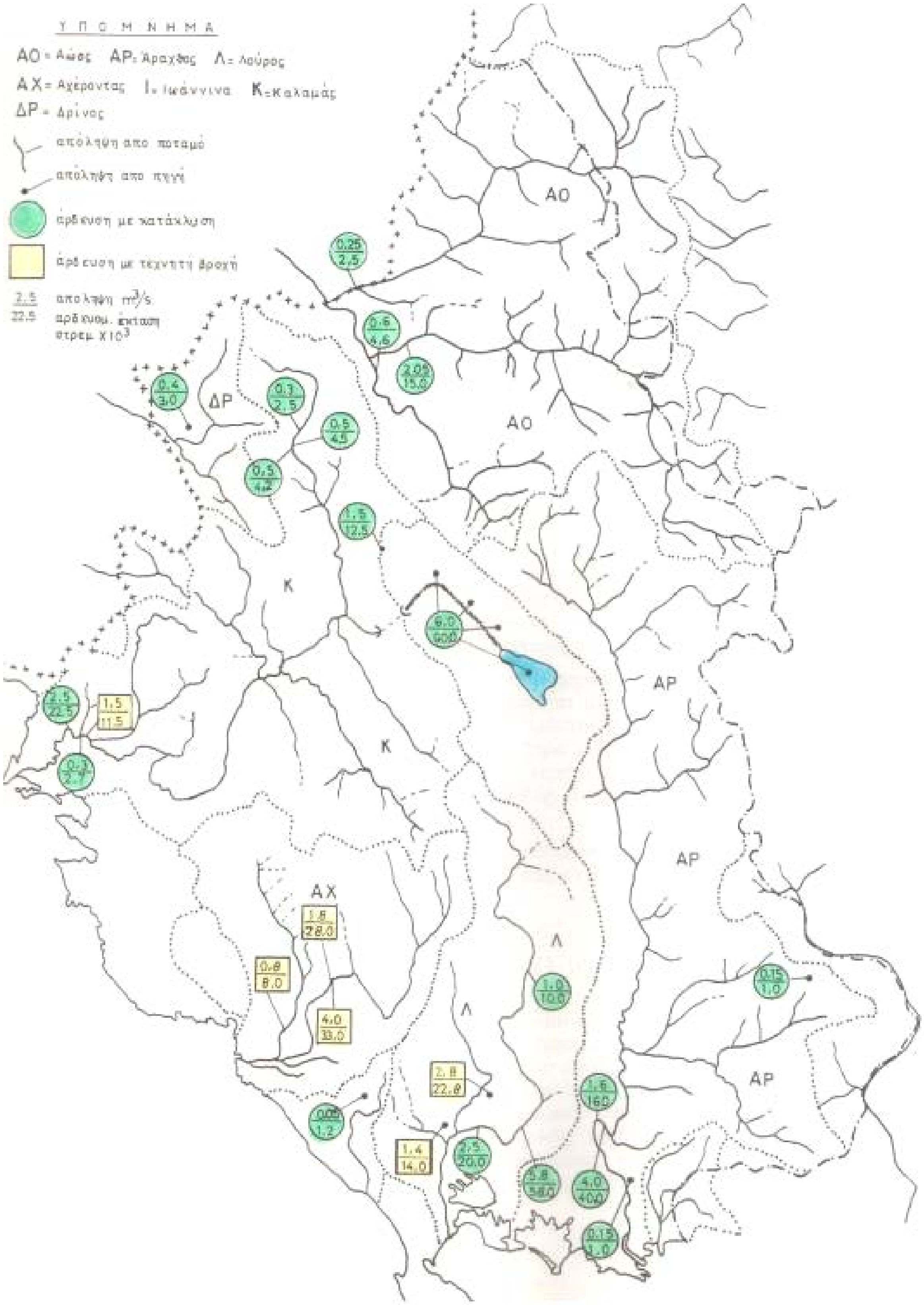


Fig. 8 Irrigation methods for the region of Epirus, Greece (I.G.M.E., 2000)

Irrigation water needs theory

In order to evaluate the irrigation needs of a landscape or a farm field the reference and crop evapotranspiration (Fig. 9) are calculated using several methodologies. Allen et al. (1998) published a manual for computing irrigation needs on crops. FAO states that Penman-Monteith methodology for the evaluation of evapotranspiration is the most efficient methodology and it should be used in all cases. Also, for the evaluation of water needs in landscapes the WUCOLS methodology, as it is proposed by the California Department of Water Resources (Costello et al., 2000), can be used. In the next chapters the above methodologies are presented.

Irrigation needs in crops

This section presents an updated procedure for calculating reference and crop evapotranspiration from meteorological data and crop coefficients. The procedure, first presented in the FAO Irrigation and Drainage Paper No. 24 'Crop Water Requirements', and it in FAO Irrigation and Drainage Paper No. 56 'Crop Evapotranspiration, guidelines for computing crop water requirements' is termed the 'Kc ETo' approach, where the effect of the climate on crop water requirements is given by the reference evapotranspiration ETo and the effect of the crop by the crop coefficient Kc.

The FAO Penman-Monteith method uses standard climatic data that can be easily measured or derived from commonly measured data. All calculation procedures have been standardized according to the available weather data and the time scale of computation. The calculation methods, as well as the procedures for estimating missing climatic data, are presented in this publication.

The term evapotranspiration (ET) is commonly used to describe two processes of water loss from land surface to atmosphere, evaporation and transpiration. Evaporation is the process where liquid water is converted to water vapor (vaporization) and removed from sources such as the soil surface, wet vegetation, pavement, water bodies, etc. Transpiration consists of the vaporization of liquid water within a plant and subsequent loss of water as vapor through leaf stomata.

Evaporation and transpiration (Fig. 9) occur simultaneously and both processes depend on solar radiation, air temperature, relative humidity (i.e., vapor pressure deficit) and wind speed. Transpiration rate is also influenced by crop characteristics, environmental aspects and cultivation practices. Different kinds of plants may have different transpiration rates. Not only the type of crop, but also the crop development, environment and management should be considered when assessing transpiration. For example, when the crop is small, water is predominately lost by soil evaporation because little of the soil surface is covered by the plant, but once the crop is well developed and completely covers the soil, transpiration becomes the main process (Allen et al., 1998).

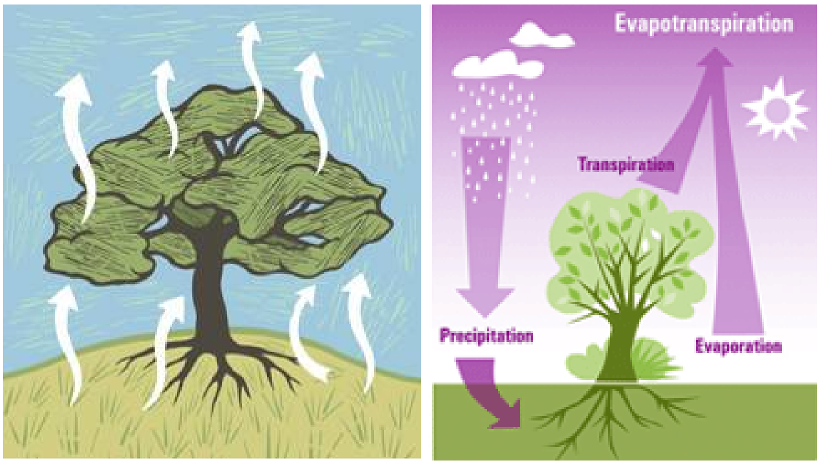


Fig. 9 Evaporation and transpiration procedures

Reference evapotranspiration (ETo) is defined as the rate at which readily available soil water is vaporized from specified vegetated surfaces (Jensen et al., 1990). Then reference evapotranspiration is defined as the ET rate from a uniform surface of dense, actively growing vegetation having specified height and surface resistance, not short of soil water, and representing an expanse of at least 100 m of the same or similar vegetation (Allen et al., 2005). The concept of the ETo was introduced to study the evaporative demand of the atmosphere independent of crop type, crop development and management practices. If water is abundantly available at the reference surface, soil factors do not affect; however, ET may decrease overtime as soil water content decreases. Relating ET to a specific surface provides a reference to which ET from other surfaces can be related. It obviates the need to define a separate ET level for each crop and stage of growth and is referred to as crop ET (ETc). ETo values measured or calculated at different locations or in different seasons are comparable as they refer to the ET from the same reference surface. The only factors affecting ETo are climatic parameters and ETc can be determined from ETo using a crop specific coefficient (Kc).

Globally, irrigation is the main user of fresh water, and with the growing scarcity of this essential natural resource, it is becoming increasingly important to maximize efficiency of water usage. This implies proper management of irrigation and control of application depths in order to apply water effectively according to crop needs. Daily calculation of the Reference Potential Evapotranspiration (ETo) is an important tool in determining the water needs of different crops. The United Nations Food and Agriculture Organization (FAO) has adopted the Penman-Monteith method as a global standard for estimating ETo from four meteorological data (temperature, wind speed, radiation and relative humidity), with details presented in the Irrigation and Drainage Paper no. 56 (Allen et al., 1998), referred to hereafter as PM:

Eq. 1 Penman-Monteith ETo model

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

where

Rn – net radiation at crop surface [MJ m^{-2} day^{-1}]

G – soil heat flux density [MJ $m^{-2}day^{-1}$]

T – air temperature at 2 m height [^{o}C]

u2 – wind speed at 2 m height [m s^{-1}]

es – saturation vapor pressure [kPa]

ea – actual vapor pressure [kPa]

es -ea – saturation vapor pressure deficit [kPa]

Δ – slope vapor pressure curve [kPa $^{o}C^{-}1$]

γ – psychrometric constant [kPa $^{o}C^{-1}$]

The PM model uses a hypothetical green grass reference surface that is actively growing and is adequately watered with an assumed height of 0.12 m, with a surface resistance of 70s m^{-1} and an albedo of 0.23 (Allen et al., 1998) which closely resemble evapotranspiration from an extensive surface of green grass cover of uniform height, completely shading the ground and with no water shortage. This methodology is generally considered as the most reliable, in a wide range of climates and locations, because it is based on physical principles and considers the main climatic factors, which affect evapotranspiration.

Hargreaves, using grass evapotranspiration data from a precision lysimeter and weather data from Davis, California, over a period of eight years, observed, through regressions, that for five-day time steps, 94% of the variance in measured ET can be explained through average temperature and global solar radiation, Rs. As a result, in 1975, he published an equation for predicting ETo based only on these two parameters:

Eq. 2 Hargreaves initial Eto model

$$ET_o = 0.0135\ R_s (T + 17.8)$$

where: Rs is in units of water evaporation, in mm day^{-1}, and T in ^oC.

Irrigation needs in landscapes

Turfgrasses and ornamental plants are considered an integral part of landscape ecological systems worldwide which provide esthetic value (Roberts et al., 1992). Turfgrass provides functional (i.e. soil erosion reduction, dust prevention, heat dissipation, wild habitat), recreational (i.e., low cost surfaces, physical and mental health) and aesthetic (i.e. beauty, quality of life, increased property values) benefits to society and the environment (Fender, 2006; King and Balogh, 2006). However, critics of grass maintain it not only wastes time, money and resources, but even worse, that efforts to grow grass results in an excessive use of water and pesticides, resulting in an environmental pollution. Although this could sound drastic for turfgrasses, its water requirements have been established by scientific study, which means that any application of water in amounts exceeding turf requirements can be attributed to human factors, not plant needs (Beard and Green, 1994). Turfgrasses have been utilized by humans to enhance their environment for more than ten centuries and, for those individuals or group that debate the relative merits of any single landscape material, the complexity and comprehensiveness of these environmental benefits that improve our quality-of-life are just now being quantitatively documented through research (Beard and Green, 1994).

Reliable research-based data on landscape plants water requirements is very limited, with few sources of information offering quantitative estimates (Pittenger and Shaw, 2005), including the widely-referenced publication, Water Use Classification of Landscape Plants –WUCOLS- (Costello and Jones, 1999) which is not based on scientific field research. One of the main reasons why there is little availability of scientific information is the large number of plant species, and the substantial resources needed to identify the water requirements of an individual species. WUCOLS is a list intended as a guide to help landscape professional identify irrigation water needs of landscape species or for selecting species and to assist in developing irrigation schedules for existing landscapes.

The Landscape Coefficient Method (LCM) describes a method of estimating irrigation needs of landscape plantings in California on a monthly basis. It is intended as a guide for landscape professionals (Romero and, Dukes, 2009). The assignment of species coefficients was done by asking members of a committee to place the species under different water use categories and no actual field measurements support the values given in the study (Garcia-Navarro et al., 2004). Readers are advised that LCM calculations give estimates of water needs, not exact values, and adjustments to irrigation amounts may be needed in the field (Costello et al., 2000). Water needs of landscape plantings can be estimated using the landscape evapotranspiration formula:

Eq. 3 The Landscape coefficient ET model

$ET_L = K_L \times ETo$

where: ET_L: Landscape evapotranspiration (mm d^{-1}), K_L: Landscape coefficient and ETo: Reference evapotranspiration

The ETL formula differs from the ETc formula since the crop coefficient (Kc) has been substituted for the landscape coefficient (KL). This change is necessary because of important differences which exist between crop or turfgrass systems and landscape plantings.

Costello et al. (2000) pointed out the reasons why there must be a landscape coefficient: 1) because landscape plantings are typically composed of more than one species, 2) because vegetation density varies in landscapes and 3) because many landscapes include a range of microclimates. These factors make landscape plantings quite different from agricultural crops and turfgrasses and they need to be taken into account when making water loss estimates for landscapes. The landscape coefficient estimates water loss from landscape plantings and functions as the crop coefficient but not determined in the same way. Species, density and microclimate factors are used to calculate KL.

Eq. 4 Landscape coefficient's parameters

$$KL = ks \cdot kd \cdot kmc$$

By assigning numeric values to each factor, a value of KL can be determined. The selection of each numeric value will depend on the knowledge and gained experience of the landscape professional, which make the method largely subjective.

The species coefficient (ks) factor ranges from 0.1 to 0.9 and are divided into 4 categories, very low, low, moderate and high (Table 1). These species factor ranges apply regardless of vegetation type (tree, shrub, herbaceous) and are based on water use studies, and from agricultural crops. Relative water need requirements for plants have been completed for over 1800 species (WUCOLS III- list).

Table 1 Species factor (Ks) for various plants

VEGETATION	HIGH	MEDIUM	LOW
Trees	0.90	0.50	0.20
Shrubs	0.70	0.50	0.20
Ground cover	0.90	0.50	0.20
Mixed	0.90	0.50	0.20
Turfgrass	0.80	0.70	0.60

The density coefficient (kd) factor is used in the landscape coefficient formula to account for differences in vegetation density among landscape plantings (Table 2). This factor is separated into three categories: low (0.5–0.9), average (1.0) and high (1.1–1.3). Immature and sparsely planted landscapes, with less leaf area, are assigned a low category kd value. Planting with mixtures of trees, shrubs and groundcovers are assigned a density factor value in the high category. Plantings which are full but are predominantly of one vegetation type are assigned to the average category.

Table 2 Density factor (Kd) for different plants

VEGETATION	HIGH	MEDIUM	LOW
Trees	1.30	1.00	0.50
Shrubs	1.10	1.00	0-50

Ground cover	1.10	1.00	0.50
Mixed	1.30	1.10	0.60
Turfgrass	1.00	1.00	0.60

The microclimate coefficient (kmc) factor ranges from 0.5 to 1.4 and is divided into three categories: low (0.5–0.9), average (1.0) and high (1.1–1.4) (Table 3). An average microclimate condition is equivalent to reference ET conditions: open-field setting without extraordinary winds or heat inputs atypical for the location. In a high microclimate condition, site features increase evaporative conditions (e.g. planting near streets medians, parking lots). Low microclimate condition is common when plantings are shaded for a substantial part of the day or are protected from strong winds.

Table 3 Microclimate factor (Kmc) for various plants

VEGETATION	HIGH	MEDIUM	LOW
Trees	1.40	1.00	0.50
Shrubs	1.30	1.00	0.50
Ground cover	1.20	1.00	0.50
Mixed	1.40	1.00	0.50
Turfgrass	1.20	1.00	0.80

Irrigation efficiency – Uniformity

Irrigation efficiency is a critical measure of irrigation performance in terms of the water required to irrigate a field, farm, basin, irrigation district, or an entire watershed. The value of irrigation efficiency and its definition are important to the societal views of irrigated agriculture and its benefit in supplying the high quality, abundant food supply required to meet our growing world's population (Table 4 and Table 5).

Irrigation efficiency is a basic term used in irrigation science to characterize irrigation performance, evaluate irrigation water use, and to promote better or improved use of water resources, particularly those used in agriculture and turf/landscape management. Irrigation efficiency is defined in terms of:

- the irrigation system performance,
- the uniformity of the water application and
- the response of the crop to irrigation.

Each of these irrigation efficiency measures is interrelated and will vary with scale and time. The spatial scale can vary from a single irrigation application device (a siphon tube, a gated pipe gate, a sprinkler, a microirrigation emitter) to an irrigation set (basin plot, a furrow set, a single sprinkler lateral, or a microirrigation lateral) to broader land scales (field, farm, an irrigation canal lateral, a whole irrigation district, a basin or watershed, a river system, or an aquifer). The timescale can vary from a single application (or irrigation set), a part of the crop season (preplanting, emergence to bloom or pollination, or reproduction to maturity), the irrigation season, to a crop season, or a year, partial year (premonsoon season, summer, etc.), or a water year (typically from the beginning of spring snow melt through the end of irrigation diversion, or a rainy or monsoon season), or a period of years (a drought or a "wet" cycle).

Irrigation efficiency affects the economics of irrigation, the amount of water needed to irrigate a specific land area, the spatial uniformity of the crop and its yield, the amount of water that might percolate beneath the crop root zone, the amount of water that can return to surface sources for downstream uses or to groundwater aquifers that might supply other water uses, and the amount of water lost to unrecoverable sources (salt sink, saline aquifer, ocean, or unsaturated vadose zone). The volumes of the water for the various irrigation components are typically given in units of depth (volume per unit area) or simply the volume for the area being evaluated. Irrigation water application volume is difficult to measure, so it is usually computed as the product of water flow rate and time. This places emphasis on accurately measuring the flow rate. It remains difficult to accurately measure water percolation volumes groundwater flow volumes, and water uptake from shallow groundwater.

Table 4 Range of Application Efficiencies for various irrigation systems (Rogers et. al., 1997)

System Type	Application Efficiency Range* (%)		
Surface Irrigation			
Basin	60	-	95
Border	60	-	90
Furrow	50	-	90
Surge	60	-	90
Sprinkler Irrigation			
Handmove	65	-	80
Traveling Gun	60	-	70
Center Pivot & Linear	70	-	95
Solid Set	70	-	85
Microirrigation			
Point source emitters	75	-	95
Line source emitter	70	-	95

**Efficiencies can be much lower due to poor design or management. These values are intended for general system type comparisons and should not be used for specific systems*

Table 5 Example of farm and field irrigation application efficiency and attainable efficiencies

	Field efficiency (%)			Farm efficiency (%)		
Irrigation method	**Attainable**	**Pange**	**Average**	**Attainable**	**Pange**	**Average**
Surface						
Graded furrow	75	20-80	65	70	40-70	65
w/tailwater reuse	85	60-90	75	85	-	-
Level furrow	85	65-95	80	85	-	-
Graded border	80	50-80	65	75	-	-
Level basins	90	80-95	85	80	-	-
Sprinkler						
Periodic move	80	60-85	75	80	60-90	80
Side roll	80	60-85	75	80	60-85	80
Moving big gun	75	55-75	65	80	60-80	70
Center pivot						
Impact heads w/end gun	85	75-90	80	85	75-90	80
Spray heads wo/end gun	95	75-95	90	85	75-95	90
LEPA wo/end gun	98	80-98	95	95	80-98	92
Lateral move						
Spray heads wo/hose feed	95	75-95	85	85	80-98	90
Spray heads wo/canal feed	90	70-95	90	90	75-95	85
Microirrigation						
Trickle	95	70-95	95	95	75-95	85
Subsurface drip	95	75-95	95	95	75-95	90
Microspray	95	70-95	95	95	70-95	85

Water table control						
Surface ditch	80	50-80	80	80	50-80	60
Subsurface drain lines	85	60-80	85	85	65-85	70

Application Efficiency relates to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field. It might be defined for individual irrigation or parts of irrigations (irrigation sets). Application efficiency includes any application losses to evaporation or seepage from surface water channels or furrows, any leaks from sprinkler or drip pipelines, percolation beneath the root zone, drift from sprinklers, evaporation of droplets in the air, or runoff from the field (Fig. 10).

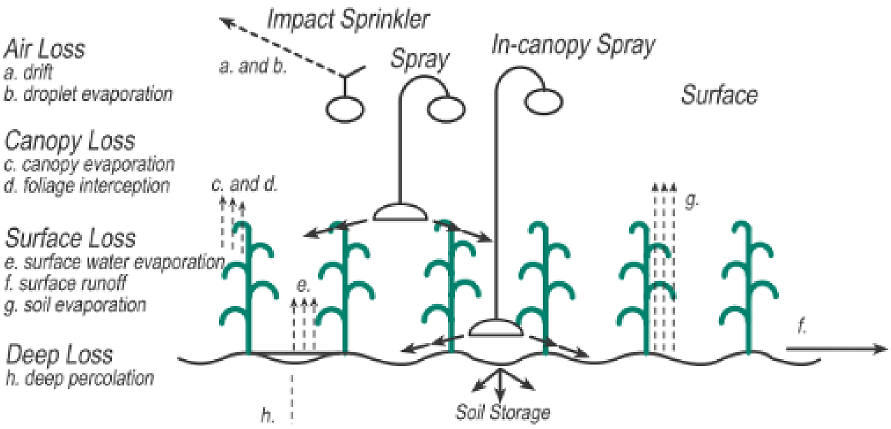


Fig. 10 Irrigation water loss and storage locations (Rogers et. al., 1997)

The fraction of water used efficiently and beneficially is important for improved irrigation practice called Irrigation Uniformity. The uniformity of the applied water significantly affects irrigation efficiency. The uniformity is a statistical property of the applied water's distribution. This distribution depends on many factors that are related to the method of irrigation, soil topography, soil hydraulic or infiltration characteristics, and hydraulic characteristics (pressure, flow rate, etc.) of the irrigation system. Irrigation application distributions are usually based on depths of water (volume per unit area); however, for microirrigation systems they are usually based on emitter flow volumes because the entire land area is not typically wetted.

Christiansen's Uniformity Coefficient (Christiansen, 1942) proposed a coefficient intended mainly for sprinkler system based on the catch volumes given as

Eq. 5 Christiansen's Uniformity Coefficient

$$C_U = 100\left[\frac{1-(\sum|X-\bar{x}|)}{\sum X}\right]$$

where C_U is the Christiansen's uniformity coefficient in percent, X is the depth (or volume) of water in each of the equally spaced catch containers in mm or ml, and $\bar{x}$ is the mean depth (volume) of the catch (mm or ml).

The Low-Quarter Distribution Uniformity factor represents the spatial evenness of the applied water across a field or a farm as well as within a field or farm. The general form of the distribution uniformity can be given as:

Eq. 6 Low-Quarter Distribution Uniformity factor

$$D_{U_p} = 100\left(\frac{\bar{V}_p}{\bar{V}_f}\right)$$

where DUp is the distribution uniformity (%) for the lowest p fraction of the field or farm (lowest one-half p ¼ 1=2; lowest one-quarter p ¼ 1=4), $\bar{V}_p$ is the mean application volume (m3), and $\bar{V}$ is the mean application volume (m3) for the whole field or farm. When p ¼ 1=2 and CU > 70%; then the DU and CU are essentially equal (Warrick, 1993). The Soil Conservation Service has widely used DUlq for surface irrigation to access the uniformity applied to a field, i.e., by the irrigation volume (amount) received by the lowest one-quarter of the field from applications for the whole field.

Typically, DUp is based on the post-irrigation measurement of water volume that infiltrates the soil because it can more easily be measured and better represents the water available to the crop. However, the post-irrigation infiltrated water ignores any water intercepted by the crop and evaporated and any soil water evaporation that occurs before the measurement. Any water that percolates beneath the root zone or the sampling depth will also be ignored.

The scheduling coefficient is another measure of uniformity. It is the ratio between the average precipitation rate (application rate) and the lowest precipitation rate in the sprinkler layout (Solomon, 1988).

Eq. 7 Scheduling coefficient

$$SC\% = \frac{\text{PRavg}}{\min \text{PR}}$$

Catchment data from can tests are used to calculate this value. The scheduling coefficient has a value equal to or greater than 1.0 and can be thought of as a multiplier to determine sprinkler system timing. For example, if the average application rate for a system was 12 $mmhr^{-1}$ and the driest area had an application rate of 7 $mmhr^{-1}$, the scheduling coefficient would equal 12/7 = 1.7. This means that if a group of plants required 9 mm of water per day, this irrigation system would have to be operated for 1.3 hours per day (1 hr/12 mm × 9 $mmday^{-1}$ × 1.7) to insure that all plants received an adequate supply of water. This illustrates the point that a scheduling coefficient closer to 1.0 is desirable indicating a more uniform irrigation system.

Irrigation scheduling

Proper irrigation scheduling is the application of water to crops and landscapes only when needed and only in the amounts needed; that is, determining when to irrigate and how much water to apply. With proper irrigation scheduling, crop yields and landscapes will not be limited by water stress from droughts, and the waste of water and energy used in pumping will be minimized. Other benefits include reduced loss of nutrients from leaching as a result of excess water applications, and reduced pollution of groundwater or surface waters from the leaching of nutrients.

Crop water requirements

Water is used in a cropped or landscape field in several ways: 1) assimilation into the plant and plant fruit, 2) direct evaporation from the soil or other surfaces, 3) transpiration, which is the loss of water vapor from plant leaves, and 4) other beneficial uses such as leaching of salts, crop cooling, and freeze protection. Usually less than 1% of the water used in crop production is assimilated into the plants. Other beneficial uses (category 4, above) may be significant, but they depend on factors other than maintaining adequate soil water content, and they will not be considered in this publication.

Most of the water applied to meet the water requirements of a crop is used in evaporation and transpiration. Evaporation and transpiration are important for cooling a crop in order to maintain temperatures in the range that permits photosynthetic activity and crop growth to occur. Transpiration also helps transport nutrients into and through plants. The combination of evaporation and transpiration is called evapotranspiration (ET). Because the amount of water assimilated by a plant is very small as compared to ET, ET is often considered to be the crop water requirement - the amount of water required by a growing crop to avoid water stress.

Delivering water to a crop in the field results in losses which increase the amount of water that must be pumped to supply the crop water requirement. Losses may occur because of inefficiencies in the conveyance system, evaporation and wind drift (especially if water is sprayed through the air), surface runoff, or percolation below the root zone. These losses can be minimized through good management practices, but they are impossible to completely eliminate. They must be considered when determining the total (or gross) irrigation water requirement.

Estimating Evapotranspiration

Because climatic conditions largely determine ET, various methods based on meteorological factors have been developed to estimate ET rates. The ET estimation equations which can be applied on a daily basis for irrigation scheduling require inputs of measured or estimated solar radiation. The Penman equation, which is believed to be the most accurate, is also mathematically complex and difficult to use manually. Crop ET is estimated by multiplying potential ET by water use coefficients (Kc) for specific crops, growth stages, and management factors. Kc values for many crops have been published by Doorenbos and Pruitt (1977), Papazafiriou, (1999).

Soil-water Storage

During irrigation, water infiltrates (penetrates) the soil surface. It is then distributed in the soil by gravity and soil capillary forces (attraction of water molecules to soil particles). As the soil (Fig. 11) becomes wetter, gravitational forces dominate and water drains downward through the soil. Drainage is rapid at first, but after one to two or three days (depending on soil type, layering, etc.) it decreases to a very small rate so that, for practical purposes, it may be neglected. At this time, soil moisture in the root zone may be considered to be in storage; it can be depleted primarily by plant transpiration or evaporation from the soil surface.

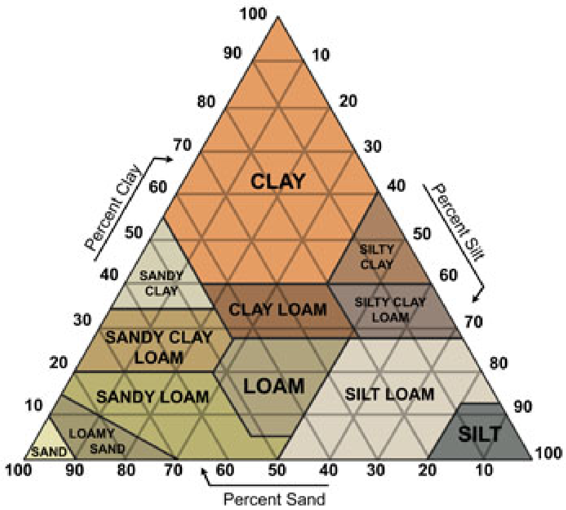


Fig. 11 Soil textural classes based on the percentage of sand, silt, and clay

This upper limit of water storage (Fig. 12) in the soil is called "field capacity" (FC). A practical lower limit of soil water may be defined as the soil-water content below which severe crop water stress and permanent wilting occurs. This lower limit has been defined as the permanent wilting point (PWP). While plants may remove some water below this level, such extraction has little or no significance in irrigated agriculture, although it may be crucial for plant survival. In fact, yield reduction typically occurs long before PWP is reached. The difference between FC and PWP is called the available water capacity (AWC).

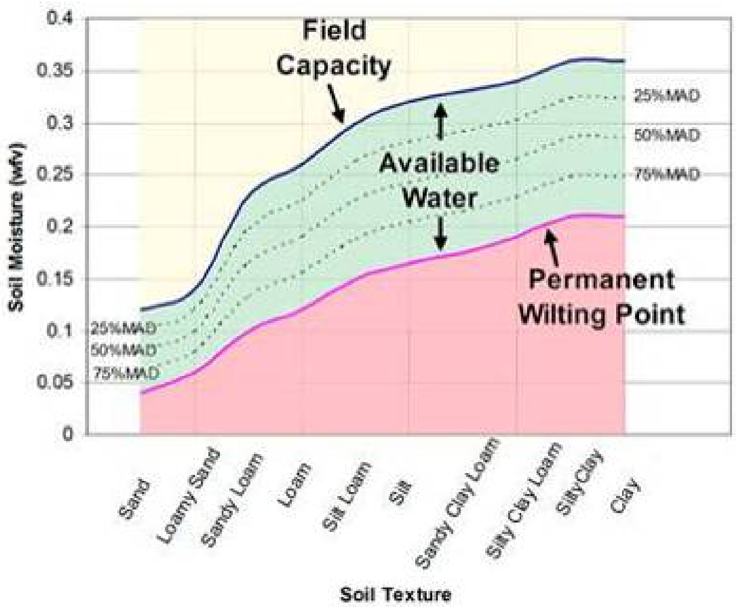


Fig. 12 The relationship between soil textural classes and the FC, AW, PWP

Table 6 and Table 7 present typical values of Saturation, FC, PWP and AWC for various soil types. Available water capacity may also be estimated in the field by applying a known amount of water to the soil when the profile water content is near PWP, observing the volume of soil wetted, and calculating the volume of water stored per unit volume of soil. Once AWC is known, the total depth of water available (AW), and thus the capacity of the soil-water reservoir, can be obtained by multiplying AWC by the crop effective root zone depth. For layered soils, AW is calculated by adding the multiples of AWC and depths of all soil layers contained in the crop root zone.

Table 6 Ranges considered for the soil water content at saturation, field capacity and permanent wilting point for the 4 soil classes Soil water content (vol %)

Soil class	Saturation	Field Capacity	Permanent Wilting Point
I. Sandy soils	32 – 51	9 – 28	4 – 15
II. Loamy soils	42 – 55	23 – 42	6 – 20
III. Sandy clayey soils	40 – 53	25 – 45	16 – 34
IV. Silty clayey soils	49 – 58	40 – 58	20 - 42

Table 7 Typical AWC for various soil types (http://websoilsurvey.nrcs.usda.gov/app/)

Soil Texture	Available water capacity		
	Low	High	Average
	- inch of water / inch of soil -		
Coarse sands	0.05	0.07	0.06
Fine sands	0.07	0.08	0.08
Loamy sands	0.07	0.10	0.08
Sandy loams	0.10	0.13	0.12
Fine sandy loams	0.13	0.17	0.15
Sandy clay loams	0.13	0.18	0.16
Loams	0.18	0.21	0.20
Silt loams	0.17	0.21	0.19
Silty clay loams	0.13	0.17	0.15
Clay loams	0.13	0.17	0.15
Silty clay	0.13	0.14	0.13
Clay	0.11	0.13	0.12

Allowable Soil Water Depletion

The allowable soil water depletion is the fraction of the available soil water that will be used to meet ET demands. As ET occurs, the soil water reservoir begins to be depleted. As the soil dries, the remaining water is held more tightly by capillary forces in the soil, making it more difficult for the plant to extract it. For this reason ET will start to decrease long before the PWP is reached. Since the lower ET will generally reduce yields, growers should irrigate before the root zone water content reaches a level that restricts ET. The critical soil water depletion level depends on several factors: crop factors (rooting density and developmental stage), soil factors (AWC and effective root depth), and atmospheric factors (current ET rate).

The water budget procedure

The water-budget procedure is also called a water balance or bookkeeping procedure. If the balance on a starting date and the dates and amounts of deposits and withdrawals are known, the balance can be calculated at any time. Most importantly, the time when all funds (or water) would be withdrawn can be determined so that a deposit can be made to avoid an overdraft (or an irrigation can be scheduled to avoid water stress).

As the crop grows and extracts water from the soil to satisfy its ETc requirement, the stored soil water is gradually depleted. In general, the net irrigation requirement is the amount of water required to refill the root zone soil water content back up to field capacity. This amount, which is the difference between field capacity and current soil water level, corresponds to the soil water deficit (D). The irrigation manager can keep track of D, which gives the net amount of irrigation water to apply. On a daily basis, Dc can be estimated using the following accounting equation for the soil root zone:

Eq. 8 DC soil water deficit

$$Dc=Dp+ETc-P-Irr-U+SRO+DP$$

where Dc is the soil water deficit (net irrigation requirement) in the root zone on the current day, Dp is the soil water deficit on the previous day, ETc is the crop evapotranspiration rate for the current day, P is the gross precipitation for the current day, Irr is the net irrigation amount infiltrated into the soil for the current day, U is upflux of shallow ground water into the root zone, SRO is surface runoff, and DP is deep percolation or drainage.

The last three variables in Eq. 8 (U, SRO, DP) are difficult to estimate in the field. In many situations, the water table is significantly deeper than the root zone and U is zero. Also, SRO and DP can be accounted for in a simple way by setting Dc to zero whenever water additions (P and Irr) to the root zone are greater than Dp + ETc. Using these assumptions, equation 1 can be simplified to:

Eq. 9 DC simplified, soil water deficit

$$Dc= Dp+ETc-P-Irr$$ (if Dc is negative, then set it to 0.0)

It has to be noted that Dc is set equal to zero if its value becomes negative. This will occur if precipitation and/or irrigation exceed (Dp +ETc) and means that water added to the root zone already exceeds field capacity within the plant root zone. Any excess water in the root zone is assumed to be lost through SRO or DP.

The amounts of water used in the equations are typically expressed in depths of water per unit area (e.g., inches of water per acre). Eq. 9 is a simplified version of the soil water balance with several underlying assumptions. First, any water additions (P or Irr) are assumed to readily infiltrate into the soil surface and the rates of P or Irr are assumed to be less than the long term steady state infiltration rate of the soil. Actually, some water is lost to surface runoff if precipitation or irrigation rates exceed the soil infiltration rate. Thus, Eq. 9 will under-estimate the soil water deficit or the net irrigation requirement if P or Irr rates are higher than the soil infiltration rate.

Knowledge of effective precipitation (P - SRO - DP), irrigation, and soil infiltration rates (e.g. inches per hour) are required to obtain more accurate estimates of Dc. Secondly, water added to the root zone from a shallow water table (U) is not considered. Groundwater contributions to soil water in the root zone must be subtracted from the right hand side of the equation in case of a shallow water table. Eq. 9 will over-estimate Dc if any actual soil water additions from groundwater are neglected.

It is a good practice to occasionally check (e.g., once a week) if Dc from equation 2 is the same as the actual deficit in the field (soil water content readings using soil moisture sensors). Remember that Dc is the difference between field capacity and current soil water content. Therefore, the actual deficit in the field can be determined by subtracting the current soil water content from the field capacity of the root zone. If Dc from Eq. 9 is very different from the observed deficit, then use the observed deficit as the Dc value for the next day. These corrections are necessary to compensate for uncertainties in the water balance variables. Field measurements of current soil water content can be performed using the gravimetric method (weighing of soil samples before and after drying) or using soil water sensors like gypsum blocks (resistance method).

In irrigation practice, only a percentage of AWC is allowed to be depleted because of AWC is allowed to be depleted because plants start to experience water stress even before soil water is depleted down to PWP. Therefore, a management allowed depletion (MAD, %) of the AWC must be specified. Ranges of rooting depth for selected crops are given in Table 7. The rooting depth and MAD for a crop will change with developmental stage.

The MAD can be expressed in terms of depth of water (dMAD; inches of water) using the following equation.

Eq. 10 dMAD

dMAD= (MAD / 100)*AWC*Drz

where MAD is management allowed depletion (%), AWC is available water capacity of the root zone (inch of water per inch of soil), and Drz is depth of root zone (see Table 8).

Table 8 Ranges of maximum effective rooting depth (Zr), and soil water depletion fraction for no stress (p), for selected crops (Allen et. al., 1988)

Crop		Maximum Root Depth (m)
Tomato		0.7-1.5
Cucumber		
	- Fresh Market	0.7-1.2
	- Machine harvest	0.7-1.2
Turf grass		
	- cool season	0.5-1.0
	- warm season	0.5-1.0
Apples, Cherries, Pears		1.0-2.0
Apricots, Peaches, Stone Fruit		1.0-2.0
Citrus		
	- 70% canopy	1.2-1.5
	- 50% canopy	1.1-1.5
	- 20% canopy	0.8-1.1
Kiwi		0.7-1.3
Olives (40 to 60% ground coverage by canopy)		1.2-1.7

The value of dMAD can be used as a guide for deciding when to irrigate. Typically, irrigation water should be applied when the soil water deficit (Dc) approaches dMAD, or when Dc ≥ dMAD. To minimize water stress on the crop, Dc should be kept less than dMAD. If the irrigation system has enough capacity, then the irrigator can wait until D approaches dMAD before starting to irrigate. The net irrigation amount equal to Dc can be applied to bring the soil water deficit to zero. Otherwise, if the irrigation system has limited capacity (maximum irrigation amount is less than dMAD), then the irrigator should not wait for Dc to approach dMAD, but should irrigate more frequently to ensure that D does not exceed dMAD.

Generally the basic steps for water budget irrigation scheduling are:

1. Determine the depth of the effective root zone.
2. Determine the starting point for soil moisture in the effective root zone. This may be the soil moisture calculated at the end of the previous day. Or, it may be the reading from a neutron probe or some other volumetric measurement.
3. Determine the different amounts of water going into and out of the effective root zone. That is, calculate crop water use for that day, estimate rainfall that infiltrates (if it rains that day), estimate infiltrated irrigation water (if there was an irrigation that day), etc. etc.
4. Solve the water budget equation

Irrigation Auditing procedure

General

Farm and Landscape irrigation auditing is an effective tool for maximizing water use efficiency in urban landscapes such as home lawns, commercial properties, sports fields and cultivations such as kiwi trees, citrus trees and wine trees. An audit can be used to improve the efficiency of existing irrigation systems. Irrigation audits consist of three main activities: site inspection, performance testing, and irrigation scheduling (Tsiogiannis et. al., 2014). Each activity can result in significant water and cost savings. Together, these activities provide landscape and cultivation maintenance personnel with a customized irrigation program based on site specific conditions and irrigation system performance.

Site Inspection

Over time, even the most efficiently designed irrigation system will begin break down. In absence of a regular maintenance program, minor operation and performance problems can continue for months resulting in excessive water use and poor efficiency, which can reduce plant quality. Sunken sprinkler heads that do not “pop-up” properly, misaligned spray patterns that throw water onto streets, sidewalks or hardscapes, and broken or missing sprinkler heads resulting from vandalism or mower damage can result in significant water waste.

Performance problems are often inherent in an irrigation system. A sprinkler system where the heads are spaced too far apart will result in poor water distribution and/or dry or hot spots on the landscape. In order to compensate for this poor uniformity, the system is often set to operate longer, which in turn over-waters most of the landscape. Insufficient or excessive operating pressure will also lead to high water loss through wind drift or poor coverage. Low water pressure is generally caused by insufficient static pressure and/or high pressure losses through valves, meters, piping and other components of the irrigation system. Visual indications of low water pressure include large water droplets and short sprinkler throw. High water pressure, on the other hand, indicates an absence of proper pressure regulation devices. High pressure is generally characterized by excessive misting of water that is easily evaporated or carried by the wind.

Performance Testing

Sprinkler application devices, including pop-up spray heads, rotors, micro-sprays and bubblers are designed to operate within specific operating pressures and head spacing. Manufacturer’s specifications catalogs rate the performance, mainly flow rate (in gallons per minute) and precipitation rate (in inches per hour), based on these parameters. Commonly, the rated performance listed in the catalogs does not accurately represent actual performance.

For irrigation scheduling purposes, the most accurate determination of precipitation rate is achieved by conducting catch can tests (Fig. 13 and Fig. 14). Catch can tests measure the amount of water that actually hits the ground at various points within the landscape, and also serves to measure application uniformity. Since irrigation systems commonly use different types and brands of sprinklers, it is important to conduct catch can tests for each individual zone or “station” on an irrigation system.

Fig. 13 Catch can test on a landscape (Koboti Arta, Greece)

Fig. 14 Catch can test on a farm field

Following is the general approach to conducting catch can test both in a landscape and in a farm field:

1. Turn on the irrigation system, one zone at a time, to locate and mark sprinkler heads.
2. Starting with zone 1, layout catch devices only on the part of the landscape or the farm field covered by zone 1. Catch devices should be placed in a grid-like pattern throughout the zone

to achieve an accurate representation of sprinkler performance. Note: Try not to place catch devices too close to sprinkler heads to avoid altering spray patterns.

3. Turn on zone 1, allowing water to partially fill the catch devices. Keep track of the number of minutes that the zone is allowed to operate.
4. After a measurable amount of water has fallen, measure the depth of water (in inches) contained in each device using a ruler. (It is recommended that the ruler measure in "tenths" of inches). Record these values on a data sheet. Also record how long (in minutes) the zone was operated. If catch containers do not have „parallel sides", then water volume may need to be measure and then corrected for container opening area.

Repeat steps 1-4 above for each remaining zone on the system.

Irrigation scheduling

The answer to the question, "when do I irrigate and how long?" has been based on assumptions and generalizations in regards to sprinkler system performance and plant water requirements. Audits replace many of the assumptions we make in irrigation scheduling (Table 9). With irrigation auditing, we customize our irrigation schedules based upon on catch can results. Rather than using the longtime recommendation of "fifteen minutes, three times per week" (for landscapes), run times can be adjusted for individual zones based on measured precipitation rate.

Table 9 Modified Irrigation schedule from irrigation audits (RDNO-GVW)

Lawn		Rotors	Sprays	Low-Volume Sprays
April	Minutes / Week	73	22	79
	Water Budget	55%	60%	55%
May	Minutes / Week	92	27	108
	Water Budget	70%	75%	75%
June	Minutes / Week	119	36	130
	Water Budget	90%	100%	90%
July	Minutes / Week	132	36	144
	Water Budget	100%	100%	100%
August	Minutes / Week	112	27	122
	Water Budget	85%	75%	85%
September	Minutes / Week	73	22	79
	Water Budget	55%	60%	55%
Fall/Winter		OFF	OFF	OFF
	Assumed precipitation rate:	*0.47 in/hr	*1.75 in/hr	*0.43 in/hr

Shrubs		Dripline	Sprays	Low-Volume Sprays
April	Minutes / Week	35	18	74
	Water Budget	33%	50%	55%
May	Minutes / Week	63	27	96
	Water Budget	60%	75%	70%
June	Minutes / Week	98	32	122
	Water Budget	93%	90%	90%
July	Minutes / Week	105	36	135
	Water Budget	100%	100%	100%
August	Minutes / Week	91	32	122
	Water Budget	86%	90%	90%
September	Minutes / Week	35	18	74
	Water Budget	33%	50%	55%
Fall/Winter		OFF	OFF	OFF
	Assumed precipitation rate:	*0.58 in/hr, based on 0.9GPH, 18"x18" spacing	*1.75 in/hr	*0.43 in/hr

Determining when to irrigate should be based upon the depth of the plant's root zone and the type of soil therein. Together, root depth and soil type define the amount of water that is available for plant use. A six-inch clay soil, for example, will hold more water that will six inch of sand. Thus, the number of irrigations per week will be less in the clay, though the amount of water the plant needs will remain the same. Root depth also influences irrigation frequency. Shallow rooted turfgrass, for example, will require more frequent irrigations than will a turfgrass with a deeper root zone. A simplified method for soil classification in the field is presented in Fig. 15 Empirical method for soil classification (RDNO-GVW).

The first step in determining how long to irrigate is to first determine how much water that you should apply each irrigation event. Plant water requirements vary significantly in urban landscapes due to the variety of plant species, maintenance practices and microclimates. Water requirements also vary with climate trends and rainfall patterns. Turfgrass, which is generally assumed to be the highest water user, requires up to 1-inch per week during the summer with less in the spring and fall.

Fig. 15 Empirical method for soil classification (RDNO-GVW)

Once it is determined how much water is needed each irrigation, the conversion to zone run time is simple. The following equation is used to determine zone run times:

Eq. 11 Run time calculation

Run Time per Irrigation = (Targeted irrigation depth ÷ Zone precipitation rate) x 60

where: Run Time per Irrigation in minutes, Targeted irrigation depth in mm and Zone precipitation rate in mm per hour

Equipment for Irrigation Auditing

The equipment (Fig. 16) that is necessary and important for an irrigation audit generally consists by:

- Design tools (ruler etc.)
- Tablet with WiFi and GPS capabilities (applications/software: scan, stopwatch, unit converter calculator, word processor, spreadsheet and GIS)
- Pressure Gauge (with Pitot tube)
- Flow pressure meter (for pipe diameters up to 1''). Adaptor for 1'' pipes and spare sealing rubbers.
- Ultrasonic flow meter for larger diameter pipes
- Portable wind meter
- 40-80 pre-numbered Catch-cans (250 and 100ml, probability for wire or rope stands or hangs) Store cans according to numbering.

- 1-2 special rulers for measuring depth and volume at catch cans
- Vernier caliper to measure pipe diameters and other component's dimensions
- 1-2 Handheld soil moisture probes with reading device
- 1-2 paintbrushes to clean soil moisture sensors
- 1 EC/pH meter
- 1 pair of VHF
- 1-2 Tape measure (30 and 100m)
- 1 marked rope (150m)
- 4 Pressure gauges (0-15bar)
- 1 Soil auger
- 1 Photo camera (preferably waterproof)
- Survey equipment for checking height differences – slope (conventional optical levels)
- Other: Protection gloves, mattock, shovel, trowel, pruner, various tools, (screwdrivers, pruning scissors etc) and fittings for connecting measurement devices like pressure gauges to the irrigation system, containers for soil samplers, 2 volumetric cylinders, of 100-250 ml with reading per ml to measure volume, 2 funnels, rope, wire, pliers, clothe and clothes, mark tape (to mark catch can position in field, sticks (to mark soil moisture measurement points).

Fig. 16 Irrigation audit equipment (TEIEP)

Audit procedure

The first phase of a traditional irrigation audit starts with inspection of the site plans and system tune-up. The irrigation auditor has to obtain the necessary information. In this initial phase, the main components are (Tsirogiannis et. al., 2014):

Obtain any available site plans/maps of the irrigation system layout and location of specific components (Fig. 17, Fig. 18): heads, lines, valves, water lines, wiring, controllers, pumps, backflow prevention devices, water meters, water connections, shut off valves, drain valves, etc.). It is not unusual that plans may need to be updated and system features accurately located and mapped.

Inspect the system and the system operation. Water information at this stage may include: pressure tests, sources, and flow data. The auditor would also document the current programming schedule and main/satellite controller features or capabilities such as: number of programs, ability to repeat cycles, number of zones per controller, syringe cycle ability, interfacing with any sensors to affect scheduling, During inspection of the irrigation system components, The Irrigation Association (2003) recommend evaluating for:

- Valve performance
- Sprinklers that are tilted, sunken, broken, missing, clogged, misaligned, or with spray deflected by objects
- Rotation speed
- Plugged nozzles
- Drainage from low sprinkler locations
- Leaks detection and repair
- Areas with slow water drainage or ponding, dry areas, compaction/thatch/runoff

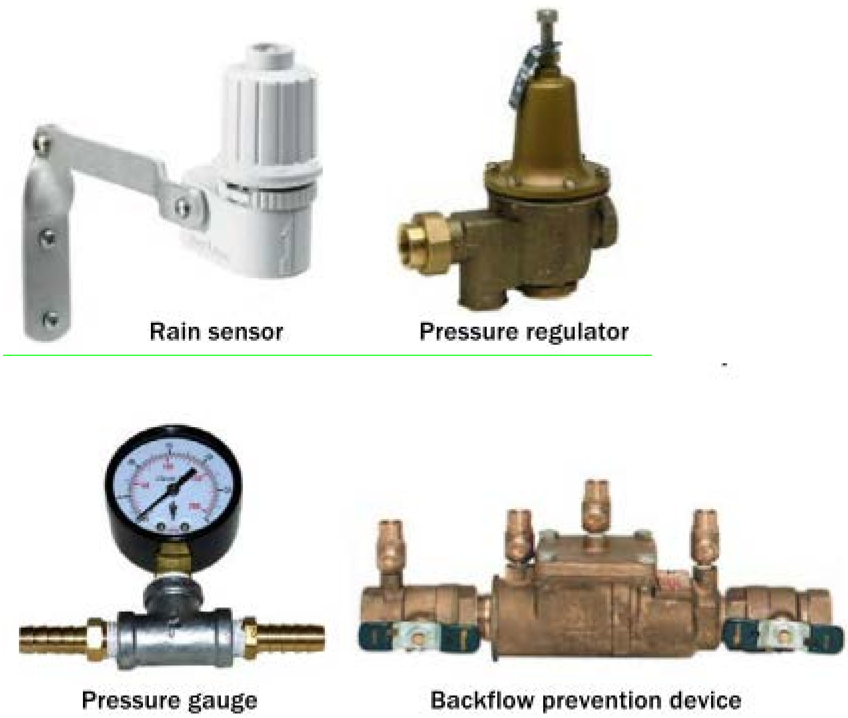


Fig. 17 Irrigation equipment on a landscape or a farm field

The second phase focuses on documenting system performance by the catch-can method. Initially, select appropriate zones that will be representative of the whole course. There may be a combination of zones selected that represent different soil/climatic site conditions; locations such as fairways, tees, greens, and roughs; problem sites where there is a history of irrigation problems related to system inadequacies; and zones that are considered the best on a course. If data from these selected zones demonstrate that water uniformity is acceptable or can be improved (new nozzles, head replacement, addition of some heads, etc.) using the existing system, then a full audit of all zones can be performed. This would be the most robust audit but does require considerable time and effort in contrast to selected, representative zones.

Fig. 18 Irrigation sprinklers, driplines, controllers

Sometimes the initial sites selected for catch-can evaluation as well as other information from the water audit reveals major problems with the irrigation system and may indicate investigation of major renovations or replacement. In this instance, there is no need to further assess current equipment performance, but to plan for a system with the performance needed to achieve the water conservation goals desired. Typical examples, of such major problems are:

- Improper design such as sprinkler spacing or zoning or scheduling capability
- Inadequate piping, pressure, or flow rate for system operation
- Outdated equipment or worn out equipment

During the test periods for the catch-can method, it is critical that system pressure and wind conditions be suitable and recorded. However, the test should also represent conditions similar to normal irrigation conditions. Typical information obtained from each test zone is:

- System pressure
- Wind speed and direction
- Sprinkler rotation speed
- Type of sprinklers and nozzles---are nozzles worn or not matched for precipitation rate
- Head spacing between heads and between rows of test areas must be determined in order to calculate precipitation rate of each zone; and to determine proper design

- Catch can data to determine water application rate and uniformity over the zone. If more than one zone covers a test area, then both zones must be operated. Note the location and spacing of the catch can grid.
- Controller information such as type, run time or multiple run times
- Determine additional site conditions such as: soil type, grass type, rooting depth, any microclimate influences

Analytical procedures in irrigation auditing

Hundreds of components make up a complete functioning irrigation system. The system will work well if it has been well designed, equipment carefully selected and it is competently installed, well maintained and well managed. Sounds simple! Unfortunately it only takes one component to fail or one part to not perform to specifications and the performance or effectiveness of the whole system is diminished. It is therefore important to regularly check the functioning and performance of all irrigation systems. The performance of the irrigation system can be assessed in terms of:

- Efficiency of water application to meet the needs of the plant
- Reliability of the system (breaks, failures, malfunctions etc.) and
- Quality of management of the system.

Therefore, what are the requirements of an effective and efficient irrigation system?

- Water applied at the correct precipitation rate without runoff or losses.
- Water applied uniformly.
- Correct depth / volume of water applied to meet site needs.
- Water applied at the right time (taking into account rainfall and climatic conditions).

General

The process of taking field measurements to evaluate the existing performance of an irrigation system is the basis of an audit. An integral part and outcome of the audit is the development of irrigation schedules (how much to apply, when to apply) that meet the needs of the site. The audit will also provide information on how to improve the performance of the system. An audit with follow up improvements to the system if required should benefit the irrigation manager both in the improved efficiency of water application and also in the management of the system. Poor irrigation systems not only result in a waste of water and nutrients, they are expensive in labor and time. In many cases an audit results in direct cost savings through reduced water consumption.

Conducting an Irrigation Audit

Base Audit Information

Conducting an audit of an irrigation system requires the establishment of an accurate record of the system, the site and the vegetation. The foundation to building a quality irrigation management program is a detailed plan, which not only includes records of locations of important features, but also reference to accurate details of equipment. The make, model and size of components (sprinklers, valves etc.) must be recorded.

Details of the water supply and control equipment are particularly important - pump or meter, controller, master valves, etc. It is also critical that details of control programs for each control station be noted so that recommendations can be made on the appropriate run times of the system as tested, to meet the needs of the vegetation (turf) at the particular site. For example, it may be recommended that the sprinkler be operated for 35 minutes to apply 8 mm. In addition to the system performance details the auditor would have taken into account, the root zone depth of the turf, soil type, water-holding properties of the soil and recommended depletion amount at each irrigation event.

Test Conditions

An audit should be carried out under conditions, which provide fair representation of the normal performance of the system. The climate conditions, in particular wind, should be within acceptable limits during the test. A maximum wind speed of 10 kph can be used as a guide.

The system pressure should be checked to see that the equipment to be tested is operating under design conditions. A pilot tube gauge (small diameter tube inserted into water stream) can be used to check nozzle pressures. When using this method it is important to note that the nozzle pressure will be higher than the inlet (base) pressure to the sprinkler head. Irrigation systems are most commonly designed on inlet pressure and so this difference needs to be taken into account when analysing a system.

Identifying Problems

The system should be operated prior to the actual audit to check the functioning of the various components. This stage of the audit process is sometimes referred to as the "walk through". Often, problems that directly affect the performance of the system will be observed. For example, a sprinkler head may be damaged or blocked. These problems should be fixed prior to the audit test. It does not make sense to evaluate the performance of an irrigation system that has readily fixable problems. This check procedure is included, as a first step. Some of the problems that might be identified during the walk through include:

- Malfunctioning valves
- Sunken sprinkler heads
- Incorrect or non-rotation of sprinkler heads
- Tilted heads
- Plugged nozzles
- Broken casings and missing parts
- Distorted spray distribution
- Incorrect nozzles installed
- Leaking pipes, valves, fittings, equipment, broken seals
- Incorrect operating pressure - high, low

Any problems observed should be identified according to position and controller station. This information should be recorded and noted on the plan as part of a maintenance record of the irrigation system. Not all problems can be fixed prior to the test. The audit may indicate system deficiencies (problems) such as incorrect sprinkler spacing or low operating pressures that may involve major works or design changes.

Audit Results

Key Performance Data

The two key performance readings that an audit will provide are the mean precipitation rate and the evenness or uniformity of the application. Both are essential information for the management of an irrigation system. It is the responsibility of the system designer to select a precipitation rate appropriate to the soil type and site. Outlet equipment (eg. sprinkler nozzle) should be selected so that the sprinklers or sprays will apply water to match the design rate. An audit test will tell you what is actually being achieved in the field. It provides a check for new systems and accurate information on the precipitation performance for existing systems.

The precipitation rate (rate of water falling on to the ground), expressed in millimeters (depth) per hour, is used in conjunction with the recommended irrigation depth, to determine the duration of irrigation. It is also used to ensure that the water is being applied at a rate that will not result in runoff and water loss from the area. All overhead sprinkler and spray irrigation systems apply water unevenly. Good design is about selecting equipment and operating conditions to achieve a high level of uniformity so that efficient irrigation can be achieved. Whilst there are several indexes used to measure uniformity, the recommended index coefficient for turf is the Distribution Uniformity (DU) coefficient. The audit test will provide a DU value for each area tested. Distribution Uniformity (DU) and the Scheduling Coefficient (SC).

The industry standard is that DU should not be less than 75% (Connellan, 2011). Low values indicate poor uniformity and a wide range in readings within the test area. If the DU value is significantly lower than 75%, for example 65%, then the system should be investigated to determine possible causes.

There are many reasons why the sprinklers may not be applying water evenly including low operating pressure, incorrect sprinkler spacing, incorrect nozzle size, damaged sprinkler head or excessive wind. Additional measurements taken during the test, such as pressure and flow rate, will often provide an indication of the possible cause.

In addition to providing a measure of non-uniformity, the value of DU can be used to provide a time adjustment factor, called the Scheduling Coefficient (SC), for the control program. In order to ensure that all parts of the irrigated area receive an adequate depth of water, it is recommended that the sprinkler run times are increased to allow for unevenness in the application. For example, the SC25% value corresponding to a DU of 75% is 1.33 (SC25% = 1/ 0.75). This SC25% value has been calculated using the same field as that used to calculate DU. There are other SC terms in use. It is important to clarify which SC term is being used in each situation.

Pressure Testing

An accurate pressure gauge is an extremely valuable tool for the evaluation and monitoring of irrigation systems. Pressure is the heart rate of the irrigation system. Part of the audit test will involve checking the actual sprinkler operating pressure and pressure variation throughout the system. Some of the key information that can be provided through pressure measurements include:

- Checking the sprinklers are operating at correct (optimum) pressure?
- What is the pressure variation along the lateral? Is it acceptable?
- What is the pressure variation between stations and sprinklers in different parts of the system?
- What is the amount of pressure loss due to friction in mainlines and submains?
- What is the pressure loss across valves and special fittings?

Pump Systems

Pump Performance

Many people consider pumping plants to be either working or not working with no middle ground in terms of performance. This is certainly not the case. Potentially, there is a huge range of flow, pressure and efficiency combinations. Pumps that have been operating for some time can change in performance due to wear, changes in control, changes in power output especially from diesel and petrol driven pump units and in the case of electric motors changes in the electrical supply voltage.

In many areas, particularly in urban localities, demand for electrical supply is increasing and maintaining high quality supply during the irrigation season is a problem.

There may also have been changes in the hydraulics of the irrigation system that may require adjustment to the pump configuration and operation. A common source of changed pump performance conditions is increased flow rate resulting from the installation of more sprinkler heads or the fitting of larger nozzles. These changes can reduce the efficiency of the pump or in some cases may justify a different pump. A thorough check of the pump on a regular basis is therefore strongly recommended.

Pump Testing

The measurement and interpretation of the performance of the pump requires considerable expertise and should be carried out by qualified personnel. Pump delivery flow rate and pressures provide the basis for analysing pump performance. Broadly, the testing should show if the required duty (the design flow rate and pressure) is being achieved and it will also indicate the efficiency of the pump. Irrigation pumps are selected to operate within specific efficiency ranges. Electric powered pumps can be directly checked for efficiency by measuring the electrical power being consumed (current and volts) and comparing this to the energy of the water (flow rate and pressure) being delivered by the pump.

The use of solid state speed control and data-logging facilities within the pump control module is now providing access to higher quality historical pump performance information. Stored data, on both electrical and hydraulic aspects, can be used by the pump specialist to develop the best advice for the pump and irrigation system.

Full details on the pump and its performance characteristics should be held by the irrigation manager as part of the irrigation system document record. A pump curve can be used to check the current performance of the pump and is likely to be required to make recommendations on improving pump performance and changing the irrigation system.

Factors for quantification of an efficient irrigation operation

After audit inspection is made, the results are used to calculate several factors important for efficient irrigation operation. These are (Irrigation Association, 2003):

- Distribution uniformity (DU) a measure of how uniformly water is applied over an area, where a DU of 100 is 100% uniformity. Normally, the DU is based on the average of all samples and the average of the lowest 25% of readings; and in this case would be termed DULQ. For example in gulf courses an irrigation system with DULQ > 80 is good. The DU can be used to determine irrigation water requirement for a zone, where irrigation water requirement = plant water requirement / DU.
- Run time modifier (RTM), which is used to adjust timing in an irrigation zone to allow adequate water over the whole site – i.e., not dry spots.
- Gross Precipitation Rate (PRgross) is based on flow from the sprinkler and sprinkler spacing to obtain an average sprinkler precipitation rate over the area in inches/hour. It does not take into account any water loss that occurs between the sprinkler nozzle and the turfgrass.
- Net Precipitation Rate (PRnet) is a measure of the amount of water that actually reaches the turfgrass at a particular location. This is determined from the catch can data.
- Scheduling Coefficient (SC) measures uniformity in an area by comparing the lowest precipitation rate in a defined area to average precipitation rate over the entire test area. The lowest precipitation rate may be based on the driest 1, 2, 5, or 10% of the defined area. The SC indicates the quantity of additional water that must be applied to adequately irrigate the driest area that was defined.

- Coefficient of Uniformity (CU) is another measure of irrigation uniformity based on comparing average catch can precipitation to the average deviation from the catchment's mean. While used in agriculture, it is less useful in turfgrass situations.
- When the irrigation water requirement is determined by using the DU, the run times in minutes for the controller can be used to establish an irrigation schedule.

A very important additional piece of information that can be generated from the irrigation audit data on a zone is a densogram that visually shows the wettest and driest areas within the area. This is very valuable for making corrective measures such as changing nozzles to obtain greater uniformity.

Study area

The irrigation audits were conducted in the regions of Epirus and Western Greece (Fig. 19), in Greece, during the period of May to October of the year 2014, for the purposes of IRMA project.

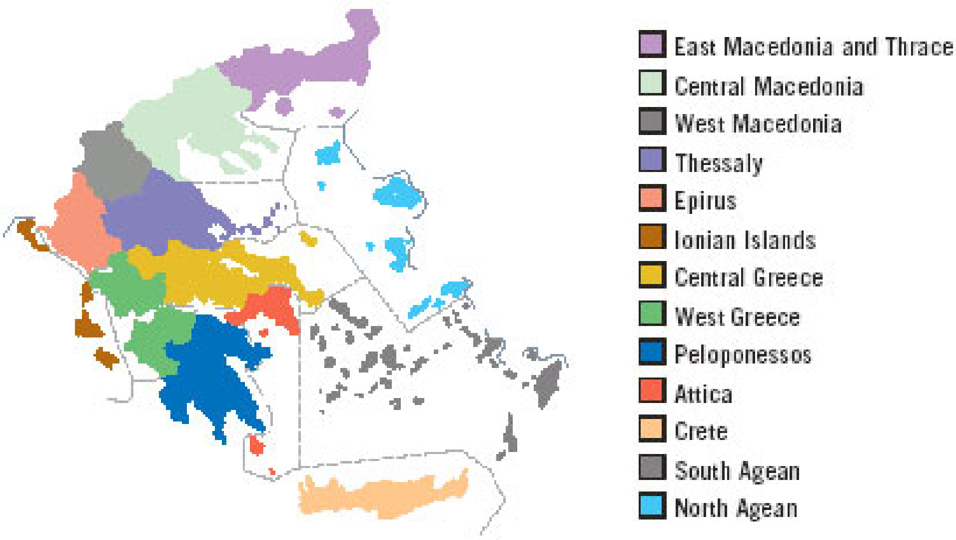


Fig. 19 Region of Epirus and Western Greece

The total number of the audits was 100 and is divided as follows (Fig. 20):

- 50 irrigation audits in farms
- 25 irrigation audits in private landscapes
- 15 irrigation audits in greenhouses
- 6 irrigation audits in public green spaces
- 4 irrigation audits football stadiums

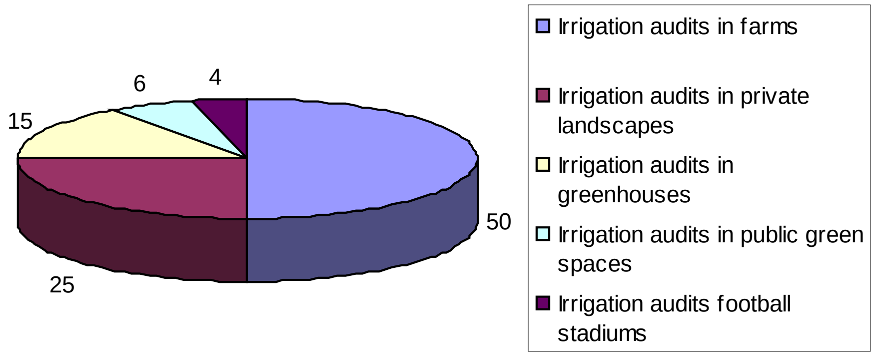


Fig. 20 Irrigation audits in study areas

The study was mainly focused in the regional entities of Arta, Ioannina, Preveza, Thesprotia and Patras (Fig. 20).

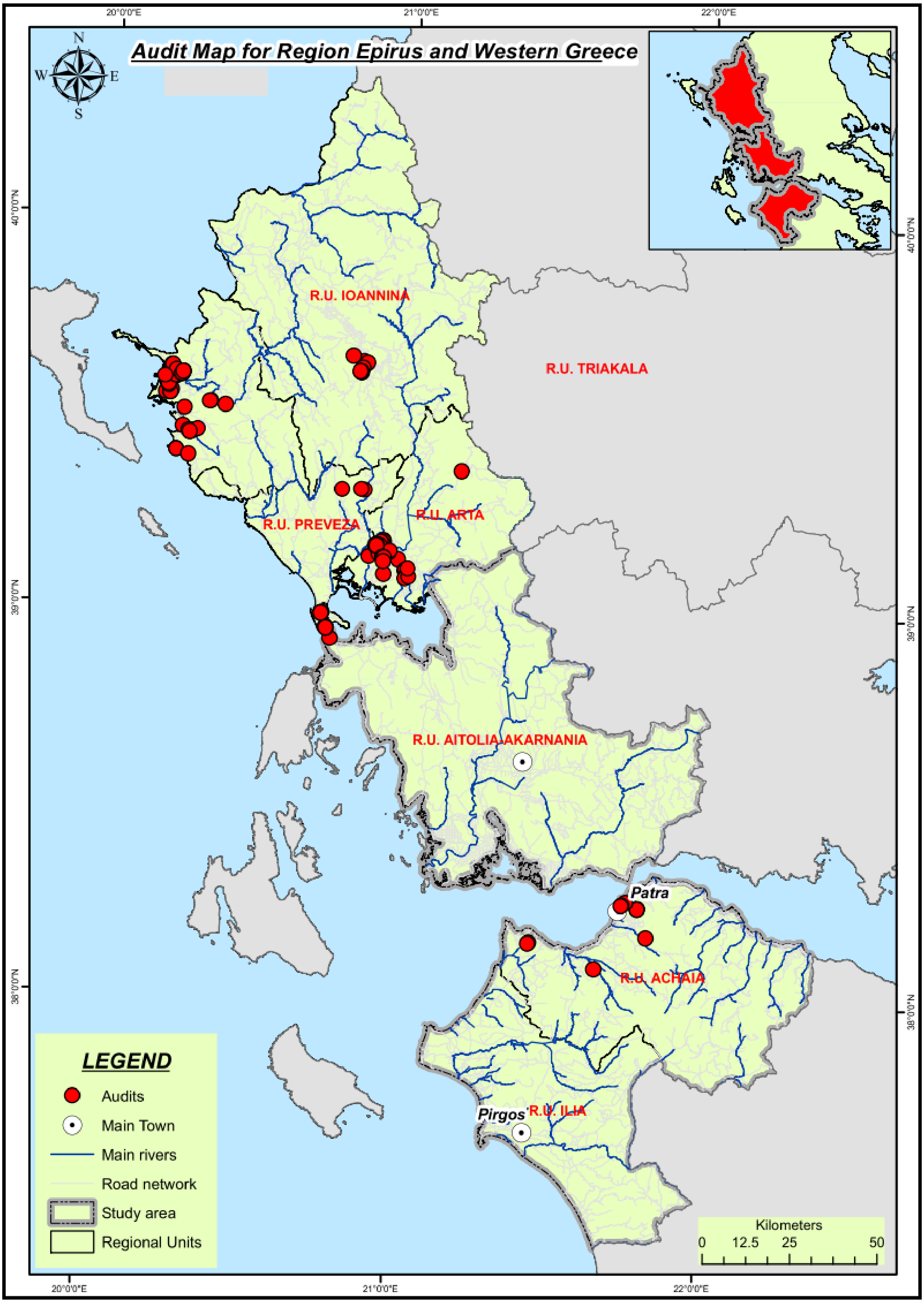


Fig. 21 Audits places in Region of Epirus and Western Greece

Region of Epirus

The region of Epirus is located in the northwest of Greece and is bordered by the Ionian Sea to the west, the Pindus mountain-range to the east and Albania to the north. It includes the prefectures of Ioannina, Thesprotia, Arta and Preveza. According to the 2011 census, the region has a population of 336,856 inhabitants which represents approximately 3.1% of the total population of Greece. It is one of the most sparsely populated regions of Greece with a population density of 36.8 inhabitants per square kilometer, compared to a national average of 77.7.

The geomorphology of Epirus is largely mountainous, with an abundance of surface waters (rivers, lakes and lagoons), extensive forests and unique flora and fauna. The total area of Epirus is 9,203 square kilometers of which 9.7% is flat land, 12.9% is semi-mountainous and the remainder is mountainous. Although figures vary according to the source used, approximately 15% of the land area is devoted to agricultural holdings, 55% is covered by grassland and used for mountain grazing, 26% is covered by forests and 2.5% is covered by surface waters. Urban and related activities account for the use of the remainder of the land. The region is dominated by the mountain-range of Pindus whose highest peak reaches approximately 2,600. Pindus, which enters Greece from Albania, constitutes a natural barrier to the east between Epirus and the rest of Greece and is the main reason for the region’s historic isolation. In general, the region has poor communication routes both internally and externally. On the west coast of the region, the port of Igoumenitsa lacks the necessary infrastructure to service large numbers of passengers and large volumes of freight merchandise and is not connected to the rest of Greece by adequate transportation networks.

The climate of Epirus is Mediterranean in the west and south, with hot summers and cold winters in central Epirus and cold in the mountainous regions, where both rainfall and snowfall are commonplace. The mountain-range of Pindus is covered by snow year-round.

The lowlands of Epirus are dominated by a shrub known as the ‘Mediterranean maquis’.

Region of Western Greece

The Region of Western Greece stretches from the northwest part of the Peloponnese to the western tip of the Greek mainland. It is one of the 13 Regions of Greece, is separated in 3 administrative districts, the Prefectures of Aitoloakarnania, Achaia, Elia and covers an area of 11,350 square kilometres (8.6% of the total area of Greece). For the most part the terrain is mountainous (45.3%) or hilly (25.6%), while only 29.1% consists of plains. All three prefectures have extensive coastal areas along the Ionian Sea and the Gulfs of Ambrakia, Patras and Corinth. According to the 2011 census, the population of the Region of Western Greece is 679,796. This makes it the fourth most populated Region of Greece, with 6.3% of the country’s total population. Today the Region of Western Greece is a modern communications and transport hub that connects Greece to the rest of Europe. The busy port of Patras is not only the Region’s capital but also the country’s main gateway to Western Europe.

Climatic conditions

Generally, the climate in the area is typical of the Mediterranean climate: mild and rainy winters, relatively warm and dry summers and, generally, extended periods of sunshine throughout most of the year. A great variety of climate subtypes, always within the Mediterranean climate frame, are encountered in several regions of Greece. This is due to the influence of topography (great mountain chains along the central part and other mountainous bodies) on the air masses coming from the moisture sources of the central Mediterranean Sea. In climatological terms, the year can be broadly subdivided into two main seasons: The cold and rainy period lasting from mid-October until the end of March, and the warm and dry season lasting from April until September.

During the first period the coldest months are January and February, with, a mean minimum temperature ranging, on average, between 5 -10 degrees Celsius near the coasts and 0 – 5 Celsius over the mainland, with lower values (generally below freezing) over the northern part of the country. Long stretches of consecutive rainy days are infrequent in the study areas, even during the winter.

The winter is milder in the Aegean and Ionian Islands compared to Northern and Eastern mainland Greece. During the warm and dry period the weather is usually stable, the sky is clear, the sun is bright and there is generally no rainfall. There are, however, infrequent and brief intervals of rapid rain or thunderstorms chiefly over mainland areas.

In Table 10 to Table 18 and in Fig. 22 up to Fig. 26 for the evaluation of the evapotranspiration and the irrigation schedule, the climatological conditions of the available meteorological stations are presented (NWS, 2014). In region of Epirus the meteorological stations that were used were for the area of Ioannina, Artas, Preveza and Igoumenitsa, and for Region of Western Greece for the area of Patras. The data were collected from the Greek National Meteorological Survey.

Table 10 Climatology conditions of the City of Arta, Region of Epirus Greece (ETo FAO Paper 56/Hargraves)

Month	Tmin (°C)	Tmax (°C)	Tmean (°C)	Rain (mm/month)	ETo (mm day^{-1})
Jan	5.58	13.23	8.93	200.78	2.52
Feb	6.38	14.25	9.80	202.75	2.72
Mar	8.25	17.45	12.35	172.40	3.25
Apr	11.55	22.00	16.38	86.55	3.81
May	15.13	26.00	20.00	98.00	4.07
Jun	19.08	30.50	24.40	35.10	4.48
Jul	21.88	33.78	27.38	2.95	4.97
Aug	22.53	34.78	28.10	4.15	5.39
Sep	19.00	29.83	23.85	100.15	4.79
Oct	14.88	23.65	18.68	192.23	3.78
Nov	11.60	19.50	15.08	184.33	3.15
Dec	7.08	14.63	10.43	204.55	2.59

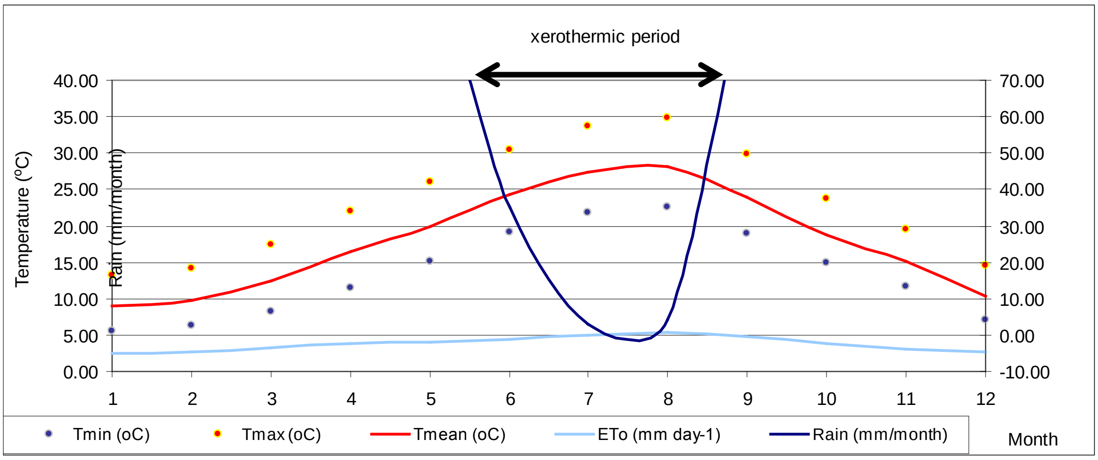


Fig. 22 Ombrothermic diagram for city of Arta

Table 11 Climatology conditions of the City of Ioannina, Region of Epirus Greece (ETo FAO Paper 56/Hargraves)

Month	Tmin (°C)	Tmax (°C)	Tmean (°C)	Rain (mm/month)	ETo (mm day^{-1})
Jan	-1.20	9.45	3.60	137.43	2.38
Feb	0.45	10.70	5.15	176.23	2.58
Mar	1.70	15.08	8.00	118.53	3.36
Apr	5.08	19.55	12.18	82.15	3.94
May	8.58	23.55	15.75	123.65	4.24
Jun	11.73	28.25	20.08	54.55	4.84
Jul	13.83	32.23	23.03	39.65	5.59
Aug	13.83	33.58	23.50	15.70	6.16
Sep	10.73	27.93	18.90	95.80	5.32
Oct	6.98	20.98	13.20	181.43	4.06
Nov	3.33	16.20	8.93	202.13	3.27
Dec	-0.28	10.50	4.58	203.83	2.46

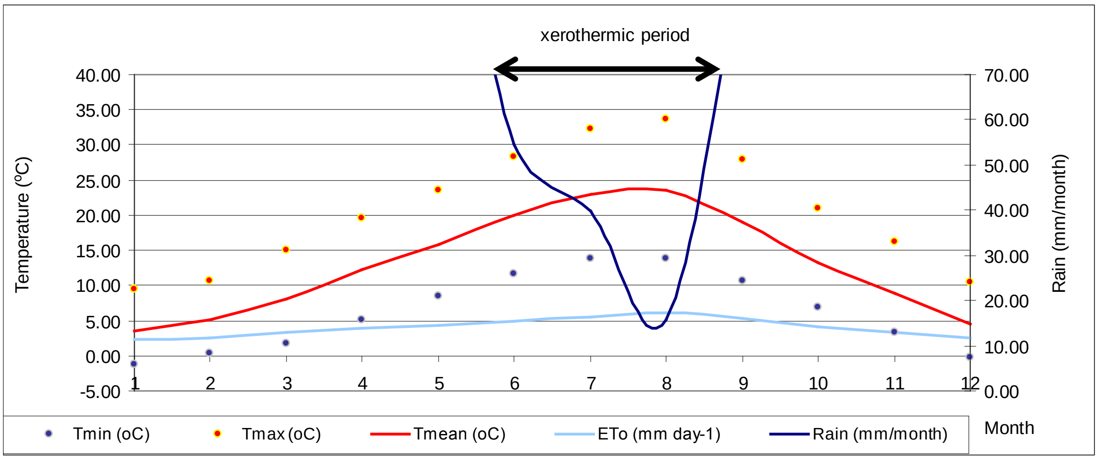


Fig. 23 Ombrothermic diagram for city of Ioannina

Table 12 Climatology conditions of the City of Preveza, Region of Epirus Greece (ETo FAO Paper 56/Hargraves)

Month	Tmin (°C)	Tmax (°C)	Tmean (°C)	Rain (mm/month)	ETo (mm day^{-1})
Jan	9.1	15	11.6	187.6	2.43
Feb	8.1	15.6	11.4	122.6	2.81
Mar	8.7	17.1	12.4	136.4	3.11
Apr	11	19.3	14.9	158.4	3.25
May	14	22.1	18	46.4	3.32
Jun	18.1	27.3	22.7	17.2	3.86
Jul	20.3	29	24.9	12.6	4.02
Aug	20.4	29.4	25.1	2.2	4.32
Sep	18	26.4	22.1	94.4	4.04
Oct	14.7	22.5	18.2	273	3.52
Nov	11.5	18.7	14.7	101.6	2.98
Dec	8.6	15.4	11.4	226.2	2.55

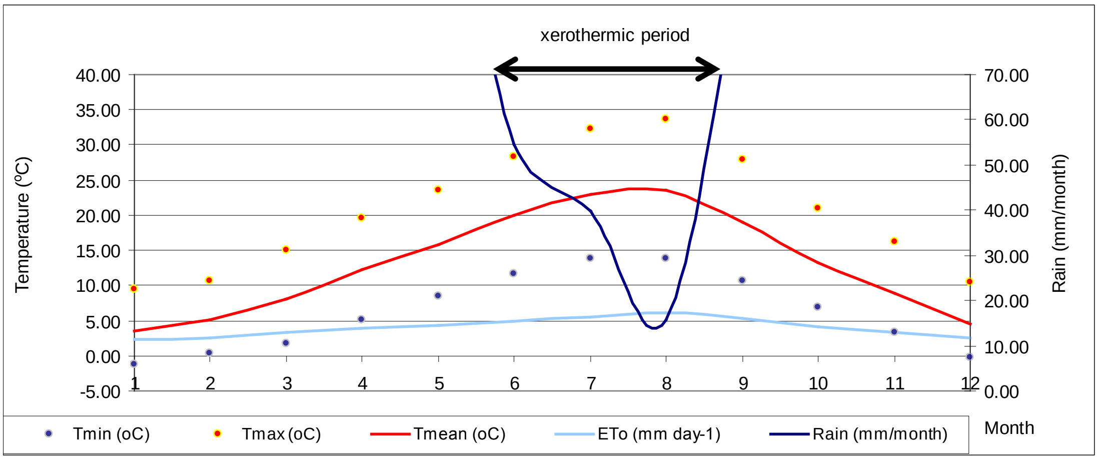


Fig. 24 Ombrothermic diagram for city of Preveza

Table 13 Climatology conditions of the City of Igoumenitsa, Region of Epirus Greece (ETo FAO Paper 56/Hargraves)

Month	Tmin (°C)	Tmax (°C)	Tmean (°C)	Rain (mm/month)	ETo (mm day^{-1})
Jan	5.27	13.39	8.93	150.11	2.59
Feb	5.19	13.57	9.11	171.71	2.74
Mar	7.26	16.44	11.69	132.97	3.18
Apr	10.21	20.44	15.16	73.21	3.64
May	13.70	24.83	19.20	63.99	4.03
Jun	17.59	29.20	23.57	35.86	4.43
Jul	20.09	32.34	26.50	0.80	4.95
Aug	20.73	32.96	26.97	1.91	5.26
Sep	16.99	27.74	22.17	91.67	4.58
Oct	13.49	22.89	17.61	211.03	3.80
Nov	10.17	18.97	14.03	212.36	3.22
Dec	6.44	14.36	9.97	182.06	2.61

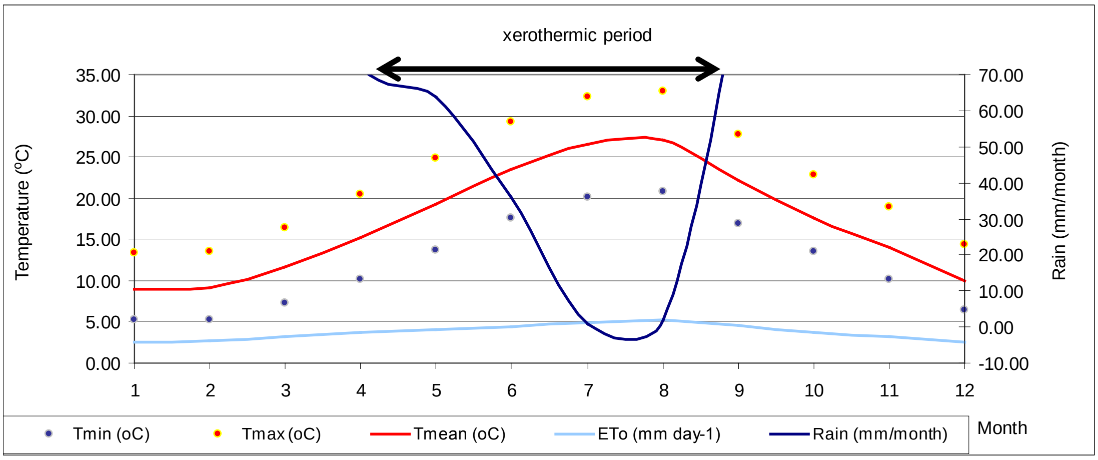


Fig. 25 Ombrothermic diagram for city of Igoumenitsa

Table 14 Climatology conditions of the City of Patras, Region of Western Greece (ETo FAO Paper 56/Hargraves)

Month	Tmin (°C)	Tmax (°C)	Tmean (°C)	Rain (mm/month)	ETo (mm day^{-1})
Jan	11.30	15.60	13.40	128.80	2.20
Feb	11.10	15.20	13.10	78.80	2.20
Mar	11.40	16.80	14.00	65.20	2.63
Apr	13.60	18.60	16.00	81.30	2.61
May	16.70	22.00	19.10	27.20	2.77
Jun	21.00	26.70	23.40	12.40	3.09
Jul	23.10	28.00	25.50	13.60	3.06
Aug	24.00	29.00	26.20	0.00	3.30
Sep	21.40	25.80	23.70	76.60	3.04
Oct	17.10	22.30	19.60	115.20	2.99
Nov	13.70	19.10	16.30	64.20	2.70
Dec	11.90	16.20	13.90	156.80	2.20

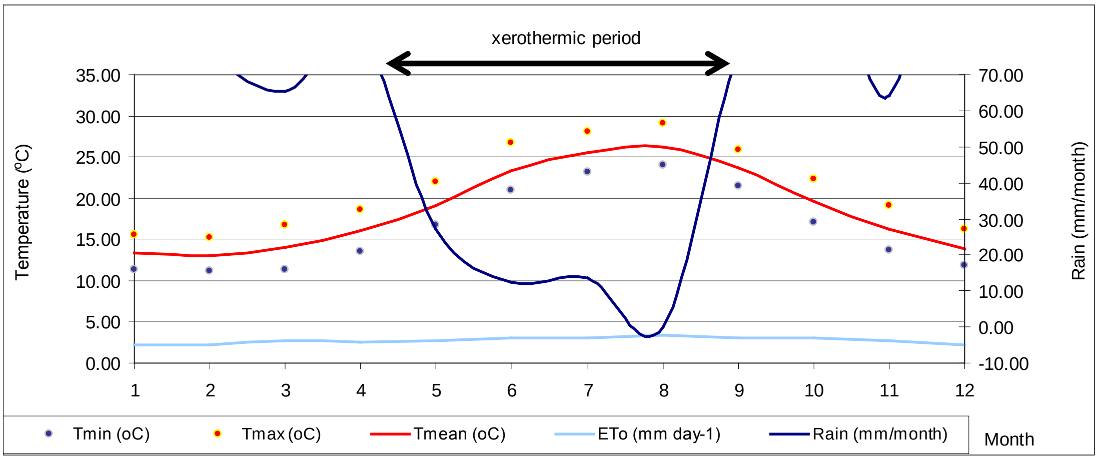


Fig. 26 Ombrothermic diagram for city of Patras

Soil parameters

Generally soil affects the irrigation program and schedule of the corps, landscapes and football stadiums, as this was analyzed is previous chapters. In Fig. 27 and Fig. 28, general maps of soil characteristics in the region of Epirus and Western Greece is presented, adapted from Lucas Soil program (Toth et al., 2013).

For the evaluation of the soil parameters of the study farms and landscapes soil samples were collected and soil analysis was conducted. In Table 15 and in Fig. 29 the statistical parameters and the triangular diagram of the soil characteristics of the study fields and landscapes are presented. By this, is concluded that in most of the study areas soils are characterized as Silty Loam, Silt and Sandy Loam. Also, soil pH an E.C. parameters have values between 5.3 and 8.1 and 0.08 to 2.93 mScm^{-1} with average values to be 7.29 for pH and 0.39 mScm^{-1} for electric conductivity.

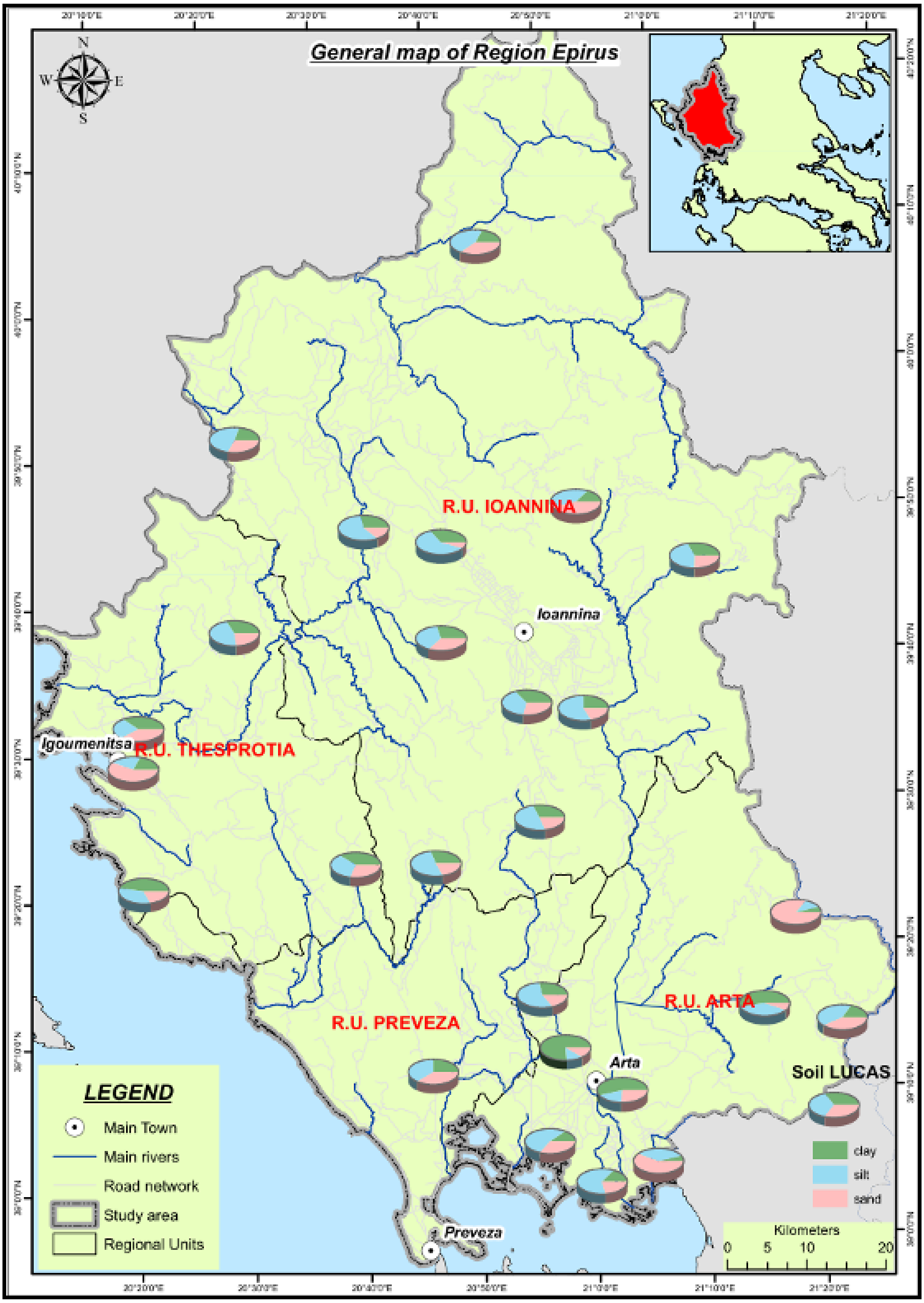


Fig. 27 Soil characteristics of the region of Epirus adapted from Lucas program (Toth et al., 2013)

Fig. 28 Soil characteristics of the region of Western Greece adapted from Lucas program (Toth et al., 2013)

Table 15 Soil characteristics of the study areas from field surveys

Number of soil samples	80	
Soil classification	**Soil type**	**Number of soil samples**
Clay loam	CL	1
Loam	L	4
Loamy Sand	LS	1
Sandy Clay Loam	SCL	2
Silt	Si	16
Silty Clay	SiC	2
Silty Loam	Sil	40
Sandy Loam	SL	14
Soil parameter	**pH**	**EC ($mScm^{-1}$)**
min	5.3	0.08
average	7.29	0.39
max	8.1	2.93
s.d.	0.46	0.44

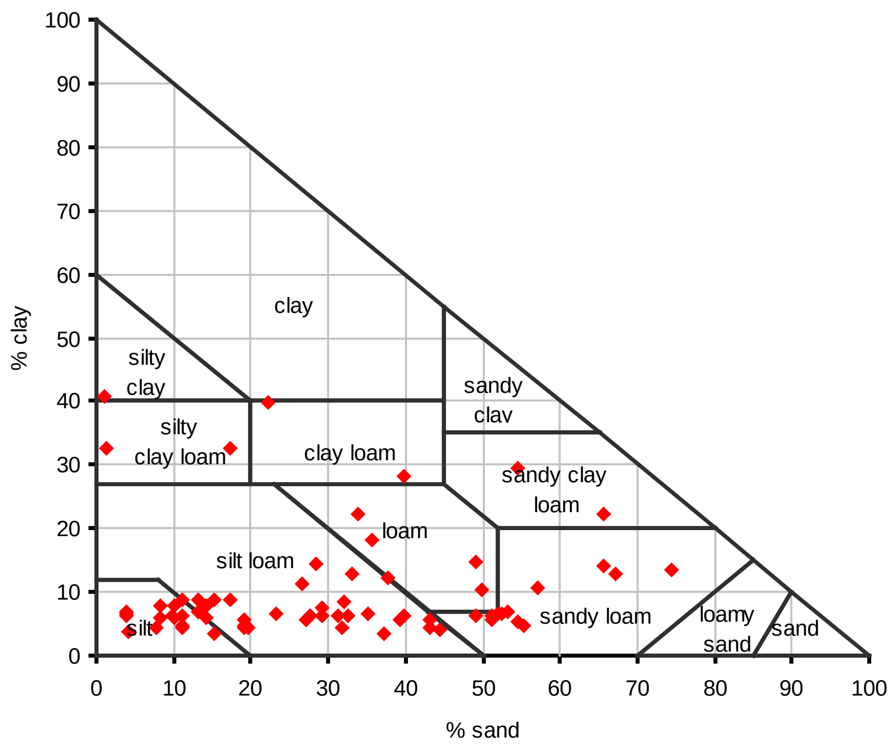


Fig. 29 Triangular diagram for soil classification of the study fields and landscapes

In Fig. 30 and Fig. 31 the spatial location and the characteristics of the soil samples of the irrigation audits, for Region of Epirus and Region of Western Greece are presented.

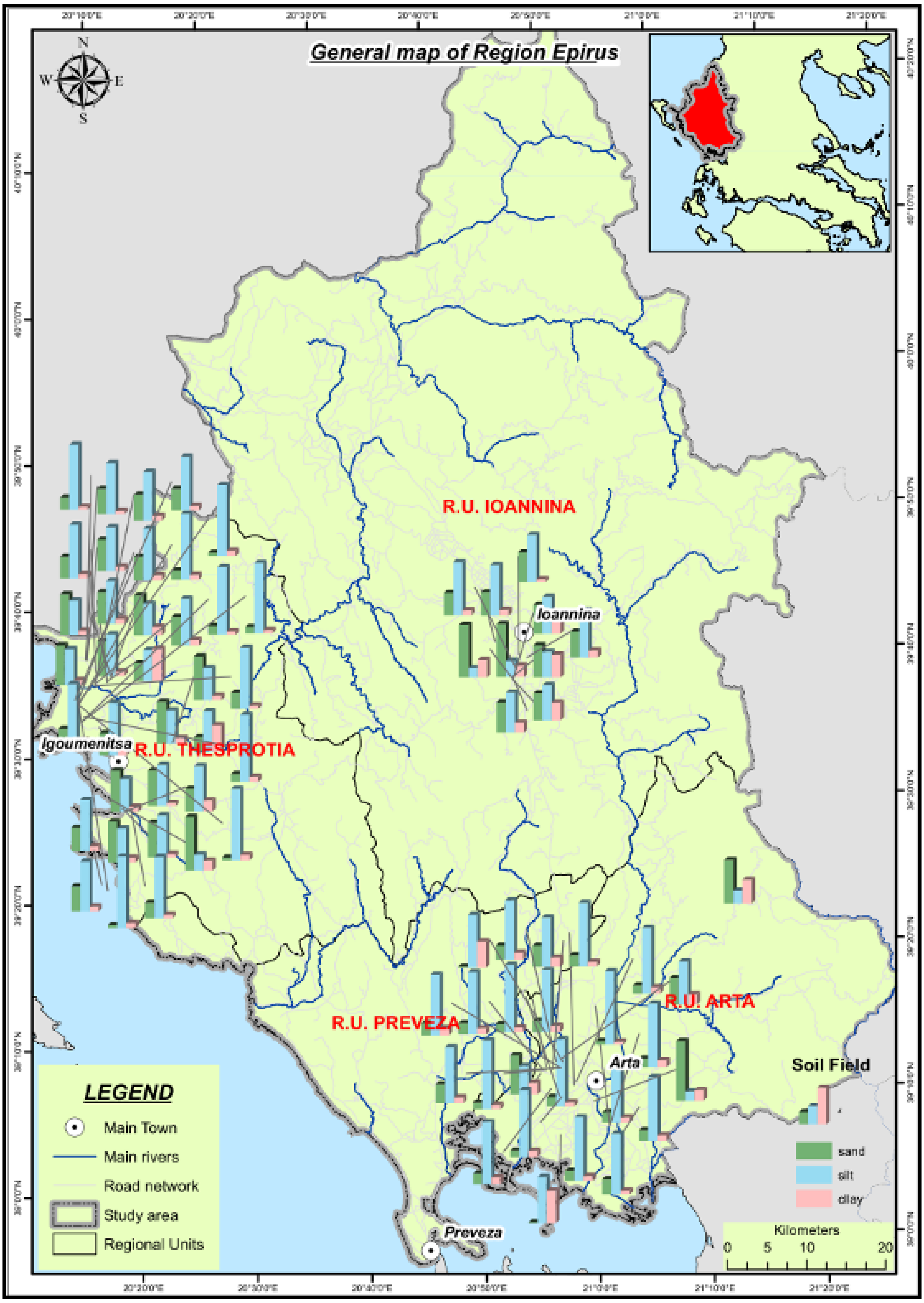


Fig. 30 Soil characteristics for soil samples from region of Epirus

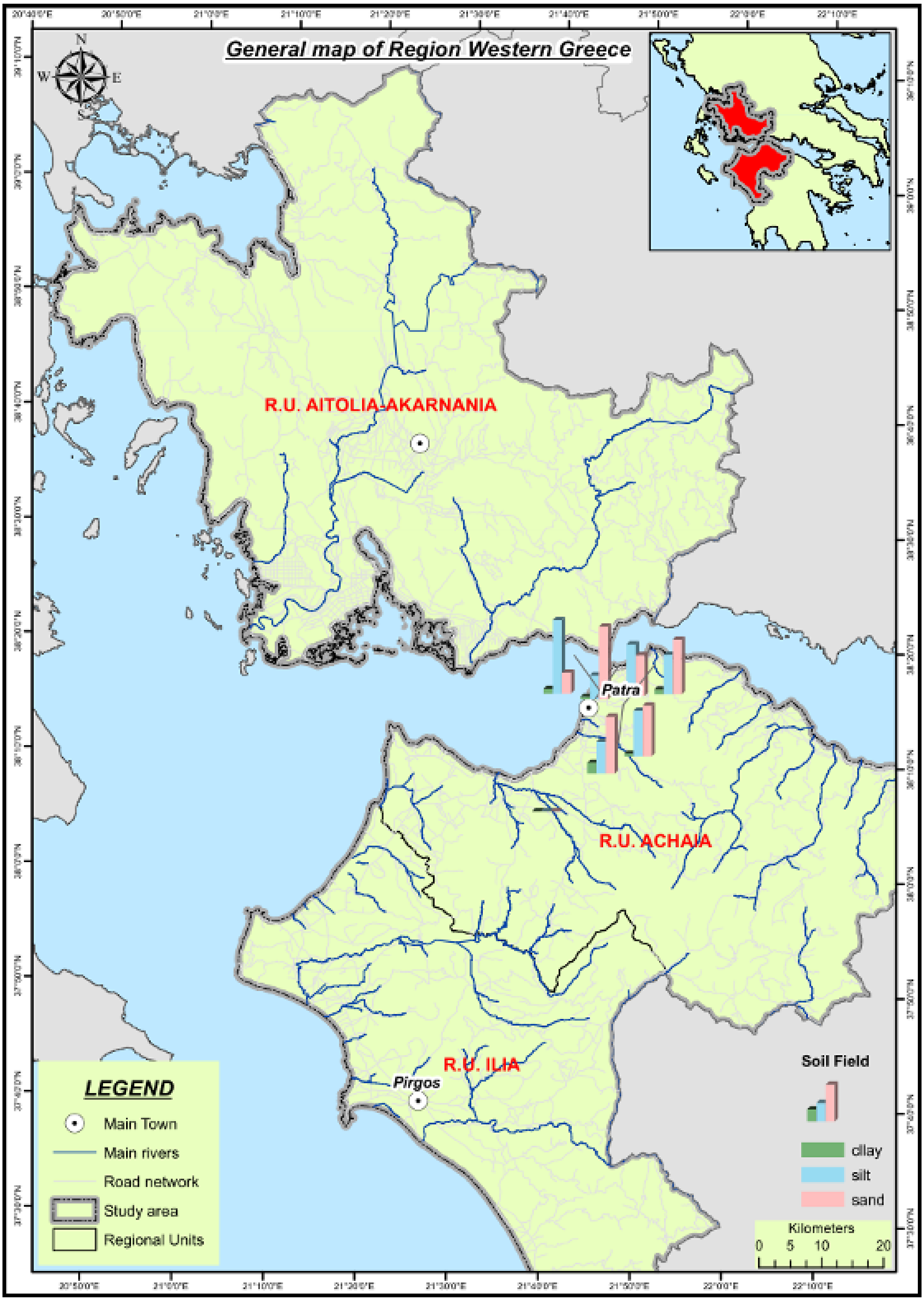


Fig. 31 Soil characteristics for soil samples from region of Western Greece

Auditing procedures in study areas

General

In this chapter the auditing procedures and results from the study areas, for the farm fields, landscapes, greenhouses and football stadiums are analyzed. For this reason the irrigation system and its parts (pipes, valves, sprinkles, etc.), the catch can test and the uniformity indexes are presented. Finally, the problems that were recorded during the audits, as well as some suggestions for the improvement the operation of irrigation systems are given.

Irrigation audits in farm fields

The cultivation of study farm fields, was Citrus trees, Kiwi trees, Cherry trees, Olive trees, Wine trees, Pomegranate trees and apples trees. The study farms were in the area of the regions of Epirus and Western Greece. The area of the study farms was between 0.12ha and 3.6ha with the average of 1ha. The age the owners of the study farms was in average 50 years, with younger farmers to manage larger farm fields. Here it should be mentioned that an irrigation audit was never before conducted in any of this farms.

Irrigation system design

Regarding the design of the systems the following basic observations were made:

- The water supply source of the study farms was from irrigation canals, drills, and water tanks, with the majority of the irrigated farms from irrigation canals (Fig. 32).
- No irrigation water cost, or electricity costs were observed, for all the farm fields.
- It was found that the design, the study and the installation of systems was held by artisans rather than agronomists or other relevant scientists.
- The irrigation system in the design and implementation followed the telescopic method with larger pipeline diameters to be in the main conduit (Fig. 33).
- The usual diameter of the main pipe was Ø110 and the irrigation networks were branched in secondary and tertiary pipelines.
- The total absence of filters in pipelines in the study farms was also a finding.
- At the same time control systems as controllers, rain sensors, electric valves, etc. were completely absent too.
- Also key components of irrigation systems such as check valves, air valves, drain valves, water meters etc. were not identified.
- Regarding the irrigation pipelines, for the majority of the study farms the composed material was PVC with standard 25mm diameter for the application pipelines (Fig. 34).
- The outlets of the irrigation water for crops were micro-sprinklers, with average water supply 90 - 160 Lh^{-1} and wetting diameter 6-10m according to the manufacturer's documentation with quadratic order in the field. In four of the study farms irrigation dripline was used, with water supply $4Lh^{-1}$ (Fig. 35).
- The water pressures at the water source were about 3atm in average while in the sprinklers were about 1-1.2atm, due to losses on the irrigation system.

a.

b.

Fig. 32 Water source a. Irrigation canal, b. Drill

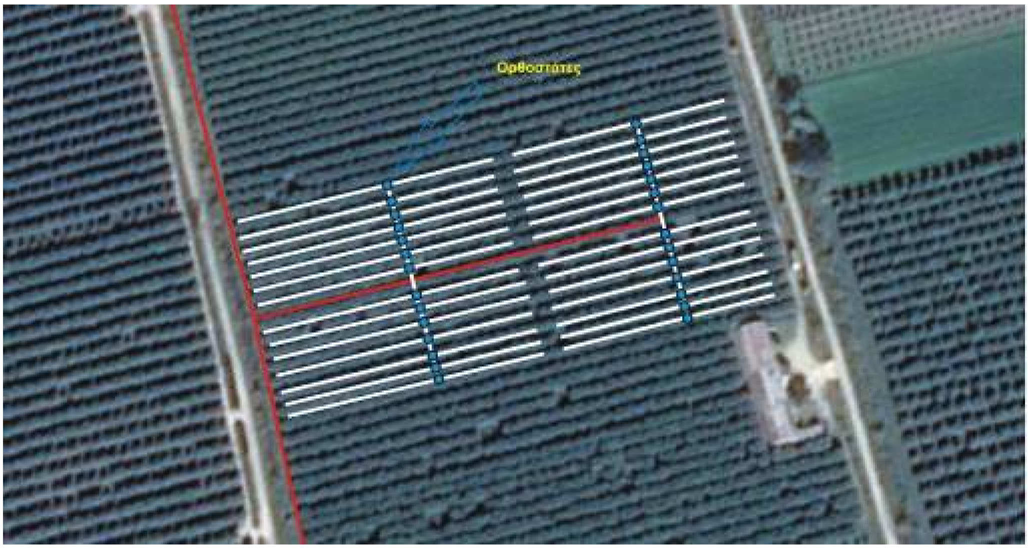


Fig. 33 Irrigation system design (telescopic method)

Fig. 34 Irrigation pipes main pipes, secondary and tertiary

Fig. 35 Irrigation dripline in linear crop layout

Catch can tests

The catch can test (Fig. 36) was performed for all the study farms, and the procedures, that were applied, are analysed in previous chapters. Generally the test time was about 15-20min and the number of the catch cans was at least 20.

In Table 18 an indicative catch can test is presented, as this was applied in a study farm. The water pressure on the sprinklers was measured, in selected positions, and also the soil moisture before and after the irrigation of the field.

Fig. 36 Catch cans positions (red circle) in a study farm field

Table 16 Catch test in a study farm field

		Operating pressure	Radius (for sprinklers)	Pipe flow rate
Outlet / Pipe-pos.		bar	m	lh^{-1}
1		1.2	2.4	90 lh^{-1}
2		1.2	2.1	90 lh
3		1.15	2.2	90 lh
4		1.2	2.5	90 lh
5		1.15	2.5	90 lh
6		1.2	2.5	90 lh
7		1.10	2.2	90 lh
8		1.1	2.3	90 lh
9		1.1	2.2	90 lh
10		1.2	2.5	90 lh
Measur. (select unit)		Soil moisture (v/v %)		
		Before	After	Difference
Pos / Catch Can	ml	% v/v	% v/v	% v/v
1	38	10.80%	35.60%	24.80%
2	25	14.60%	47.10%	32.50%
3	18	19.20%	26.80%	7.60%
4	18	15.80%	32.90%	17.10%
5	60	13.70%	38.00%	24.30%
6	23	15.40%	23.00%	7.60%
7	30	16.70%	33.20%	16.50%
8	36	12.90%	29.40%	16.50%
9	25	15.90%	28.80%	12.90%
10	32	16.80%	23.10%	6.30%
11	62	10.50%	44.40%	33.90%
12	52	17.50%	44.20%	26.70%
13	25	15.50%	24.70%	9.20%
14	18	13.40%	29.80%	16.40%
15	32	17.10%	30.70%	13.60%
16	62	18.00%	36.60%	18.60%
17	120	13.20%	44.60%	31.40%
18	60	18.60%	37.30%	18.70%
19	50	15.80%	41.30%	25.50%
20	40	17.80%	23.60%	5.80%

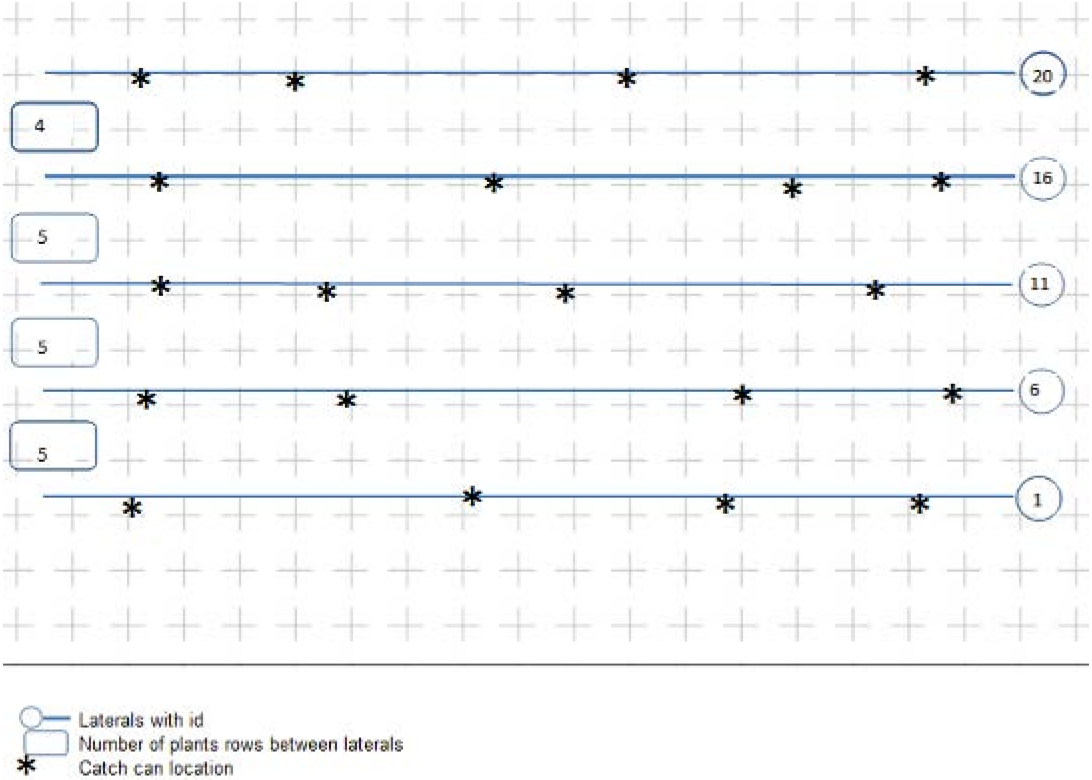


Fig. 37 Catch cans positions in a study farm field

In Fig. 36 simplified sketch of the position of the catch can is presented, including the can location, the number of the plant rows between laterals, and the laterals id. Also in Fig. 39 the results from the measurement of pressure and flow rate (Fig. 38) in a secondary pipe of an irrigation system are presented.

Fig. 38 P/Q measuring device

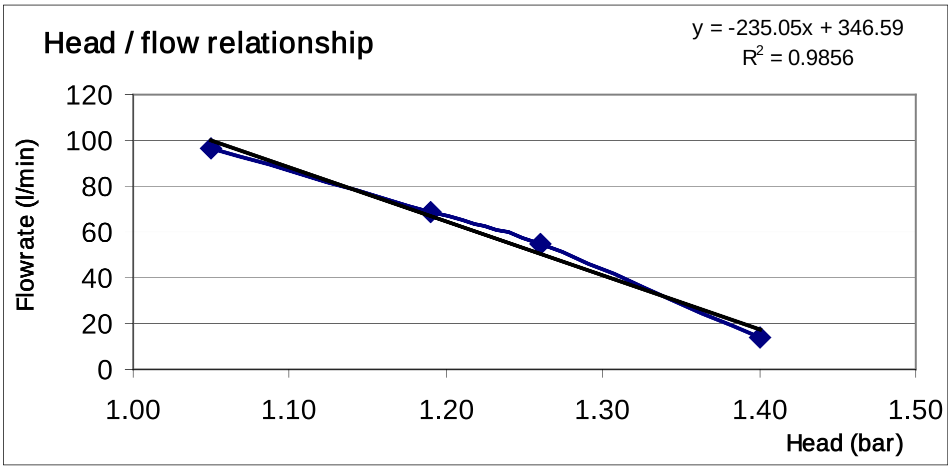


Fig. 39 Pressure - flow rate test in a secondary pipe in an irrigation system

Uniformity indexes

From the catch can test, several indexes were calculated, in order to evaluate the uniformity of the irrigation system in each farm field. The indexes that calculated were the Precipitation rate, the Uniformity index of the low quarter and the middle, the Christiansen coefficient and the SC index. The statistical parameters of the indexes are presented in Table 17 and in Fig. 40.

Table 17 Statistical parameters of the Uniformity indexes in the study farm fields

	PRavg (mm/h)	DUq	DUh	SC	CU
Min	5.07	12	18	1.19	5
Max	257	89	94	28	93
Average	27	47	58	5	53
Standard deviation	44	19	19	5	23

From Table 17 is concluded that the average participation rate is between 5.07mmh^{-1} and 257mmh^{-1}, with average in 27 mmh^{-1}. The higher values are observed in a cultivation of Pomegranate trees of 3.6ha, irrigated with dripline with flow rate 4Lh^{-1}. Lower values are observed in a cultivation of Citrus trees of 2.2ha, irrigated sprinkler system (flow rate 160Lh^{-1}). Generally the Precipitation Rate was affected by the type of the water source, the type of the water pump and design of the irrigation system.

Fig. 40 Uniformity indexes in selected study farms (Y: Uniformity indexes – X: farm field)

As for the Uniformity indexes, farm fields present low uniformity values, both for DUlq, DUlh indexes and Christiencen coefficient (Fig. 40). Only in seven farms the DUlq index was higher that 80%, while the majority of them had value near 60%. Regarding DUlh and Christiansen coefficient, this indexes were follow the distribution of the DULq index. The low values of irrigation efficiency, is caused, by the design of the irrigation system, and by the management and maintenance actions of the irrigation system. Farms with problematic at design and installation irrigation systems, and farms, with problems, as they described next, had as a result low uniformity values. For the farms with driplines the uniformity is expected to be about 95% and from the audits is calculated about 80% (one field) and about 60% (three fields).

Irrigation schedule

The irrigation program of each farm is depending on the type of the crop, the soil parameters, and the availability of the irrigation water. From the audits is concluded that the irrigation schedule is different, depending on the above parameters. In Table 18 the applied irrigation period, the irrigation duration and the number of days between two irrigation facts are presented, for each type of crop of the study farms.

Table 18 Irrigation program characteristics for farm fields

Crop type	Irrigation period (months)	Irrigation duration (hours)	Number of days between irrigation events
Apple trees	6	1.5	1
Chery trees	5	12	14
Citrus trees	2-5	2-5	3-30
Clover crops	6	1	1
Herb crops	8	1	4
Kiwi trees	4-6	0.6-3	1-3
Olive trees	4	5	15
Pomegranate trees	4	10	7
Wine trees	5	10	7

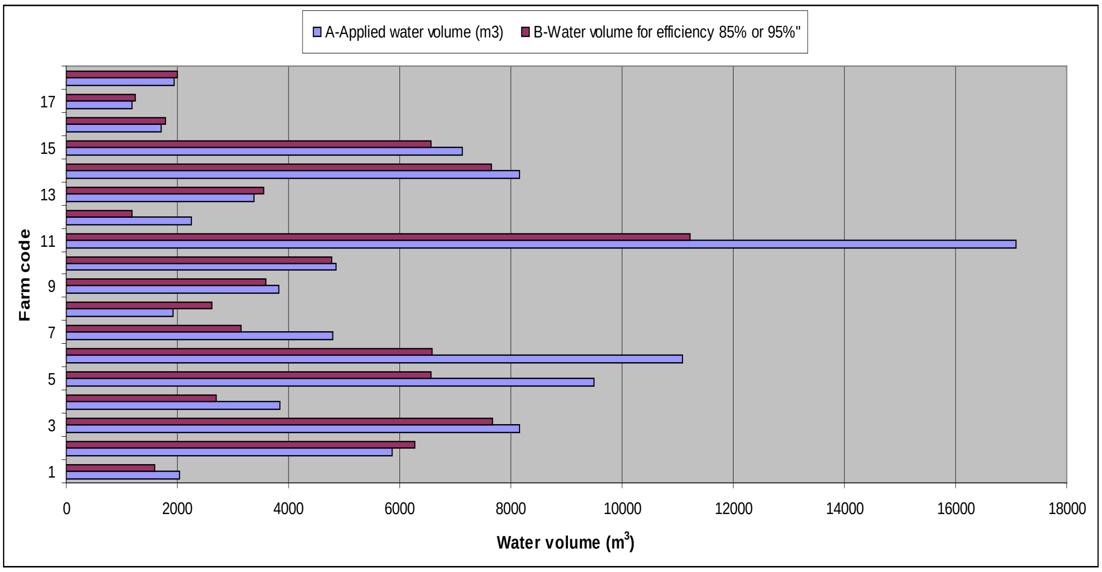
Generally for Citrus trees, and Kiwi trees, which are the majority of the study crop the irrigation schedule varies and as a result the irrigation period, duration and the irrigation days are different. For Citrus trees the irrigation period is 2 to 5 months while in Kiwi trees is 4 to 6 months. Also, for Citrus trees the irrigation time (hours) is 2 to 5 hours and the days between two irrigations are 3-30 days. For Kiwi trees the irrigation time (hours) is 0.6 to 3 hours and the days between two irrigations are 1-3 days.

The uniformity of the irrigation process, as it was analyzed before, affects the irrigation schedule. Specially, low uniformity indexes, lead to higher water volumes by the farmers or the managers, so that the irrigation water needs of the crops to be covered.

In Table 18 the applied irrigation water volume is calculated, by the parameters of Table 23. Also the irrigation water volumes were calculated, for irrigation uniformity 85%, the theoretical for sprinkler irrigation and for uniformity 95% for drip irrigation.

Table 19 Applied water volumes and irrigation water volumes for uniformity of 85 and 95% for the study farms.

Study farm	Applied irrigation volume (m^3) (from field measurements)	Irrigation volume for uniformity 85% or 95% (from irrigation schedule)	Irrigation volume for audit uniformity (from irrigation schedule)
1	2041	1597	1912
2	5863	6281	29261
3	8146	7677	10955
4	3840	2691	5108
5	9504	6563	8446
6	11088	6580	11289
7	4800	3136	3705
8	1920	2613	2884
9	3825	3588	8430
10	4860	4785	11083
11	17088	11215	15620
12	2246	1194	4149
13	3379	3552	5895
14	8146	7648	10641
15	7128	6563	8575
16	1714	1794	5636
17	1188	1246	2557
18	1944	1992	2970
19	3840	-	3127
20	4680	3738	8646
21	1024	821	2569
22	3600	3136	3706
23	2520	5140	11079
24	16200	14396	20085
25	192	497	662
47	10125	-	5091
49	3780	-	3857
50	2126	14596	30308
51	2890	-	2620
52	9720	6249	19038
53	3240	3735	4017
55	396	2988	6342
56	306	1836	2053
57	9234	5742	6775
59	5387	-	5462
60	3645	2788	3159
61	5400	4374	5389
62	9504	7446	8544
63	2160	1234	1782
64	3267	2175	3479
65	1597	2805	8602
66	2430	2488	3302
67	28809	8988	10335
68	284	3346	5350
69	1226	2506	5494
70	270	1489	3813
71	606	1170	1589
72	108	-	235
75	1714	993	1596
76	2314	1986	2311



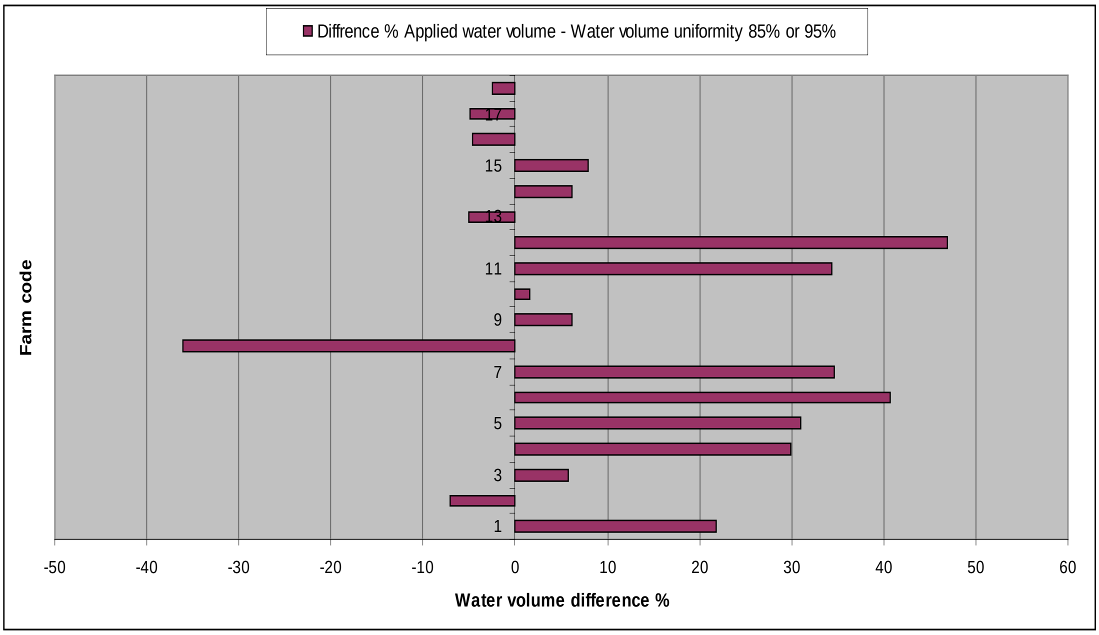


Fig. 41 Applied irrigation volume, Water volume for irrigation uniformity 85% and 95%, Difference % between applied irrigation volume and water volume for uniformity 85% or 95% for selected study farms.

In Fig. 41 Applied irrigation volume, Water volume for irrigation uniformity 85% and 95%, Difference % between applied irrigation volume and water volume for uniformity 85% or 95% for selected study farms. The applied irrigation volume, the water volume for irrigation uniformity 85% and 95% and the difference % between applied irrigation volume and water volume for uniformity 85% or 95% for selected study farms are presented.

For the majority of the study farms, farmers empirically irrigate corps more than the necessary water volume (as this is calculated for crop type, and the theoretical uniformity coefficient). In selected cases the applied irrigation volume was lower than the theoretical. Also, in Table 19 the water volume for the uniformity that was calculated from the catch can test is presented. As it is showed low values of uniformity, lead to higher values of irrigation water for covering irrigation needs.

Problems in irrigation system design and management

At the auditing procedure on the study farms, several problems were recorded, which affects the uniformity and the management of the irrigation system. That problems were categorized, as design problems and management problems. The water source was, as it was mentioned previous irrigation canal or drill. In some cases, the irrigation canal sediments or mud and as a result, given the absence of necessary filters, problems were observed in the performance of the irrigation system (Fig. 42). Control equipment like manometer, water meter, controllers, were not recorded for the majority of the study farms, and in some cases this equipment was broken (Fig. 43).

Fig. 42 Irrigation water source from canal and tank for avoid soil mud in irrigation system

a.  b. 

Fig. 43 a. Manometer in good condition, b. broken manometer

Also, leakages were recorded at the beginning of the water pump or in junctions, between the main pipe and the secondary pipes (Fig. 44 up to Fig. 49).

Fig. 44 Leakages in irrigation pipes (main pipe)

Fig. 45 Leakages in irrigation pipes (secondary pipes)

Fig. 46 Leakages in irrigation pipes (tertiary pipes)

In all the study farms a characteristic record was the total absence of control systems, like irrigation controls and control valves. Also at the junctions of the main pipe with the secondary pipes no filters were recorded (Fig. 47).

Fig. 47 Total absence of filter in junctions

Another problem that was recorded, was the usage sprinklers with differed technical characteristics (flow-rate, flow diameter), and as a result non uniform irrigation was applied on the corps. Also, in some cases an inclination of the sprinklers from the vertical was recorded, which leads to different from the theoretical (manufactures manual) flow diameter of the sprinkles (Fig. 48).

a.

b.

Fig. 48 a. Different sprinklers on a farm, b. inclination of a sprinkler from the vertical

Drainage problems, for the majority of the study farms were not recorded, because farmers were constructed ditches for avoiding flood phenomena especially during winter (Fig. 49).

Fig. 49 Ditches for avoiding flood phenomena in a study farm

Another problem that was recorded, was related with the applied irrigation schedule. In particular, as it is analysed in Table 19 in some farms, the applied irrigation volumes were extremely high compeering with the theoretical or the necessary volumes, as they calculated by the audit procedures. This had as a result increased costs of production.

Irrigation audits in greenhouses

These types of irrigation fields, are special cases, from the general auditing process. In greenhouses the irrigation process was more controlled, than in the open field, were the total amount of the irrigation water was more manageable.

Irrigation system design

Greenhouses characterized from controlled conditions, for maximizing crop production. Generally, a main pipe is connected with the water source (water canal or drill) and after that secondary pipes. In greenhouses, the evapotranspiration process is different than this in the open field, and this should be evaluated.

Fig. 50 Irrigation system in a greenhouse

Irrigation in greenhouses can applied with sprinklers hanged from the roof or with drip pipes and emitters near the ground surface. In both cases, high uniformity indexes expected, because of the controlled conditions of irrigation. In Fig. 50 and Fig. 50 parts of the irrigation system in a greenhouse are presented.

Fig. 51 Hydrocyclone, drill and irrigation fertilizer system in a selected greenhouse

Catch can test – Uniformity indexes

From the can tests (Fig. 50) the uniformity indexes were calculated. Uniformity indexes are near 85% in greenhouses. The high uniformity indexes values in greenhouses are due to controlled conditions of the management of the production activity (Table 18). Here it should be mentioned that from the catch can test, high Pravg values were recorded, in most of the greenhouses. This affects the duration of the irrigation event and the applied irrigation values.

Fig. 52 Evaluating soil moisture, water quantity and pressure in a greenhouse

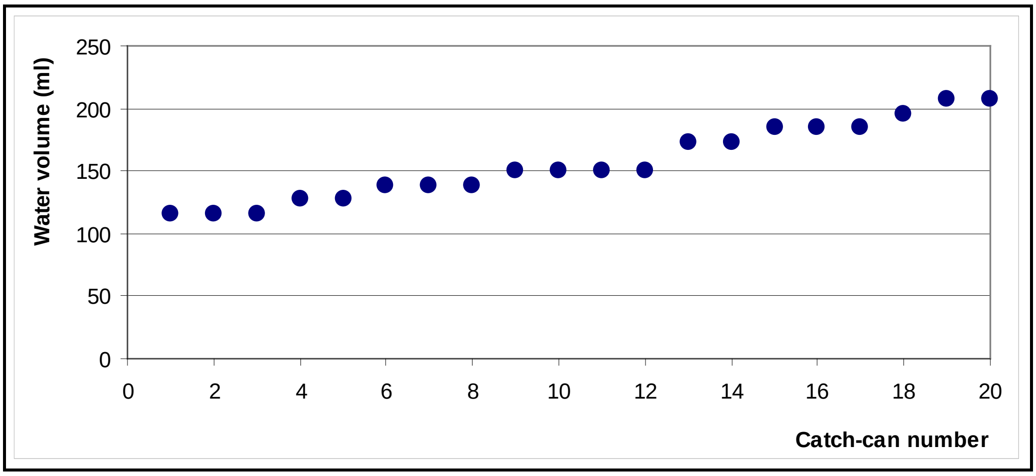


Fig. 53 Water volume fluctuation in catc-cans

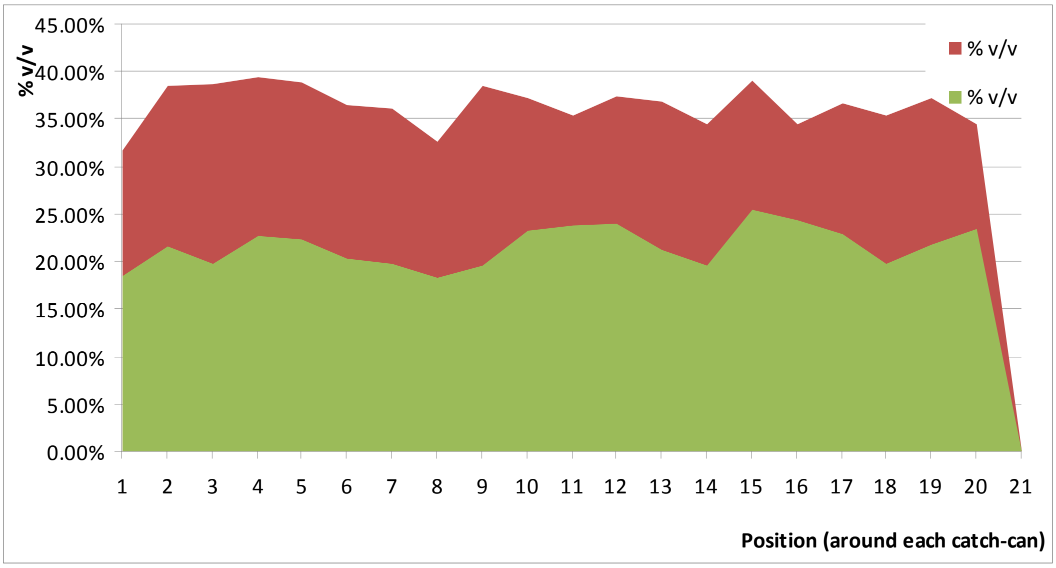


Fig. 54 Substrate moisture before and after irrigation

In Fig. 50 and Fig. 50 the water volume fluctuation and the substrate moisture before and after irrigation from a catch-can test in a greenhouse are presented.

Table 20 Uniformity indexes in study greenhouses

Greenhouse	Dulq	Dulh	SC	CU
1	1.2	83.0	1.4	83.0
2	75.0	87.0	1.5	86.0
3	81.0	88.0	1.7	88.0
4	80.0	85.0	1.4	85.0
5	72.0	84.0	1.5	83.0
6	77.0	86.0	1.5	86.0
7	81.0	88.0	1.5	88.0
8	77.0	85.0	1.5	85.0
9	82.0	88.0	1.4	87.0
10	81.0	88.0	1.3	88.0
11	74.0	83.0	1.5	83.0
12	77.0	84.0	1.4	83.0
13	82.0	88.0	1.3	88.0
14	78.0	88.0	1.4	87.0

In Fig. 50 in a diagram is presented for the uniformity indexes in the study greenhouse. From this is concluded the high values of the indexes, mainly due to the controlled conditions on the greenhouses. Here should be mentioned that most of the greenhouses are new aged and this affects the quality of the materials and the design procedures. Also in most of them the design of the irrigation system was made by professionals.

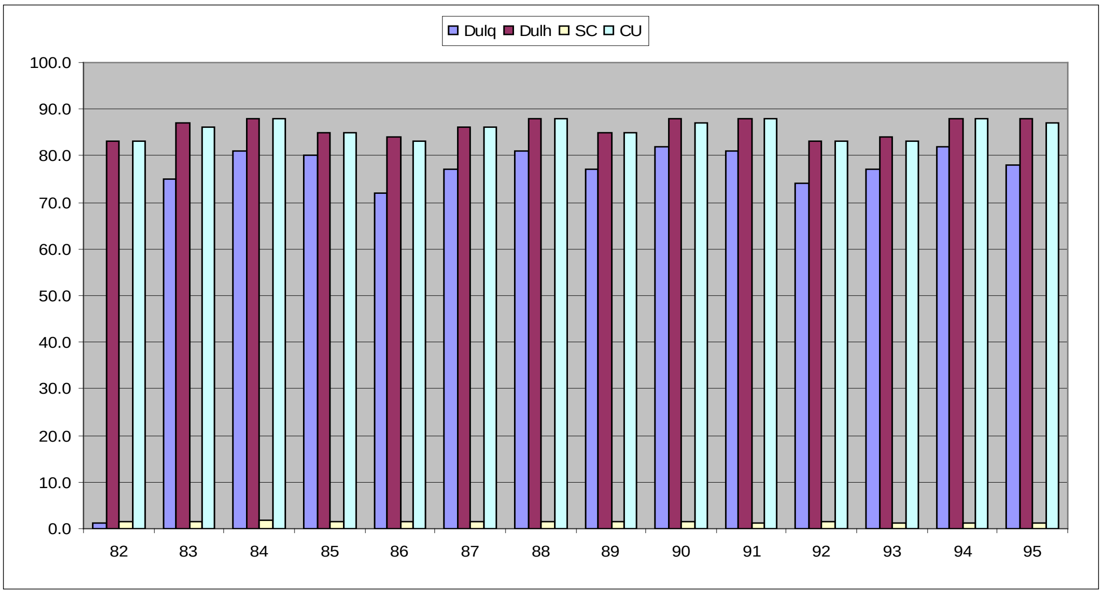


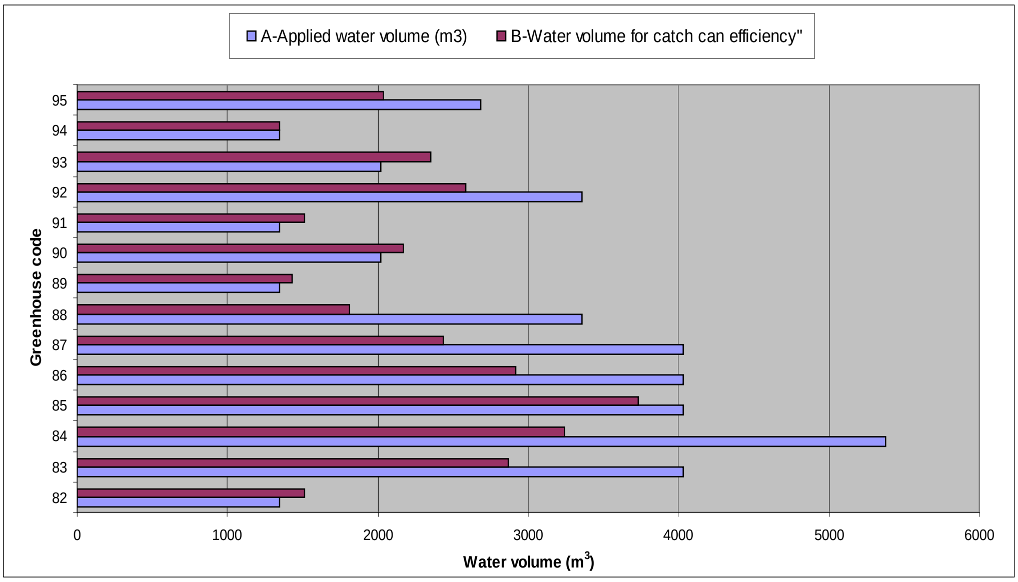
Fig. 55 Uniformity indexes for the study greenhouses

Irrigation schedule

The irrigation program of each greenhouse is depending on the type of the crop, the soil parameters, and the availability of the irrigation water. Generally more controlled conditions are presented. From the audits is concluded that the irrigation schedule is different, depending on the above parameters. In Table 18 the applied irrigation period, the irrigation duration and the number of days between two irrigation facts are presented, for each type of crop of the study farms.

Table 21 Irrigation program characteristics for greenhouses

Crop type	Irrigation period (months)	Irrigation duration (hours)	Number of days between irrigation events
Tomatoes	12	0.33	2
Cucumbers	12	0.33	2
Tomatoes	12	0.33	2
Cucumbers	12	0.3	2
Tomatoes	12	0.5	2
Cucumbers	12	0.3	2
Tomatoes	12	0.4	2
Tomatoes	12	0.3	2
Tomatoes	12	0.3	2
Tomatoes	12	0.3	2
Tomatoes	12	0.3	2
Tomatoes	12	0.3	2
Tomatoes	12	0.3	2
Tomatoes	12	0.3	2



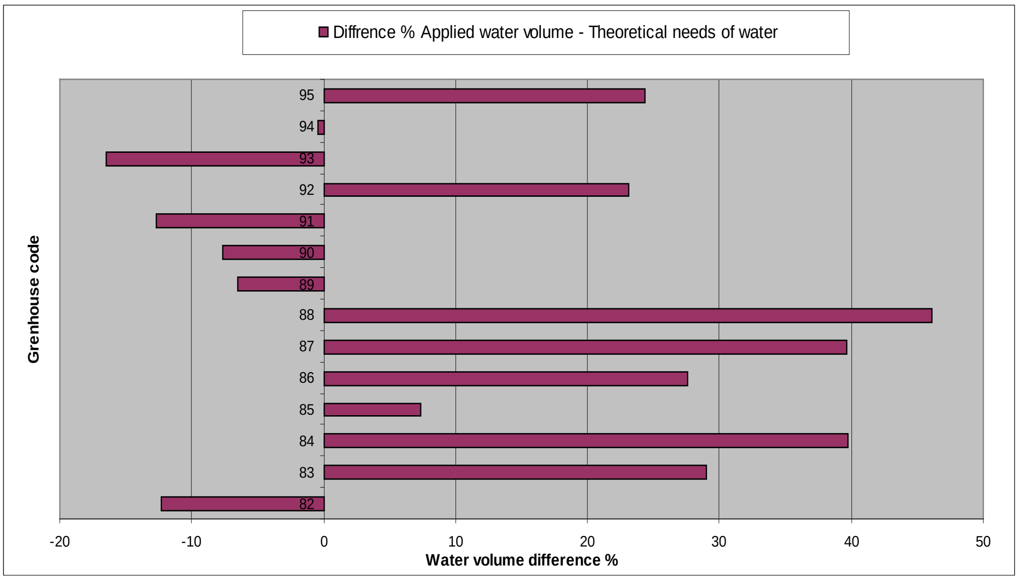


Fig. 56 Applied irrigation volume, Water volume for catch can efficiency, Difference % between applied irrigation volume and water volume for catch can uniformity for selected greenhouses.

Table 22 Applied water volumes and irrigation water volumes for catch can uniformity for the study greenhouses.

Study greenhouse	Applied irrigation volume (m^3) (from field measurements)	Irrigation volume for audit uniformity (from irrigation schedule)
1	1344	1510
2	4032	2863
3	5376	3241
4	4032	3735
5	4032	2919
6	4032	2435
7	3360	1810
8	1344	1432
9	2016	2171
10	1344	1515

11	3360	2584
12	2016	2349
13	1344	1350
14	2688	2034

Generally for study greenhouses the irrigation period was 12 months and the irrigation duration was 0.3-0.4 hours per day. Each irrigation event was applied in every 2 days. Both for the two crop types the irrigation schedule was similar.

From the catch can test the uniformity of the irrigation process was calculated, using the uniformity indexes that were analyzed in previous. In Table 18 the applied irrigation water volume is calculated, form the parameters of Table 23.

In Fig. 41 Applied irrigation volume, Water volume for irrigation uniformity 85% and 95%, Difference % between applied irrigation volume and water volume for uniformity 85% or 95% for selected study farms. For the majority of the study farms, farmers empirically irrigate corps more than the necessary water volume (as this is calculated for crop type, and the uniformity coefficient). In selected cases the applied irrigation volume was lower than the theoretical. Is it was presented before high Pravg values were recorded in study greenhouses, and as a result more water, than the needed, is applied in crops. Generally due to high Pravg values the irrigation duration should be lower 50% for water conservation.

Problems in irrigation system design and management

In greenhouses, some problems were recorded, with broken pipes, or broken sprinklers. In some cases leakages were recorded between the junctions of the water source and the fertilizer or the main pipe and the secondary pipes (Fig. 58 and Fig. 58). In general, in greenhouses irrigation problems appeared usually due to faulty management of the irrigation system, than the design process.

Here it should be noticed that also in greenhouses, although the design of the irrigation system was made by professionals none drawing, or schedule of the irrigation system was recorded.

Fig. 57 Irrigation problems in greenhouses (leakages in irrigation pipes)

Fig. 58 Irrigation problems in greenhouses (leakages in junctions between secondary pipes and tertiary)

Irrigation audits in landscapes

Irrigation audits were occurred in 25 private and 6 public landscapes in the region of Epirus and Western Greece in Greece. The analysis of the audits is presented below.

Irrigation system design

The irrigation system in the landscapes is in all cases was underground, with sprinklers or emitters and control devices to be in the surface. The water source in the majority of the study places was the urban water network system. This has as a result, high quality irrigation water (drinking water) and low pressures (pressures lower the 1.5 atm) for the irrigation system.

In Fig. 59 a simplified sketch of the irrigation system on a landscape is presented. Generally landscapes areas are less than 0.01ha with low pressures, and controllers for the management of the irrigation process.

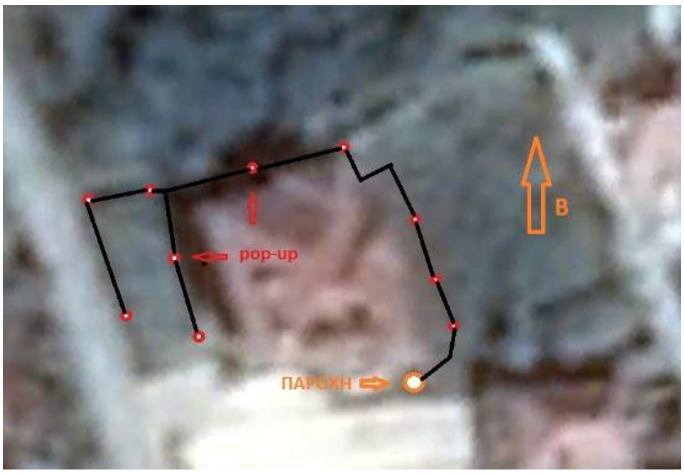


Fig. 59 Simplified irrigation network for a private landscape

In most of the landscapes controllers were used for the management of the irrigation system (Fig. 60). The irrigation zones, that they manage, and the number of them were controlled by the area of the landscape area, the number of the sprinklers or the micro-sprinklers and emitters and the technical characteristics of them (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**).

Fig. 60 Controllers for irrigating landscapes in the study area

Fig. 61 Emitters in study landscapes

Fig. 62 Control valves in study landscapes

In landscapes the design and the management of the irrigation system was performed by agronomists, or relevant scientists. Basic equipment like filters, valves, electro-valves, etc were recorded (Fig. 62).

The diameter of the irrigation pipes was usually Ø32 to Ø20, under the ground about 0.5 to 1m, and the irrigation design was according to the positions of the sprinklers (Fig. 63). Here it should be mentioned that none irrigation drawing of the irrigation system was recorded during the audit procedure.

Fig. 63 Irrigation design of landscapes according to the positions of the sprinklers (Rainbird, 2001)

Catch can test

Catch can test was performed in all the study landscapes, with the same procedures as they described in previous sessions (Table 23). The duration of the test was about 10-15 minute for each irrigation zone. The irrigation process, due to low pressure of the water supply system, for the majority of the landscapes was applied in several stages. The number of the cans was controlled from the dimensions and the area of the landscapes and the positions of the sprinkles. The usual number of the cans was ten for a landscape.

Table 23 Catch test in a study landscape

	Measur. (select unit)	Soil moisture (v/v %)		
		Before	After	Difference
Pos / Catch Can	ml	ml	ml	% v/v
1	20	33.60%	34.80%	1.20%
2	15	33.80%	36.30%	2.50%
3	25	32.50%	37.70%	5.20%
4	30	31.20%	35.80%	4.60%
5	28	30.80%	36.70%	5.90%
6	10	32.10%	37.50%	5.40%
7	14	31.70%	35.80%	4.10%
8	5	30.10%	32.10%	2.00%
9	5	29.10%	35.10%	6.00%

In Fig. 64, Fig. 65 and Fig. 66 the results of an indicative catch can test and the flow rate – pressure test are presented.

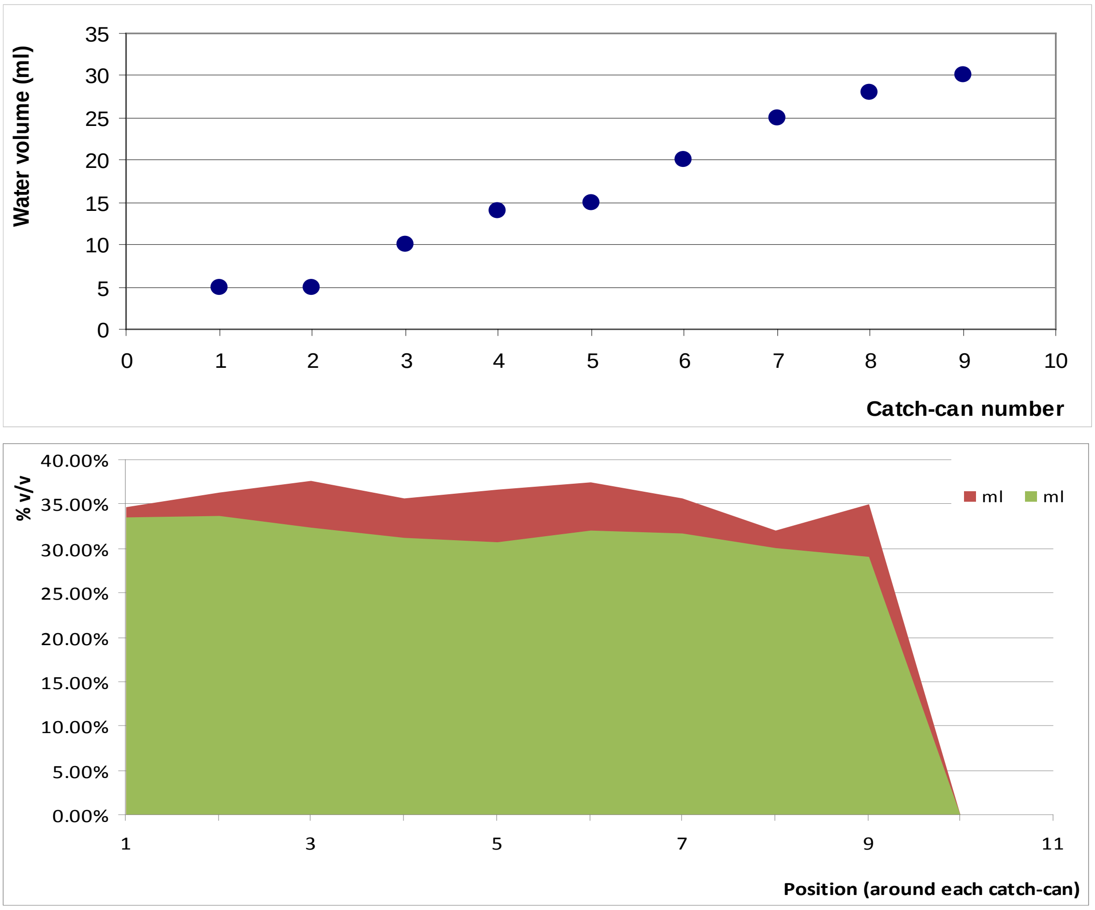


Fig. 64 Catch can test results

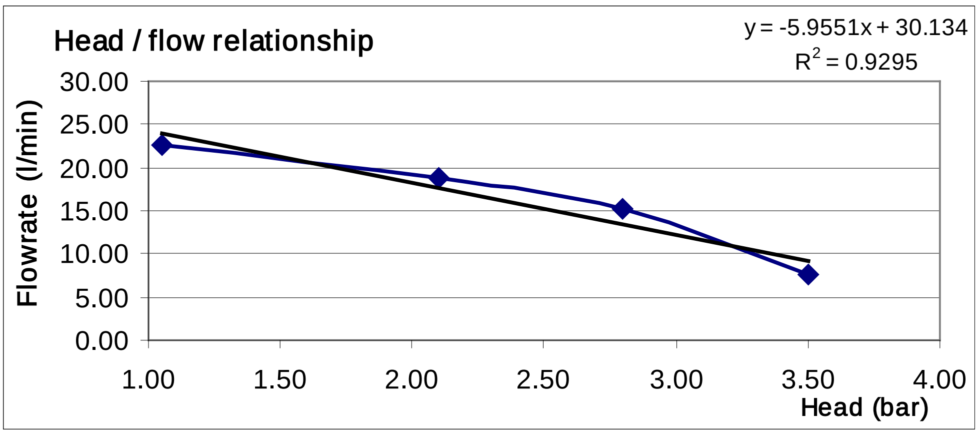


Fig. 65 Head / flow relationship in a study landscape

Fig. 66 Catch can test and flow rate - pressure test

In landscapes the flow rate-pressure test was applied to the main pipe of the irrigation system, due to dimensions of the flow rate-pressure meter. Comparing to farm fields, catch can test and flow rate test procedures were quicker and more flexible in landscapes.

Uniformity indexes

The irrigation uniformity indexes were calculated for the study farms and the statistical parameters of them are presented in Table 24.

Table 24 Statistical parameters of the Uniformity Indices in the study landscapes

	PRavg mm/h)	DUq	DUh	SC	CU
Min	3	30	33	1	11
Max	118	97	97	8	95
Average	23	61	73	2	70
St. deviation	30	17	15	2	18

From Table 24 is concluded that the average participation rate is between 3 mm/h and 118 mm/h, with average in 23 mm/h. The higher values are observed in a landscape were the water source was a drill, and high pressures were recorded. Generally the Precipitation rate was influenced by the type pressure of the water source, the loses factor and the design of the irrigation system.

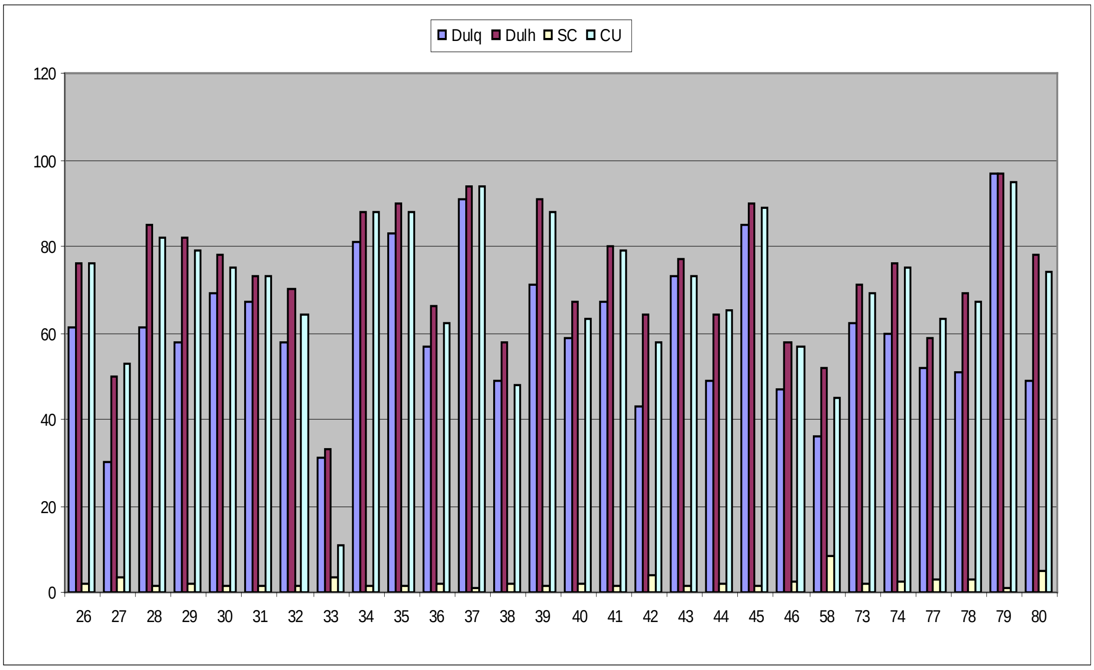


Fig. 67 Uniformity indexes for the study landscapes

As for the Uniformity indexes, generally landscapes had medium uniformity values, both for DUlq, DUlh indexes and Christiansen coefficient. Ten of them had DUlq index values higher that 80%, while the majority of them had value near 73%. Regarding DUlh and Christiansen coefficient, this indexes were follow the distribution of the DUlq index, like in farm fields. Low values in irrigation efficiency, is caused, by the design of the irrigation system, and by the management and maintenance of the irrigation system. Landscapes with wrong design and installation irrigation systems, had as a result low uniformity values.

Irrigation schedule

The irrigation schedules were calculated for each landscape. In Table 25 the applied irrigation period, the irrigation duration and the number of days between two irrigation facts are presented, for each type of plant material of the study landscapes.

Table 25 Irrigation scheduling characteristics for landscapes

Crop type	Irrigation period (months)	Irrigation duration (hours)	Number of days between irrigation events
Herbs	6-7	0.67	2
Horticulture	6	0.5-1.5	1
Rock garden	5	2	1
Turf	4-6	0.17-1	1-4

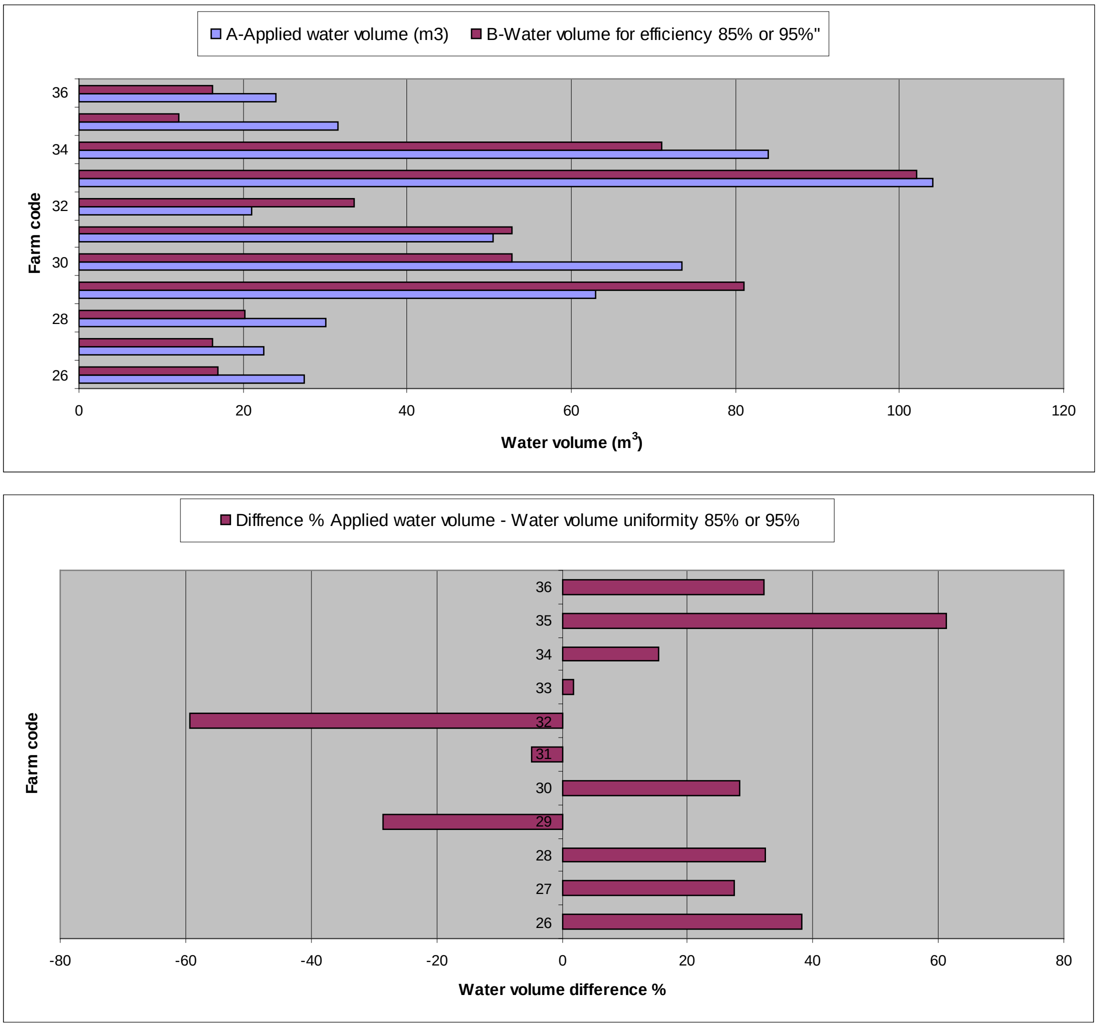


Fig. 68 Applied irrigation volume, Water volume for irrigation uniformity 95%, Difference % between applied irrigation volume and water volume for uniformity 95% for selected study landscapes.

In Fig. 68 the applied irrigation volume, the water volume for irrigation uniformity 95% and the difference % between applied irrigation volume and water volume for uniformity 95% for selected study landscapes is presented. Generally, for the majority of the landscapes, the applied irrigation volume, was higher than the theoretical, and only in few landscapes was lower. Generally, in landscapes, due to lower than the theoretical uniformity indexes, irrigation volumes were higher than the theoretical, for covering the irrigation needs of the plant material.

Problems in irrigation system design and management

In general, conditions in landscapes presented better irrigation characteristics, than farm fields. This is due to deter design of the irrigation system, and to better management and maintenance of the irrigation process by agronomist, or relevant scientist.

Although that, during the auditing some problems were recorded. In some landscapes, which were close to the sea, the irrigation process was heavy influenced by strong winds, which especially in summer, caused non uniformity conditions (Fig. 69). This explains the low uniformity indexes in landscapes with Code 35 and 24.

Fig. 69 Strong wind affects irrigation process in coastal landscapes

Fig. 70 Drainage problems in a landscape

Also, some drainage problems, were recorded in several landscapes, and this was due to leakages and losses from the main pipes of the irrigation system. That phenomena where local, and easily observed (Fig. 70).

Characteristic views of wrong design of the irrigation system in a landscape are presented in Fig. 71. In these, either the sprinkles are in wrong position, or the plant material prevents the irrigation process. Also in Fig. 72, a "plant fence" was grow in front of the sprinkler, and as a result, irrigation in this part of the field is not effective and uniform.

Fig. 71 Wrong irrigation process

Fig. 72 Creation of a "plant fence" in front of a sprinkler

Finally in some landscapes the operation of the sprinklers, was not as the theoretical, and technical problems, were recorded like, broken parts of the sprinklers, of buried in the ground, or non rotated sprinklers. These phenomena were few in number, and recorded mainly in landscapes in which the management was held by non-educated and professional persons.

Irrigation audits in football stadiums

These types of irrigation fields, are special cases, from the general auditing process. In football fields, the auditing process was the same, as this in farm fields or the landscapes.

Irrigation system design

The irrigation system in football fields follows the same principles, than in landscapes, were the position of the sprinklers, and the pipes are controlled from the dimensions of the field. In this case the dimensions and stable, and fixed from the beginning of the construction of the field.

Usually the irrigation pipes are Ø70 and are in depth of 1m under the ground. The sprinklers have usually high flow rate and flow diameter, rotated 360^o in the central part of the field and 90^o and 180^o in the angular parts. From the auditing process no drawings or irrigation plants were recorded for the study football stadiums. A simplified drawing of an irrigation drawing in a football stadium is presented in Fig. 73.

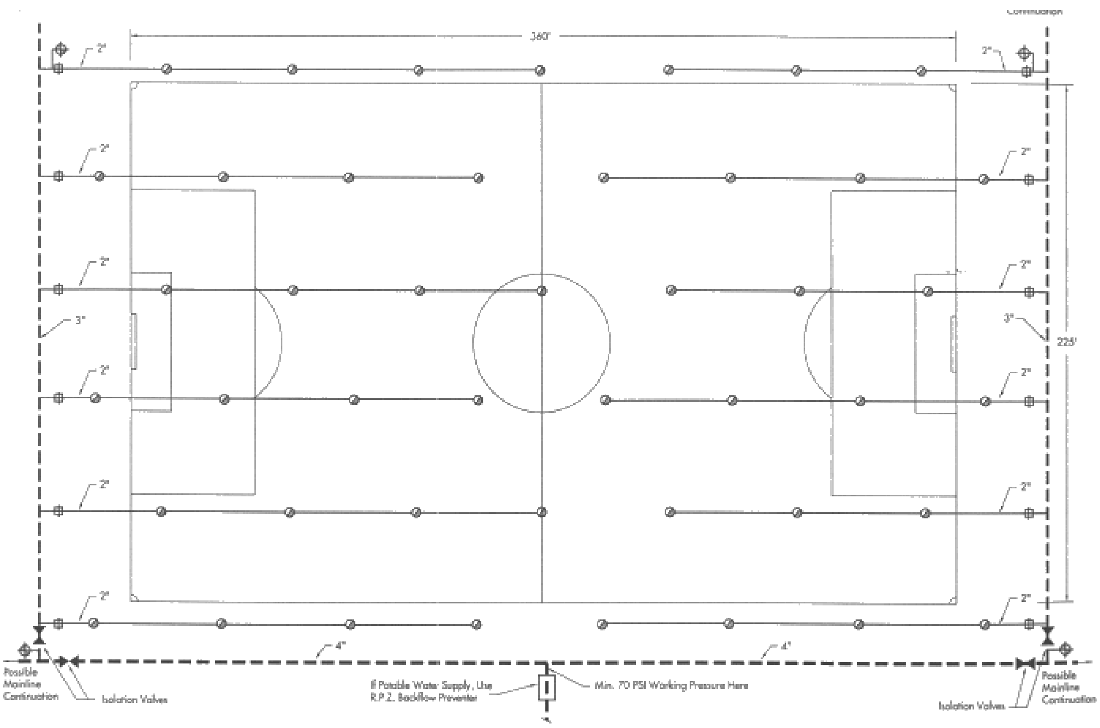


Fig. 73 Simplified irrigation system in a football field

Catch can test – Uniformity indexes

In the study areas, catch can tests were performed for evaluating the irrigation characteristics of each system. In football stadiums the cans positions are presented in Fig. 74 and Fig. 75 and are stable and fixed. From the can test the uniformity indexes were calculated for the football stadiums and was found near 70%. In football stadiums, uniformity indexes controlled by factors that affects the irrigation process in the open fields.


Fig. 74 Catch test in a study football field

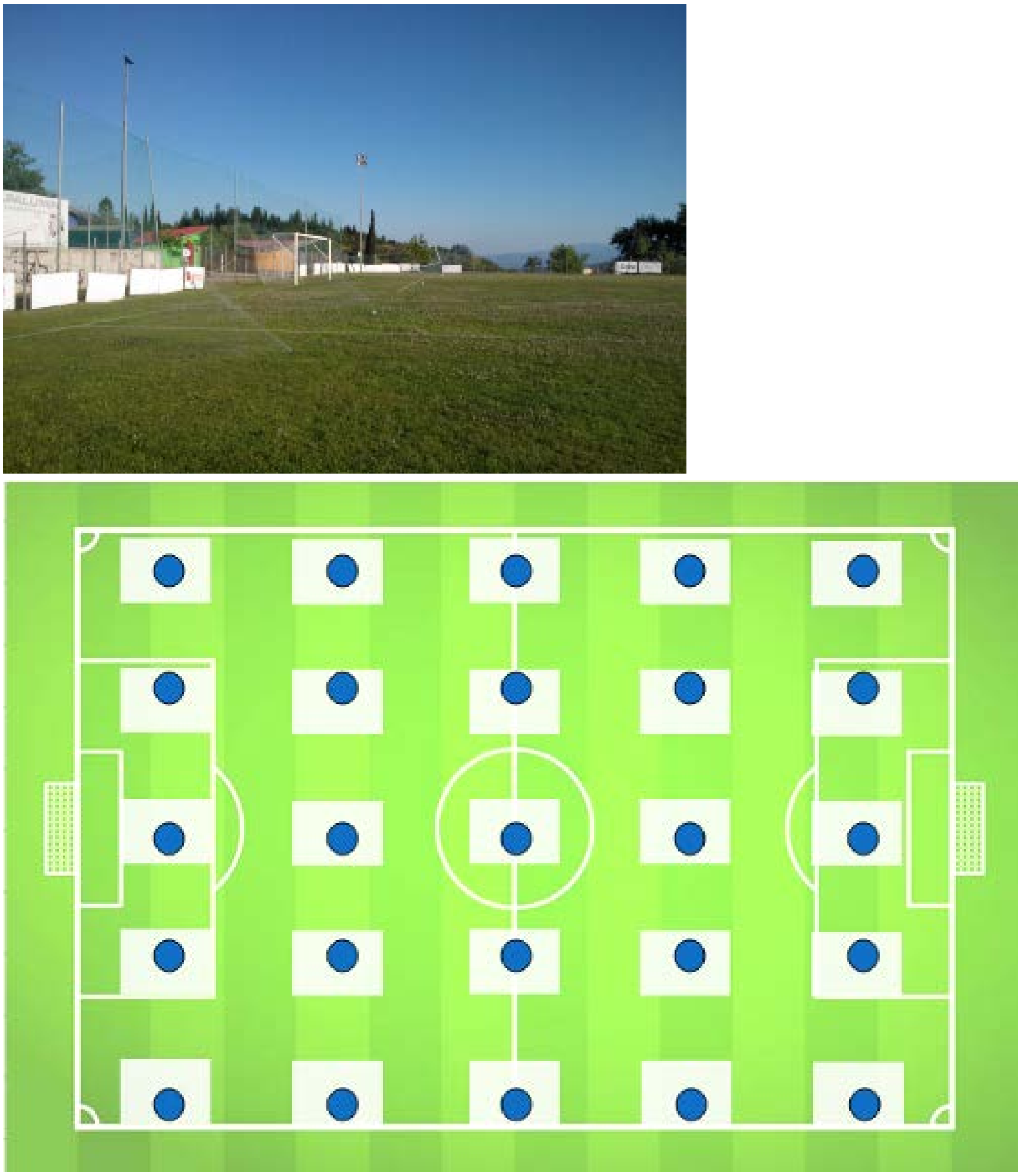


Fig. 75 Catch can positions in a football field

Irrigation schedule

The irrigation program in football stadium is stable, and irrigation period starts from April to September, with irrigation applied every 2 days for about 15-20minutes, according to the meteorological conditions, of the study area. In greenhouses, the type of the crop or the vegetation controls the irrigation program.

Problems in irrigation system design and management

Problems that recorded in the study football fields, involved broken sprinklers, or non rotated sprinklers, especially in the football fields (Fig. 76). Leakages were recorded in one stadium, but this phenomenon was local and due to heavy rain that day in the area (Region of Western Greece). The main problems in football stadiums were the lack of maintenance costs, for the management of the irrigation system and the plant material.

Fig. 76 Irrigation problems in football field

Audit time evaluation and cost estimation

About the time and the costs that needed for the audit procedure, detailed information is presented, based on the audits in the study farms, landscapes, greenhouses and football fields (Fig. 76).

The time for the inspection in the study farms was in average 2 hours and it was controlled from the area of the study farm, the crop material and the soil conditions. In general in landscapes the inspection time was lower than this in farms, in average of 1 hour, and this was due to smaller area. Also in landscapes all the irrigation systems were underground (pipes, control valves etc) and less time needed for the audit.

In greenhouses the inspection time was about 1.5 hours and this was due to more controlled conditions. Although that, a more accurate inspection needed for the irrigation system in greenhouses due to its complexity. Also in football field the time for the inspection was about 2.5 hours due to its area, and it special conditions.

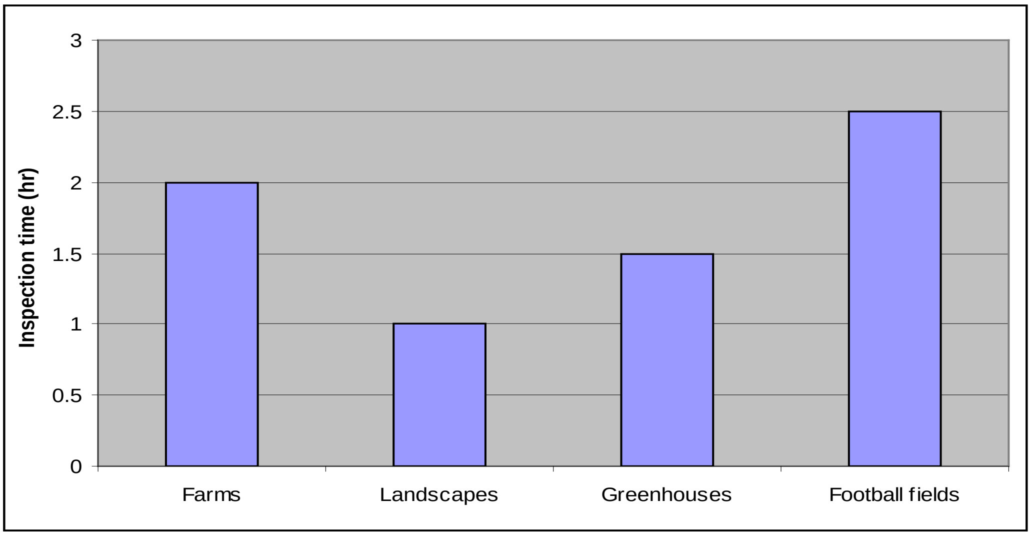


Fig. 77 Inspection time in audits for each type of inspection

Here it should be mentioned that for the auditing procedure, time was necessary for the preparation of the auditing procedure. This time was about 0.5 hour. Also time needed for the soil analysis of the samples in the lab (about 0.5 hr). Also time needed for the work analysis and the preparation of the report (between 4-5 hrs).

For the evaluation of the cost of each audit procedure from the inspection on the field to the presentation of the results, the parameters that were used were:

- The preparation activities (phone calls, etc)
- The travel costs (distance from the base)
- The daily costs (with or without night stop)
- The audit costs (equipment, fittings etc)
- The costs for soil analysis at lab
- The costs for office work for data analysis and report generation
- The costs for presentation of results -recommendations

In Table 25 the costs for the above parameters, that were used for the evaluation of the audit procedure is presented.

Table 26 Costs for evaluating total costs for each audit

Work	Cost per unit		Work unit				Cost (€)
A. Preparation activities	**10**	€/h		pers		h	0.00
B. Travel Cost	**0.17**	€/km				km	0.00
						tolls etc	0.00
C. Daily Cost	**16.6**	€/day (with out night stop)		pers		day	0.00
	50	€/day (with night stop)				day	0.00
D. Audit cost (equipment, fittings etc)						-	0.00
E. Soil anlysis at lab	**10**	€/h		pers		h	0.00
F. Office work for data analysis and report generation	**10**	€/h		pers		h	0.00
G. Presentation of results - recommendations	**10**	€/h		pers		h	0.00
Cost (€)							**- €**
Total Cost (€) plus VAT (23%)							**- €**
Total Cost (€)							**- €**

(grey)	Stable costs per unit
(orange)	Work unit (to be filed)

In Table 25 the statistical values of the total costs of the audits are presented. Based on that the total cost for evaluating the irrigation process in a farm field is 176 – 202€ with average 202€. For landscapes the total costs were 176 – 216€ with average 201€. For greenhouse the total costs were 188 – 221€ and for football fields the total costs were 214€.

Table 27 Costs (€) for auditing in the study farms, landscapes, greenhouses and football fields

	Farm	Landscape	Greenhouse	Football field
Min	176	176	188	214
Aver.	**202**	**201**	**197**	**214**
Max	219	216	221	214
St.Dev	9.70	10.83	11.28	0

Actions for the improvement the operation of the irrigation system

For improving the performance of an irrigation system several actions can apply. Generally, those actions include the maximization of the irrigation efficiency and the reduction of the applied water volumes.

Maximize irrigation application efficiency

It is not possible to achieve efficient application of water with sprinkler and spray systems if the application of water is not uniform. The achievement of high uniformity should be a high priority for new systems and existing systems. There are numerous reasons why operating conditions, including pressure and flow rate, may not be optimum. The system design may be deficient, incorrect equipment may be installed or there may be equipment (e.g. valves) malfunctioning or not correctly adjusted. The use of a pressure gauge to check an irrigation system is a very valuable asset. Irrigation outlet needs to be matched to the situation. Performance characteristics including coverage, operating pressure, flow rate, droplet size, stream trajectory, blockage risk may all need to be considered. The use of microsprays in mulched areas is an example of poor outlet selection. Much of the applied water may be absorbed by the mulch. Drippers positioned under the mulch would be a better selection in many situations.

The wetting of paths, hardsurfaces and roadways is a common example of water wastage. Care should be taken to ensure that part circle sprinklers and sprays are correctly adjusted. Irrigation systems require regular maintenance. They are systems made up of many vulnerable parts. Pop-up irrigation systems are a particular issue. Sprinkler heads may not lift to the required operating position or they may become stuck in the high position and be subsequently damaged by mowers and machinery. The correct functioning of valves also needs to be constantly monitored to ensure that flow and pressure is correct. Some water can be wasted following shut down of a sprinkler or spray line as water will drain to the lowest part of the pipe system. Incorporation of low head shut down valves in sprinkler and spray heads eliminates this source of wastage.

Reduce plant water demand

The rate at which plants use water is dependent on many factors including plant species. There is potential to reduce water requirements by selecting plants that achieve the desired performance yet require less water (in landscapes). Species selection within the turf family is an area for significant potential savings. For example cool season grasses typically use 30% more water than warm season grasses.

There are sometimes opportunities to reduce water demand by replacing vegetation (turf and landscape plants) with impervious surfaces such as paving. The shape of the area to be irrigated can also affect the efficiency of irrigation. Narrow lawn areas, for example, are difficult to effectively irrigate using sprinklers or sprays. The manner in which plants are managed influences the water requirement. Frequent, close mowing of grass results in a higher demand for water than higher, less frequent mowing. Also, high fertiliser rates encourage higher demand for water. Regular aeration and dethatching of grass is recommended. Aeration assists with water penetration and dethatching minimises water absorbed by the thatch and subsequently lost or wasted.

Maximising the potential water storage in the soil should be a key water management strategy. This is particularly important for shallow plants such as grass. Encouraging deeper root systems is strongly recommended. Deep infrequent irrigations are advised rather than shallow infrequent applications. The deep watering ensures water reaches the lower parts of the root system. Allowing the root zone to dry out encourages root development in the lower part of the root system. The application of mulch is a very effective water conservation strategy. Water loss from the soil is eliminated and weed growth, which also wastes water, can be greatly restricted. Some soils exhibit water repulsion or hydrophobic properties. Various chemical treatments are available to improve wettability and infiltration properties of these soils.

Precise control of irrigation

Precision irrigation is based on knowing the appropriate depth of water that should be applied so that the soil moisture level is maintained within the desired range. Overwatering which results in overfilling of the soil water storage and drainage below the root zone is a common source of wastage of water. Detailed knowledge of the site including root zone depth and soil properties is essential in determining the correct depth. Also knowledge of the precipitation rate of the irrigation system is required to determine the appropriate operating time (run time) of the system.

The grouping of plants into areas of similar water requirements allows the irrigation system to be designed and managed so that the desired depth of water can be applied. In areas of mixed plantings, including trees in turf areas, it is necessary to divide up the control of the irrigation system so that the area close to the trees is separately controlled. If it is not then there is the risk that the irrigation system will be operated to achieve satisfactory water around the tree and so the lawn areas will be overwatered.

Adopt new technologies

An accurate estimation of the evaporation close to the site being irrigated is an extremely valuable irrigation management aid. Obtaining feedback on the moisture level in the soil assists in the control of the irrigation. Soil moisture sensors also provide valuable information on water movement through the soil and the water use characteristics of the plant. Irrigation controllers have developed beyond the stage of being sophisticated electrical switch boxes. They can now provide detailed information about the operation of the irrigation system, both electrically and hydraulically. The programming and processing capabilities of today's controllers means that all watering and equipment options can be accommodated.

Operator skills

The competent management and maintenance of an irrigation system requires a reasonable level of skill and expertise. Organisations and educational institutions should continually pursue opportunities to advance the skills of staff involved in irrigation.

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Appendices

Appendix I. Overview table for audits

Appendix II. Irrigation worksheet from a farm

Appendix III. Irrigation worksheets from a landscape

Appendix IV. Irrigation worksheets from a Greenhouse

Appendix V. Irrigation worksheets from a football stadium

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Appendix I. Overview table for audits

Code	Soil	pH	EC (mS/cm)	$CACO_3$	Xaxis	Yaxis	Owner	Culcivation	Area (m^2)	Number of sprinkles or emitters	q (l/h) per sprinkler or emitter	Irrigation months	Hours irrigation
1	SiL	7.9	0.54	11.0	189962	4380410	Dimitris Myriounis	Clover crops	3500	126	90	6	1
2	SiL	7.7	0.16	18.41	173064	4384231	Stergiou Nikolaos	Citrus trees	18000	950	160	3	6
3	Si	7.3	0.37	14.42	173926	4386213	Stergiou Nikolaos	Citrus trees	22000	990	160	4	6
4	SiL	7.2	0.52	12.48	173436	4386867	Stergiou Nikolaos	Citrus trees	9000	400	160	4	6
5	Si	7.3	0.38	14.51	173888	4386328	Stergiou Nikolaos	Citrus trees	22000	990	160	4	6
6	Si	7.3	0.38	14.51	173846	4386376	Stergiou Nikolaos	Citrus trees	22000	990	160	4	7
7	Si	7.5	0.31	11.02	174287	4384108	Kalliamouris Spyros	Kiwi trees	5000	250	160	6	2
8	Si	7.6	0.28	15.70	174635	4384775	Stergiou Nikolaos	Citrus trees	7000	400	160	4	2.5
9	SiL	7.1	1.63	9.42	175936	4388597	Antreas Gogos	Citrus trees	12000	480	170	5	2.5
10	SiL	7.1	2.93	7.82	175992	4388660	Antreas Gogos	Citrus trees	16000	360	120	5	6
11	Si	7.5	0.21	12.14	174287	4384108	Kalliamouris Spyros	Kiwi trees	18000	890	160	6	2
12	SiL	7.3	0.25	31.42	174792	4391966	Gakis Dimitrios	Citrus trees	8000	390	160	4	6
13	Si	7.6	0.25	26.94	174933	4391952	Gakis Dimitrios	Citrus trees	9500	440	160	4	6
14	Si	7.2	0.43	12.60	173890	4386220	Stergiou Nikos	Citrus trees	22000	990	160	4	6
15	SiL	7.4	0.36	17.57	173787	4386580	Stergiou Nikos	Citrus trees	22000	990	160	6	3
16	SiL	7.1	0.94	21.62	174991	4391933	Gakis Ioannis	Citrus trees	6000	238	120	4	6
17	SiL	7.1	1.63	9.42	175913	4388807	Bitos Dimitrios	Citrus trees	5000	220	150	4	6
18	SiL	7.3	0.64	4.27	176089	4390406	Lenis Xristos	Citrus trees	8000	300	160	3	9
19	SiL	7.5	0.13	17.85	177561	4389103	Lenis Xristos	Citrus trees	8500	400	160	4	5
20	SL	7.4	0.78	17.56	178023	4389767	Lenis Xristos	Citrus trees	12500	650	80	4	6
21	L	7.4	0.26	8.02	178048	4389874	Lenis Xristos	Olive trees	5000	160	160	4	5
22	SiL	7.8	0.91	12.50	177534	4389304	Lenis Xristos	Kiwi trees	4500	400	80	5	2
23	SL	7.4	0.33	12.72	172767	4388778	Grigoris Siakos	Citrus trees	16500	1000	140	3	5
24	SiL	7.4	0.43	10.50	177986	4389955	Lenis Xristos	Kiwi trees	23000	1200	100	6	2
25	SiL	7.5	0.23	15.50	180561	4373123	Marialena Anastasiou	Herbs	3700	800	4	8	1
26	SiL	8.0	0.34	11.63	175854	4367768	Eytyxiadis Georgios	Turf	50	10	110	5	0.17
27	SiL	7.8	0.34	7.07	175841	4367741	Theodoridis Georgios	Turf	48	9	100	5	0.17
28	SL	7.8	0.24	3.50	179364	4366305	Zafeiris Anastasios	Rock garden	50	1	100	5	0.25
29	SL	8.1	0.23	3.85	177806	4374389	Idioktisia Ekklisias	Turf	200	9	140	5	0.33
30	SiL	7.1	0.22		179782	4372753	Georgiou Kostas	Turf	130	7	140	5	0.17
31	SiL	7.4	0.52	9.42	178311	4379590	Mpalaskas Spyros	Turf	220	8	140	6	0.25
32	SiL	7.9	1.36	12.35	179446	4373197	Dimosia ektasi	Turf	130	5	140	4	0.50
33	SiL	7.3	0.41	11.55	182119	4373450	Santousis Konstantinos	Turf	250	13	160	5	0.33
34	SL	7.8	0.28	3.40	179731	4372720	Zafeiris Anastasios	Turf	175	30	140	5	0.13
35	SL	7.7	0.35	3.50	185780	4381517	Myriounis Paylos	Turf	30	6	140	5	0.25
36	SL	7.8	0.34	3.30	185547	4381393	Xarisis Axxileas	Turf	40	8	120	5	0.17
37	SiL	7.6	0.16	4.38	229622	4392645	S.M. Beropoulos	Herbs	200	30	8	7	0.67

Code	Soil	pH	EC (mS/cm)	$CACO_3$	Xaxis	Yaxis	Owner	Culcivation	Area (m^2)	Number of sprinkles or emitters	q (l/h) per sprinkler or emitter	Irrigation months	Hours irrigation
38	SiL	7.3	0.16	0.31	226556	4394246	Stayraki kipos	Turf	60	6	140	6	0.33
39	SiL	7.4	0.13	3.17	230642	4392241	S.M. Beropoulos	Herbs	80	50	8	6	0.67
40	SiL	7.2	0.42	8.55	229271	4390787	Biozois A.E.	Turf	60	7	80	6	0.67
41	SiL	6.4	0.44	0.82	228936	4389489	Pan. Ioanninon Kykliko	Turf	2800	25	1500	5	0.25
42	L	6.4	0.17	0.37	228842	4389548	Pan. Ioanninon Nisida	Turf	250	7	140	5	0.67
43	L	6.6	0.14	0.20	228751	4389584	Pan. Ioanninon Kipos	Turf	700	10	1500	5	0.25
44	SCL	6.8	0.15	0.84	228687	4389729	UOI Kipos Plirof.1	Turf	130	20	140	5	0.25
45	CL	6.7	0.1		228713	4389737	UOI Kipos Plirof.2	Turf	350	10	400	5	0.25
46	SL	6.8	0.2	4.47	228505	4389809	Pan. Ioanninon Kipos2	Turf	180	8	140	5	0.67
47	SiC	7.7	0.16	12.59	234915	4331854	Tziomakis Petros	Kiwi trees	10000	500	90	6	2.5
48	SCL	7.6	0.65	0.65	257366	4361134	Nakos Basileios	Turf	170	-	-	-	-
49	SL	8.0	0.19	22.37	239129	4336129	Tatsopoulou Eleni (Mpizas)	Citrus trees	11000	350	90	4	4
50	SiL	5.8	1.66	0.00	235111	4341524	Kolios Athanasios	Pomegranate tr	36000	3100	4	4	10
51	L	7.5	0.2	6.28	230720	4336915	Gkartzonikas THeodoros	Citrus trees	7000	430	120	4	7
52	SiL	6.6	0.25	0.00	234674	4340466	Dimou Eyaggelia	Kiwi trees	10000	600	90	4	1.5
53	SiCL	7.1	0.39	2.21	235141	4341089	Tsolas Mixail	Kiwi trees	6000	300	90	4	2
54	SiL	7.4	0.34	0.24	234953	4340301	Arbaniti Panagiota	Kiwi trees	6000				
55	SiL	7.3	0.35	8.20	233705	4337648	Karantzas Georgios	Citrus trees	8000	330	120	2	5
56	SiL	7.5	0.35	5.13	234291	4341101	Tsirogiannis Paylos	Citrus trees	4900	170	90	2	10
57	SiL	7.2	0.56	8.27	233905	4340111	Tsirogiannis Paylos	Kiwi trees	9250	570	90	4	3
58	SiL	6.9	0.35	4.21	236600	4338136	Kalybas Lampros	Turf	400	40	80	4	1
59	Si	7.4	0.29	7.24	236885	4338548	Kalybas Lampros	Kiwi trees	4000	285	105	4	1.5
60	SiL	7.4	0.29	3.15	233073	4340437	Tsirogiannis Paylos	Kiwi trees	5000	270	90	5	2
61	SiL	7	0.23	0.55	232636	4340085	Tsirogiannis THeofilos	Kiwi trees	7000	400	90	5	2
62	Si	7.2	0.27	0.62	233094	4340051	Tsirogiannis THeofilos	Kiwi trees	12000	880	90	4	2
63	Si	7.4	0.34	6.38	234703	4336792	Tsirogiannis Paylos	Kiwi trees	2000	120	120	5	2
64	Si	7.1	0.27	13.56	235055	4336662	Xylogiannis Dimitrios	Kiwi trees	3500	16.2	3.6	5.5	2
65	Si	7	0.5	13.44	241092	4332895	Tzigkos Xristos	Citrus trees	8000	276	90	5	3.00
66	Si	7.2	0.17	2.97	241109	4332900	Tzigkos Xristos	Citrus trees	8000	270	90	5	10
67	Si	7.6	0.09	7.00	234890	4335450	Xylogiannis Dimitrios	Kiwi trees	14000	970	90	5.5	2
68	SiL	7.6	0.16	11.33	241353	4331390	Papamixail Pantelis	Citrus trees	9000	430	110	4	0.5
69	Si	7.6	0.1	6.22	241107	4330640	Papamixail Pantelis	Kiwi trees	4000	283	90	5.5	0.58
70	SiL	7.6	0.1	6.22	242108	4331070	Papamixail Pantelis	Citrus trees	4000	250	90	4	3
71	SiL	7.6	0.1	6.22	241908	4333367	Papamixail Pantelis	Citrus trees	3500	187	90	4	4.5
72	SL	6.5	0.09	0.00	307360	4236044	Mparlis Milies-Mpala Axaias	Apple trees	1200	50	4	6	3
73	SL	5.3	0.08	0.00	307314	4235953	Mparlis Mpala Patron	Horticulture	1800	400	4	6	1.5
74	SL	7.5	0.15	1.02	307260	4236003	Mparlis Mpala Patron	Horticulture	300	8	550	6	0.5
75					294833	4218894	THanopoulos Alexios	Wine trees	12000	2000	4	5	10
76	SL	7.3	0.2	2.80	309706	4227767	Lazanas Paraskeyas	Cherry trees	10000	300	60	5	12

Code	Soil	pH	EC (mS/cm)	$CACO_3$	Xaxis	Yaxis	Owner	Culcivation	Area (m^2)	Number of sprinkles or emitters	q (l/h) per sprinkler or emitter	Irrigation months	Hours irrigation
77	SiL	7.7	0.16	21.00	276359	4226530	Papaxristodoulou Giorgos	Turf	250	20	100	5	0.25
78	SL	7.6	0.11	17.13	276059	4226230	Papaxristodoulou Giorgos	Turf	400	0.8	8	6	0.25
79	SiL	7.5	0.23	29.65	303896	4237882	Papaxristodoulou Giorgos	Turf	50	4	100	6	0.25
80	SiL	7.5	0.14	18.83	302866	4237104	Papaxristodoulou Giorgos	Turf	72	11	100	6	0.25
81	LS	7.3	0.24	16.80	302664	4236953	Gipedo Panaxaikis	Turf	7000	22	4200	6	0.25
82					219602	4313584	Papoutsis Baggelis	Tomatoes	2000	5600	4	12	0.33
83					218281	4316981	Mprikos Dimitris	Cucumbers	6000	16800	4	12	0.33
84					229531	4355949	Mprikos Christos	Tomatoes	8000	22400	4	12	0.33
85					223307	4356168	Voulistios Christos	Cucumbers	6000	16800	4	12	0.3
86					228770	4356126	Karamanis Georgios	Tomatoes	4000	11200	4	12	0.5
87					218281	4316981	Audιkou Spiridoula	Cucumbers	6000	16800	4	12	0.3
88					218461	4316635	Karamani Polikseni	Tomatoes	4000	11200	4	12	0.4
89					218461	4316635	Poulianou Aliki	Tomatoes	2000	5600	4	12	0.3
90					218465	4316640	Poulianou Erofili	Tomatoes	3000	8400	4	12	0.3
91					217068	4320792	Maki Parthena	Tomatoes	2000	5600	4	12	0.3
92					217218	4321079	Gkopis Thanasis	Tomatoes	5000	14000	4	12	0.3
93					218461	4316635	Polianou Eleni	Tomatoes	3000	8400	4	12	0.3
94					217068	4320792	Magklara Anthoula	Peper	2000	5600	4	12	0.3
95					217075	4320800	Saougkos Christos	Tomatoes	4000	11200	4	12	0.3

Code	Applied irrigation water (m3/year)	Mesured water in pump (m3/h)	Water budget for Uniformity 85-95%		Water budget from test Uniformity		Pravg	Dulq	Dulh	SC	CU	Time for inspection (hrs)	Km from base	Total cost (€)
			Water volume (m^3/year)	Irrigation time (hr)	Water volume (m^3/year)	Irrigation time (hr)								
1	2041		1597	0.85	1912	1.00	5.84	55	71	2.29	67	2.5	29	219
2	5863		6281	4.20	29261	19.53	13.2	12	18	12.95	12	2.5	17	217
3	8146	119.28	7677	2.63	10955	3.77	21.03	49	60	2.29	57	2.5	19	217
4	3840	53.01	2691	2.30	5108	4.35	20.69	31	45	8.12	39	2	21	205
5	9504	119.28	6563	5.53	8446	7.13	8.54	62	66	1.68	62	2	19	205
6	11088	109.25	6580	4.23	11289	7.27	11.2	30	50	7.33	46	2	19	205
7	4800	24.15	3136	1.37	3705	1.6	14.32	58	72	1.87	70	2	14	204
8	1920		2613	2.75	2884	3.03	14	70	77	1.57	74	2	15	204
9	3825	88.32	3588	2.37	8430	5.57	13.37	31	36	4.37	21	2	22	205
10	4860	47.15	4785	1.40	11083	3.23	22.66	28	37	4.94	18	2	22	205
11	17088	113.85	11215	1.25	15620	1.73	15.56	47	61	3.05	58	2	14	204
12	2246	69.00	1194	9.83	4149	20.47	8.04	33	41	3.15	25	2	31	207
13	3379	68.08	3552	10.95	5895	18.17	5.41	47	51	2.66	41	2	31	207
14	8146	87.40	7648	10.88	10641	15.13	5.07	42	61	4.97	59	2	19	205
15	7128	67.62	6563	1.6	8575	2.08	29.67	59	65	2.24	64	2	20	205
16	1714	68.08	1794	2.30	5636	7.20	20.7	20	27	5.08	5	2	31	207
17	1188	36.80	1246	2.53	2557	5.18	31.28	23	41	10.23	44	2	23	205
18	1944	39.74	1992	8.57	2970	12.77	9.22	54	57	2.01	46	2	26	206
19	3840	59.62			3127	6.00	6.49	79	86	1.82	83	2	23	205
20	4680	80.00	3738	5.37	8646	12.42	5.89	32	37	3.85	24	2	24	206
21	1024	12.00	821	1.32	2569	4.08	27.71	19	27	6.8	17	2	24	206
22	3600	80.00	3136	0.92	3706	1.07	13.46	65	76	1.76	73	2	23	206
23	2520	55.00	5140	3.50	11079	7.53	28.27	30	39	27.73	29	2	26	206
24	16200	80.00	14396	2.27	20085	3.17	5.69	45	61	2.79	61	2	25	206
25	192	9.20	497	0.17	662.00	0.22	120.7	20	64	7.9	60	2	18	205
26	28		17	0.25	21.28	0.32	15.51	61	76	2.03	76	1	32	183
27	23		16	0.30	29.04	0.53	12.9	30	50	3.38	53	1	32	183
28	4	1.50	20	0.70	22.68	0.78	6.26	61	85	1.64	82	1	35	183
29	63	1.73	81	0.73	94.10	0.85	5.94	58	82	1.94	79	1	14	179
30	74		53	0.30	64.12	0.37	14.84	69	78	1.62	75	1	19	180
31	50	1.68	53	0.38	68.63	0.50	11.46	67	73	1.5	73	1	1	176
32	21	1.45	33	0.50	45.45	0.68	13.14	58	70	1.72	64	1	18	180
33	104	2.99	102	0.20	296.00	0.58	22.19	31	33	3.63	11	1	19	180
34	84	2.88	71	0.05	76.63	0.05	107.72	81	88	1.32	88	1	19	180
35	32	1.36	12	0.65	12.91	0.68	6.79	83	90	1.33	88	1	19	180
36	24	1.31	16	0.52	23.41	0.75	8.47	57	66	2.08	62	1	18	180
37	17	1			17.72	1.23	117.99	91	94	1.1	94	1	132	210

Code	Applied irrigation water (m3/year)	Mesured water in pump (m3/h)	Water budget for Uniformity 85-95%		Water budget from test Uniformity		Pravg	Dulq	Dulh	SC	CU	Time for inspection (hrs)	Km from base	Total cost (€)
			Water volume (m^3/year)	Irrigation time (hr)	Water volume (m^3/year)	Irrigation time (hr)								
38	25	1.15	20	1.28	31.06	1.97	7.3	49	58	2.05	48	1	126	209
39	24	1.15	27	0.13	28.21	0.13	75.38	71	91	1.41	88	1	134	210
40	34	1.15	20	0.58	28.68	0.83	16.08	59	67	1.75	63	1	130	209
41	703		946	0.7	1123	0.82	13.6	67	80	1.67	79	1	129	209
42	49		84	0.58	125	0.85	16.44	43	64	4.03	58	1	128	209
43	281		238	0.7	294.11	0.87	3.49	73	77	1.37	73	1	128	209
44	53		44	0.3	65.11	0.45	31.92	49	64	2.09	65	1	128	209
45	75		118	0.75	125.06	0.8	12.59	85	90	1.3	89	1	128	209
46	56		61	0.7	98.99	1.13	13.5	47	58	2.65	57	1	128	209
47	10125				5091	0.95	12.63	89	94	1.46	93	2	20	205
48	-	4.97										2	72	216
49	3780	50			3857	0.93	15.1	71.0	85.0	1.7	83.0	2	6	202
50	2126	51.4	14596	0.15	30308	0.32	257.2	20.0	41.0	20.2	39.0	2	13	203
51	2890	89.1			2620	5.97	10.0	74.0	85.0	1.4	83.0	2	22	205
52	9720		6249	2.07	19038	6.3	6.2	-	28.0	-	22.0	2	13	203
53	3240		3735	1.32	4017	1.417	9.8	66.0	79.0	2.4	78.0	2	12	203
54												2	12	203
55	396		2988	5.9	6342	12.53	20.1	37.0	40.0	3.9	25.0	2	14	204
56	306	54	1836	9.15	2053	10.23	13.0	60.0	76.0	1.7	76.0	2	14	204
57	9234	73.6	5742	0.78	6775	0.92	16.6	64.0	72.0	2.2	72.0	2	14	204
58	192		188	0.3	343	0.53	17.2	36.0	52.0	8.3	45.0	2	7	202
59	5387				5462	0.88	14.0	86.0	90.0	1.2	90.0	2	6	202
60	3645	30.8	2788	0.8	3159	0.92	16.2	53.0	75.0	2.8	73.0	2	17	204
61	5400		4374	24	5389	0.98	16.3	55.0	69.0	2.1	68.0	2	17	204
62	9504		7446	0.92	8544	1.05	14.2	51.0	74.0	2.6	71.0	2	16	204
63	2160		1234	0.88	1782	1.27	14.6	46.0	59.0	3.2	50.0	2	12	203
64	3267		2175	1.77	3479	2.82	7.3	40.0	53.0	3.0	51.0	2	12	203
65	1597		2805	0.42	8602	1.27	68.2	23.0	28.0	5.8	20.0	2	15	204
66	2430		2488	8.28	3302	11	11.9	57.0	64.0	2.7	63.0	2	15	204
67	14405		8988	0.43	10335	0.5	15.0	54.0	74.0	5.9	73.0	2	14	204
68	284		3346	1.47	5350	2.33	27.1	45.0	53.0	2.7	37.0	2	18	205
69	1226		2506	0.37	5494	0.78	36.3	29.0	39.0	5.7	30.0	2	20	205
70	270		1489	18.4	3813	47.1	6.4	24.0	33.0	-	25.0	2	20	205
71	606		1170	7.65	1589	10.37	6.9	50.0	70.0	2.0	70.0	2	14	204
72	216				235	0.03	91.6	74.0	83.0	2.3	83.0	2	14	204
73	432		580	0.07	775	0.08	51.7	62.0	71.0	1.8	69.0	2	13	204
74	396		493	0.28	440	0.25	16.2	60.0	76.0	2.4	75.0	2	13	204
75	1714		993	0.07	1596	0.1	166.2	38.0	59.0	5.8	55.0	2	45	210
76	2314		1986	3.38	2311	3.95	10.4	37.0	73.0	4.1	70.0	2	27	206

Code	Applied irrigation water (m3/year)	Mesured water in pump (m3/h)	Water budget for Uniformity 85-95%		Water budget from test Uniformity		Pravg	Dulq	Dulh	SC	CU	Time for inspection (hrs)	Km from base	Total cost (€)
			Water volume (m^3/year)	Irrigation time (hr)	Water volume (m^3/year)	Irrigation time (hr)								
77	38		68	1.15	108	1.83	4.9	52.0	59.0	3.2	63.0	2	68	215
78	198		108	1.27	150	1.73	4.5	51.0	69.0	2.9	67.0	2	69	215
79	9				40.35	1.05	5.3	97.0	97.0	1.0	95.0	2	8	202
80	12		19	1.07	23.72	1.3	5.2	49.0	78.0	5.1	74.0	2	5	202
81	2079		1765	2.5	2991	4.23	4.5	54.0	56.0	1.8	52.0	2.5	4	214
82	1344				1510	0.083	194.3	1.2	83.0	1.4	83.0	1.5	9	190
83	4032				2863	0.067	201.9	75.0	87.0	1.5	86.0	1.5	0	188
84	5376				3241	0.05	237.7	81.0	88.0	1.7	88.0	1.5	101	210
85	4032				3735	0.07	199.1	80.0	85.0	1.4	85.0	2.0	99	221
86	4032				2919	0.05	209.3	72.0	84.0	1.5	83.0	1.8	101	218
87	4032				2435	0.05	207.3	77.0	86.0	1.5	86.0	2.0	0	201
88	3360				1810	0.07	208.7	81.0	88.0	1.5	88.0	1.5	1	189
89	1344				1432	0.07	200.5	77.0	85.0	1.5	85.0	1.5	1	189
90	2016				2171	0.07	193.9	82.0	88.0	1.4	87.0	1.8	1	195
91	1344				1515	0.08	183.2	81.0	88.0	1.3	88.0	1.8	10	199
92	3360				2584	0.07	193.9	74.0	83.0	1.5	83.0	1.5	10	191
93	2016				2349	0.08	186.8	77.0	84.0	1.4	83.0	1.5	1	189
94	1344				1350	0.07	178.3	82.0	88.0	1.3	88.0	1.5	10	191
95	2688				2034	0.07	187.3	78.0	88.0	1.4	87.0	1.5	10	191

Appendix II. Irrigation worksheet from a farm

	Date	Sign
My system got audited		
I received the audit results		

ETCP GREECE-ITALY 2007-2013

IRMA Subsidy Contract No: I3.11.06

www.irrigation-management.eu

Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

fill data or circle (O) in cells colored in | manH and other costs
check (√ or O) squares ☐
for extra comments, number and fill info at Notes (bottom of page)
B: Bad; M: Moderate; F: Fair; E: Excellent

WP5 Irrigation Audits

Auditing team members name (chief inspector first): Christos Myriounis; Dimitrios Myriounis

Audit No: No3

A. First contact and field work plan

Organisation	Private
Name and age	Stergiou Nikolaos
Position of contact person	Owner / Subcont/or / Manager / Other
Address	Kestrini Filiates
Telephone numbers	+306944783640
Other contact information (website, email etc)	

First contact, explanation of the procedure

Try to collect as much basic information as you can during this contact

Check Have you filled an irrigation survey questionnaire of IRMA project? Yes / No

If Yes, a copy should be inquired by the relevant contractor and most of the

If No, a communication with the relevant contractor should be made in order to register this system.

Provide information regarding the documents that you will need and ask for copies

			Comments
Yes	No	Topographic or a coverage diagram	
Yes	No	Plan of the irrigation and drainage system	
Yes	No	Pumping system / grid connection design	
Yes	No	Manuals of the system's basic components (i.e. pump operation diagram)	
Yes	No	Electric power accounts of the system	
Yes	No	Bills from the Local Land Reclamation Service (LLRS) or other similar	
Yes	No	Latest soil and/or water analysis available	
Yes	No	Latest statement regarding EU agricultural funding	
Yes	No	Registrations of the cultivation system (eg integrated management)	
Yes	No	Reports from previous audits	
		Set date, time, location for the audit	
		Selection of date based on weather conditions. In case of sprinkler system, it is recommended to select not intensely windy conditions. For accurate results note that collection of data should be time independent to prior irrigation of the study area.	
	☐	Call the day before to confirm appointment	

Notes (use numbering for references)

A, C. Basic system characteristics

Date	11/8/2014	**Time**		manH and other costs
		arrival at field	8:30	
		departure from field	10:45	

Location, type of setup, total area

Location	Valtos Ragiou	GLRS		LLRS	
		Name			
			o	'	"
Latitude	39.56628771		39.00	33.00	58.635763
Longitude	20.20619399				

Type of setup (√)

Open field	✓	Public	□
Greenhouse / Nethouse	□	Private	✓
Landscape (turfgrass, shrubs, trees)	□		
Athletic installation	□	Area (ha)	2.2

System designer	**Craftsman**	Agricult/list	Him/Her self	Other	
System constructor	**Craftsman**	Agricult/list	Him/Her self	Other	
System conservator	Craftsman	Agricult/list	**Him/Her self**	Other	
System administrator	Craftsman	Agricult/list	**Him/Her self**	Other	

Operational problems reported by the system administrator

Low pressure	✓	Low pressures
High pressure	□	
Tilted sprinklers	□	
Sunken sprinklers	□	
Spray deflection	□	
Arc misalignment	□	
Drainage from low placed sprinklers	□	
Different oulets at the same zone	□	
Missing or broken components	□	
Clogged components	□	
Leaky seals or fittings	□	
Pipe leaks	□	
Slow drainage / ponding / surface runoff	□	
Compaction / thatch	□	
Other mulfactions etc		

In case of a previous audit, confirm that the proposed improvements and repairs have been made before proceed to the new audit.

Basic system use (√)	✓	Irrigation	
	✓	Frost protection	
	□	Other	

Notes (use numbering for references)

manH and other costs

Water supply / POC (point of connection) characteristics

Source type

Irrigation canal	Spring Anakoli
Water pond / tank	
Drilling (depth (m) and pipe diameter ("))	
Civil water system	
Other	

Irrigation rules (bans, irrigation time windows etc)				
Water meter (Y/N, characteristics)	Yes	No		
Condition of water supply / POC area (circle)	Bad	Moderate	Fair ✓	Excellent
Photos ☐				

Irrigation water usage/cost, data?	Yes	No	20..	20..	20..
If yes, irrigation water usage (last 3 years, m3)					
or how many hours per year the system irrigates					
Irrigation cost (last 3 years, € y^{-1})	Labor		Materials		

Pump identification

Ask for or find manuals of components and circle if available — Manual

Manufacturer	CAPRARI
Model	HELLAS ELECTRON
Age	22
Power / max RPM	35 HP ___ rpm
Typical operating flow (select or write unit)	180 m^3/h Lm^{-1} Lh^{-1} ….
Typical operating pressure (select or write unit)	2.9 atm bar …
Pressure tank (circle and note)	Yes No — Characteristics:
Other	
Photos ☐	

Energy source (circle, or specify)	Petrol	Gas	Electricity	…	…
Power system diagram availability (circle)		Yes	No	Notes:	
Condition of power supply system (circle)		Bad	Moderate	Fair	Excellent
Other					
Photos ☐					

Energy

cost (€ y^{-1}) ______ or typical energy consumption per hour ______

this info must be treated in combination with the applied schedule data in Zone characteristics

Filters

System head filtering system

		Order	Characteristics	mesh or color
Hydrocyclone	☐			
Sand	☐			
Mesh	☐			
Disk	☐			
Reverse osmosi:	☐			
Other…	☐			

Notes (use numbering for references)

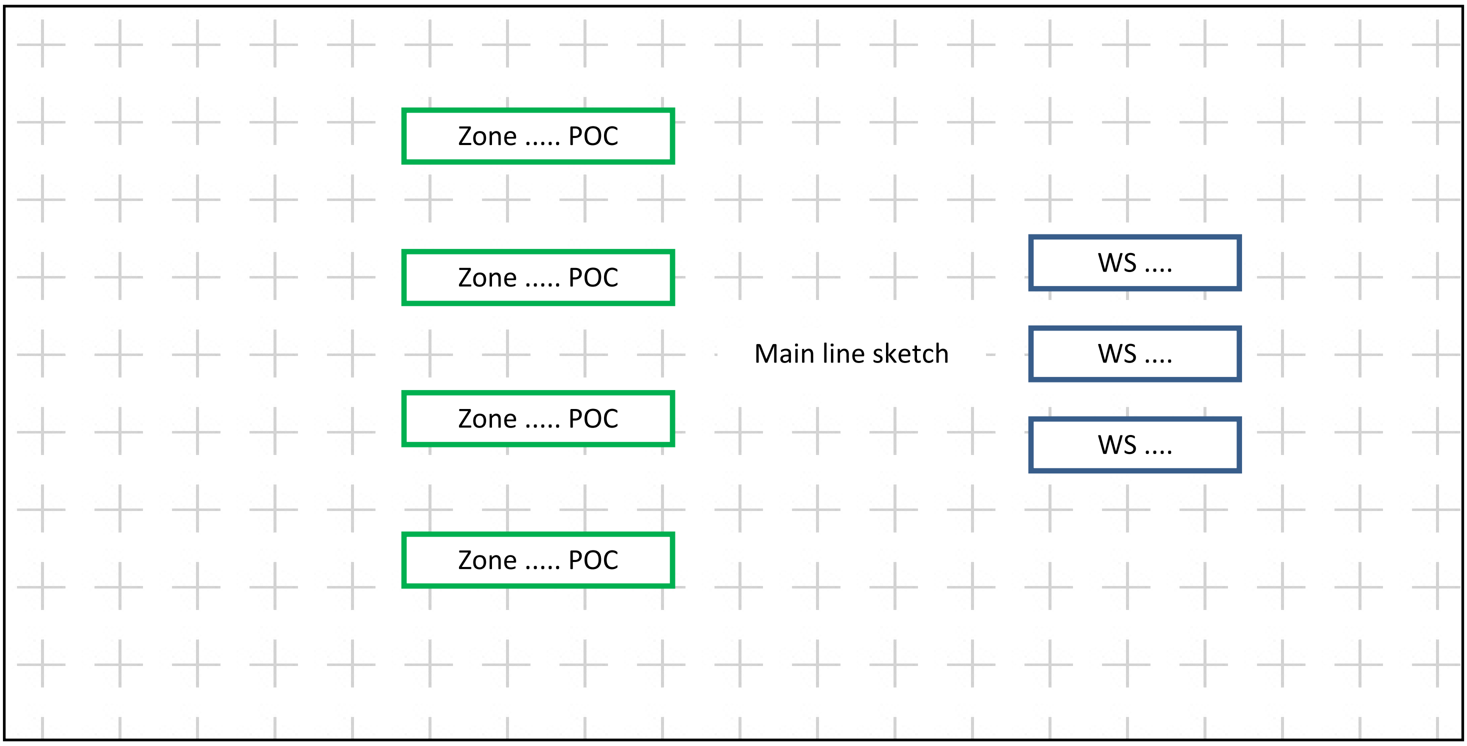
	Check	Condition (B, M, F, E)	Characteristics and comments regarding placement	manH and other costs
Other key components				
Check valve	□			
Backflow preventer	□			
Air valve	□			
Flush valve	□			
Other				
Other				
Other				

Type of main pipes (material, pressure range) and depth of installation

Section (initial - final length in m)	PVC (Ø mm)	PE(LDPE) (Ø mm)	PE(HDPE) (Ø mm)	(Ø mm)	Pressure (Schedule, atm))	Height (m)*
800	0	125			10	-0.5
-						
-						
-						

* in case of underground system enter a negative value

Basic system and surroundings that affect irrigation sketch (circle if available) Available



Show info regarding
Water supply (WS)
Mainline
Zones/Stations (A, B, C,….)
Zones' point of connection (POC)

Connection of zone control valves (circle)
Central Close to zones

Photos □

Notes (use numbering for references)

Identify irrigation system zones (stations)

Zone (A-Z and System type code)	Slope (%)	Soil sample no	Area (m^2)	Irrigation system type: Sprinkler	Micro	Other	Probability of horizontal - upward motion of water
A	0	2	22000	✓	□	□	
B				□	□	□	
C				□	□	□	
…				□	□	□	
…				□	□	□	

continued…

OF: Open field; G/N: Greenhouse / Nethouse; L: Landscape (turfgrass, shrubs, trees); A: Athletic

Zone	Plant material	Yield (kg, pieces, etc)	Crop rows dist. (m)*	Crops dist. on row (m)*	Plant material similarity (√)	Establishement year
A	Citrus Trees		4	5	✓	1990
B						
C						
…						
…						
…						

* or planting density (plants per area unit)

Notes (use numbering for references)

manH and other costs

A, C. Irrigation zone layout and components

Zone (use separate sheet for every zone, in case of greenhouse also fill the relevant sheet)

Ask for or find manuals of components

Sampling and measurements

Soil sampling	Pos:		Pos:	
skip in case that a recent	x	00-30 cm		00-30 cm
soil analysis is available		30-60 cm		30-60 cm
		cm		cm

Notes on soil layering

Select proper template to sketch the zone arangement

Valve Ask for or find manuals of components and circle if available Manual

Manufacturer

Model

Flow range

Pressure range

Condition (circle) Bad Mediocre Fair Excellent

System control

Manual control

Irrigation controller

Ask for or find manuals of components and circle if available Manual

id / Manufacturer / Model

Age

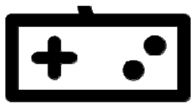
Number of stations — Power supply ◻ Current

Number of programs — ◻ Battery

Number of start times

Rain delay (Y/N)

Pump control (Y/N)	Yes	No
Water budget (Y/N)	Yes	No
Sensor(s) port (Y/N)	Yes	No
Other	Yes	No



Wiring (notes)

Sensors (check and comment regarding installation)

Rain sensor ◻

Soil moisture sensor ◻

Wind senor ◻

Other ◻

Other

Photos ◻

Filter (zone or line) Ask for or find manuals of components and circle if available Manual

Type Mesh Disk Manufacturer Model

Mesh or color

Flow range

Pressure range

Condition (circle) Bad Moderate Fair Excellent

Pressure regulator Ask for or find manuals of components and circle if available Manual

Manufacturer / Model

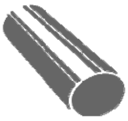
Input / output flow

Condition (circle) Bad Moderate Fair Excellent

Notes (use numbering for references)

Other key components	Check	Condition (B, M, F, E)	Characteristics	manH and other costs
Feltilisation equipment	□			
Check valve	□			
Air valve	□			
Flush valve	□			
Other ………………	□			

Type of pipes (material, pressure range) and depth of installation



	PVC (Ø mm)	PE(LDPE) (Ø mm)	PE(HDPE) (Ø mm)	(Ø mm)	Pressure (Schedule, atm))	Height (m)*
Zonepipes	75				6	-0.5
Application	25				6	0

* in case of underground system enter a negative value

Outlets

Big guns / travelling irrigators characteristics					Manual
Manufacturer					
Model					
Operating pressure				unit:	
Flow rate				unit:	
Condition	Bad	Mediocre	Fair	Excellent	

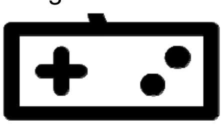
Sprinklers and micro-sprinklers characteristics						Manual
Manufacturer	Palaplast					
Model	Brown color					
Nozzles (type or	90o		180o		270o	
press/flow)..units	360o	X	…		…	
Layout type (circle)		Square	Triangular			
Distance between	4	5		Wet radius		
Condition (circle)	Bad	Moderate	Fair	Excellent		

Drippers / Emitters and Driplines characteristics:					
Individual emitters		Driplines		Height (m)	
Manufacturer					
Type or press/flow (units)					
Distances	on pipe or dripline		between pipes or driplines		
Pressure regulated?	Yes	No			
Self cleaned?	Yes	No			
Condition (circle)	Bad	Mediocre	Fair	Excellent	

Applied schedule

Manual	Month	June to beginning of October
	Number of irrigation events	7
	Run time (min)	360.00

Using controler



Program	
Start times	
Frequency	
Run time	
Special sensor application (i.e. at valve common)	

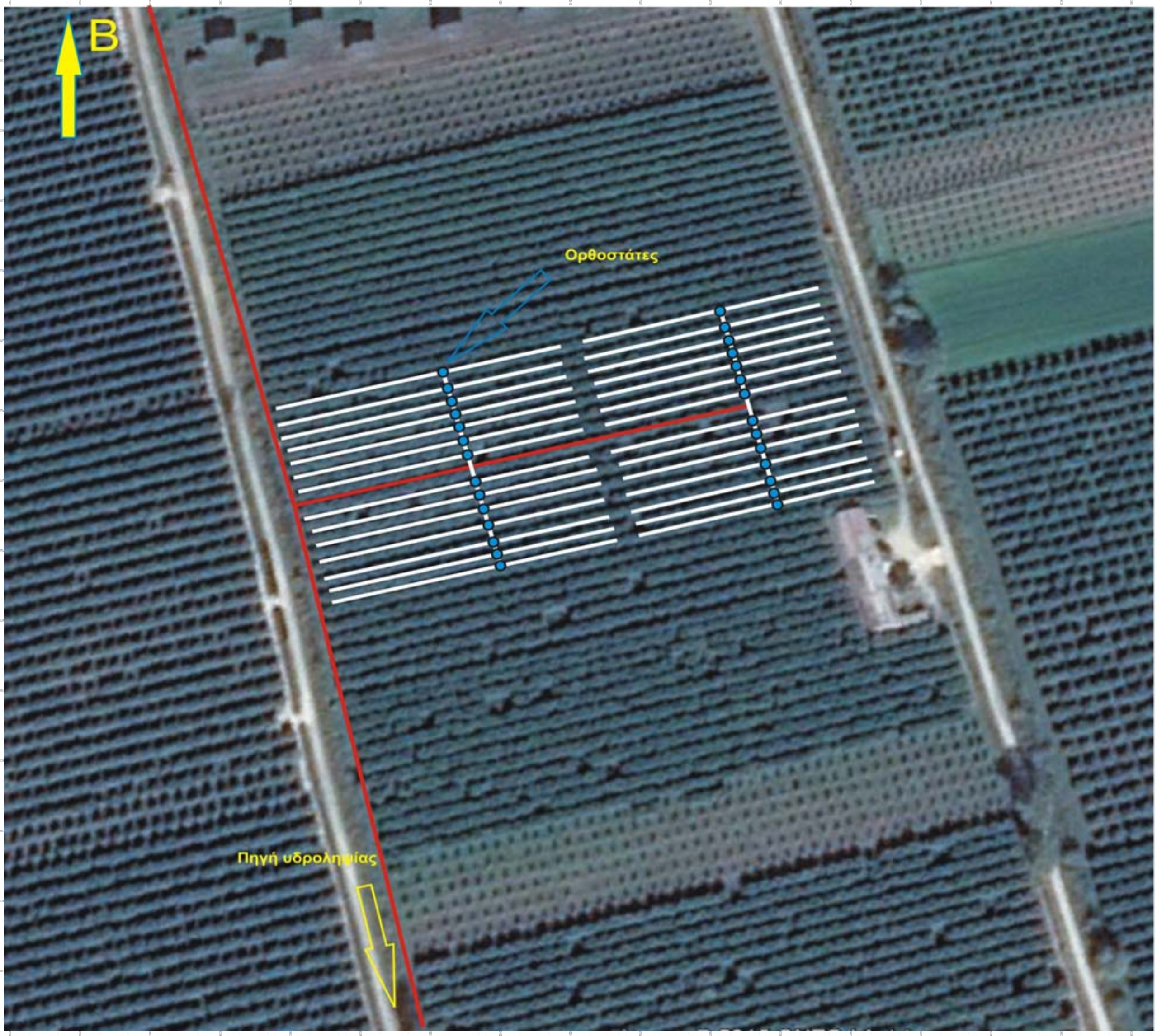
Using other approcah

Notes (use numbering for references)

Generic **Zone sketch (system zoomed in at zone scale)**

manH and other costs

Irrigation & Drainage



Mark
North direction (N)
Borders

Irrigation system layout with basic technical information
head components, pipes, pos and number of outlets, other comp.
number of outlets per lateral
Drainage system layout with basic technical information

Information regarding drainage system

Type (circle an Drainage ditches / canals
Underground pipeline system
Layering with coarse grained materials
Other

Are there any problems of inadequate drainage?
Where does the runoff terminates?

Photos □

Notes (use numbering for references)

manH and other costs

C. System operation evaluation and uniformity measurements

Zone ________ (use separate sheet for every zone)

Wind speed ________ km/h

Check and record wind speed at 2m: should be < 8 km/h (4.97 m/h)
Wind speed should be monitored also during the test if variations are sensed

Either the table or the generic or special design can be used for data keeping

Operation and measurement (in case of sprinkler systems, along with catch cans measurements)
Pressure tests must be conducted at normal operating conditions of the oulets using the appropriate pressure gauges
For pipes, at the beginning, middle, and end of every zone audited.

Outlet / Pipe-pos.	Operating pressure (bar)	Radius (for sprinklers) (m)	Pipe flow rate (….)	Comments / Observed problems
1	1.2	2.4	90l/h	
2	1.2	2.1	90l/h	
3	1.15	2.2	90l/h	
4	1.2	2.5	90l/h	
5	1.15	2.5	90l/h	
6	1.2	2.5	90l/h	
7				
8				
9				
10				
11				
12				
13				
14				
15				

Zone problems detected by the auditor

Improper zoning	
Limited controller capability	
Incorrect pressure (low / high)	
Lack of adequate flows	
Improperly sized components	
Old or worn out equipment	
Dirty or teared filters	
Tilted Sprinklers	
Spray Deflection	
Sunken Sprinklers	
Plugged Equipment	
Arc Misalignment	
Low Sprinkler Drainage	
Leaky Seals or Fittings	
Lateral or Drip Line Leaks	
Missing or Broken Heads	
Slow Drainage or Ponding	
Compaction/Thatch/Runoff	
Other	

manH and other costs

Soil moisture sensor type:

Equation used:

Measurements

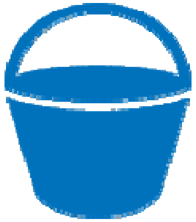
Number of catch cans 20 (at least 20)

Test duration 15 min sec

Catch-can throat diameter cm

or specific cath-can Underhill_mini

Pos / Catch Can	Measur. (select unit)	Soil moisture (v/v %) Before	After	Difference	Comments / Observed problems
	ml	% v/v	% v/v	% v/v	
1	38	10.80%	35.60%	24.80%	
2	25	14.60%	47.10%	32.50%	
3	18	19.20%	26.80%	7.60%	
4	18	15.80%	32.90%	17.10%	
5	60	13.70%	38.00%	24.30%	
6	23	15.40%	23.00%	7.60%	
7	30	16.70%	33.20%	16.50%	
8	36	12.90%	29.40%	16.50%	
9	25	15.90%	28.80%	12.90%	
10	32	16.80%	23.10%	6.30%	
11	62	10.50%	44.40%	33.90%	
12	52	17.50%	44.20%	26.70%	
13	25	15.50%	24.70%	9.20%	
14	18	13.40%	29.80%	16.40%	
15	32	17.10%	30.70%	13.60%	
16	62	18.00%	36.60%	18.60%	
17	120	13.20%	44.60%	31.40%	
18	60	18.60%	37.30%	18.70%	
19	50	15.80%	41.30%	25.50%	
20	40	17.80%	23.60%	5.80%	
21				0.00%	
22				0.00%	
23				0.00%	
24				0.00%	
25				0.00%	
26				0.00%	
27				0.00%	
28				0.00%	



29				0.00%	
30				0.00%	
31				0.00%	
32				0.00%	
33				0.00%	
34				0.00%	
35				0.00%	
36				0.00%	
37				0.00%	
38				0.00%	
39				0.00%	
40				0.00%	

Cooperation level (design the lips at the face)

Fittings that have been left at the audited system and must be replaced at the toolbox

Fittings	Diameter	Number
T		
Connector		
End cup		
Connection fittings		
…		
…		
…		
…		
…		
…		
…		

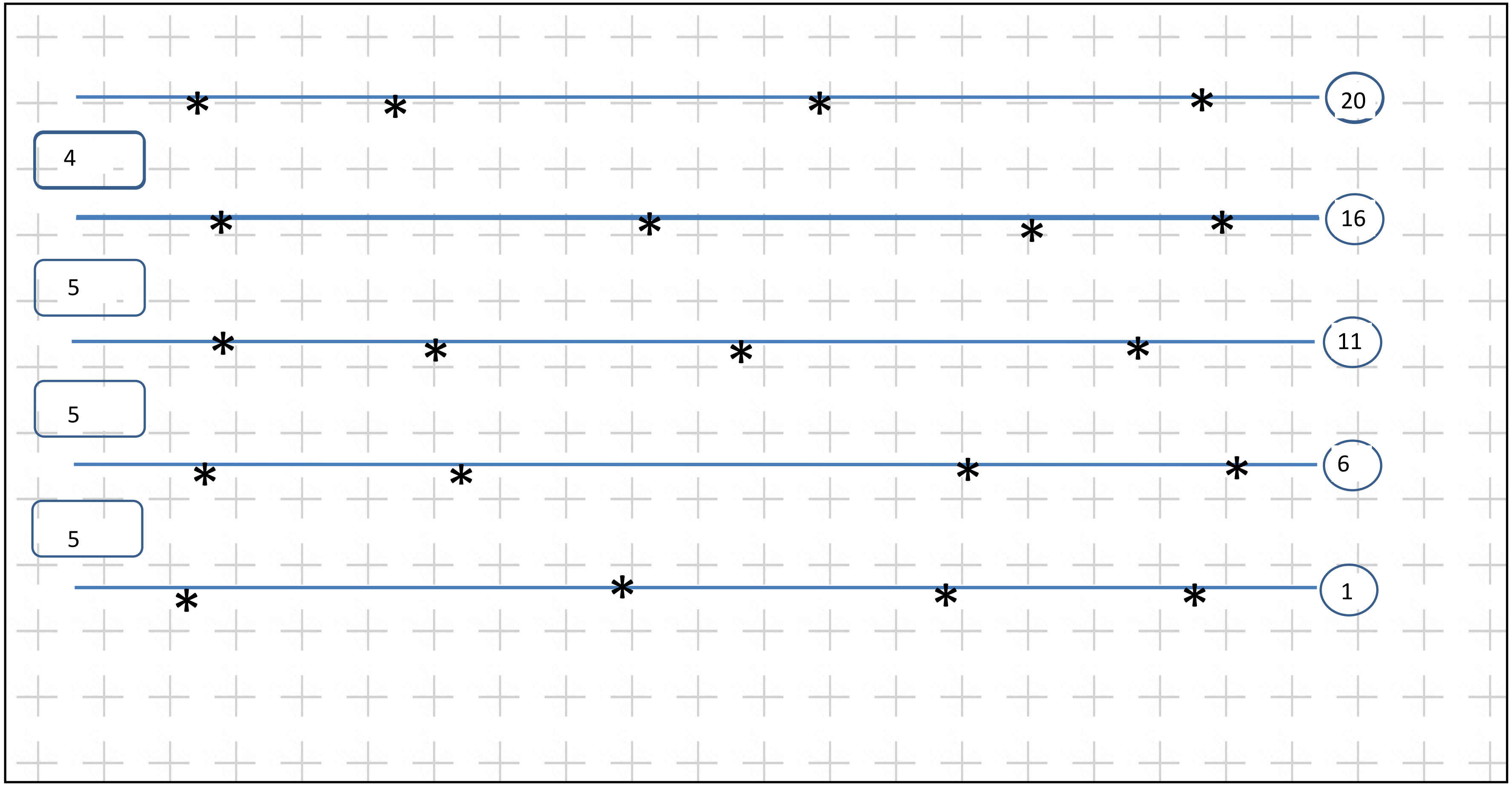
Notes (use numbering for references)

manH and other costs

Generic **Zone sketch (system zoomed in at zone scale)**

Instead of the table you can use the boxes to note catch-can no, volume, moisture around etc for each catch-can location

N arrow



Laterals with id
Number of plants rows between laterals
* Catch can location

Notes (use numbering for references)

manH and other costs

D. Data analysis and report generation

1 Soil characteristics estimation at the laboratory
pH
EC
Mechanical analysis for as many irrigation zones as needed
$CaCO_3$
Orgaic mater
2 Determination of irrigation period and estimation of monthly plant's water needs according to historical climatic data
3 Calculation of distribution uniformity coefficients (DU, CU, SC or other) using catch - cans and soil moisture data.
4 Development of a theoretical irrigation schedule and comparison with the applied one for each zone.
5 Development of information regarding the design and construction issues of the system.
6 Estimation of the potential savings in water, energy, labour and money after the application of the proposed mprovements.
7 Authoring of the final report regarding the system, the schedule, the efficiency etc. Proposals for improvement and expected savings.

E. Final activities

1 Presentation of the final report.
2 Ask if they would be interested for system repair, tune-up, adjustment and repair.
If no, why?
3 Do not forget to fill the internal form regarding the audit procedure.

D. Soil and water analysis

manH and other costs

Soil characteristics estimation at the laboratory

Soil texture analysis and other measurements in as many irrigation zones as needed

Mechanical classes determination method	
$CaCO_3$ determination method	
Organic mater determination method	

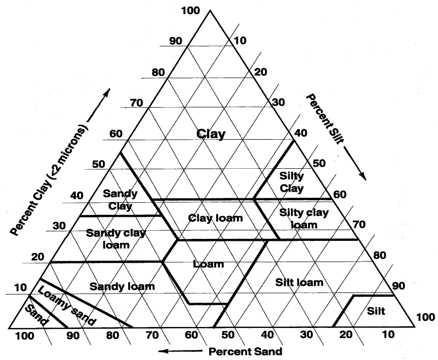
Zone	Sand (%)	Silt (%)	Clay (%)	Soil type	pH	EC	$CaCO_3$	Organic mater
A	3.92	89.68	6.4	Si	7.3	0.37	14.42124	
B								
C								
…								
…								
…								

repeat the page in case of more than one sample

Cick here to activate USDA soil texture calculator (web link)

USDA

Comments



In case of hydroponic cultivations

Zone

Substrate (check or specify):

Check	Type	Manufacturer	Particles size (mm)	…	…	…	…	…
□	Perite							
□	Pumice							
□	Rockwool							
□	….							

Comments

Water characteristics

repeat the page in case of more than one sample

Field measurements

Water source		
pH	0	
Electrical conductivity (EC)	0	dS/m

pH normal range: 6.5 – 8.4

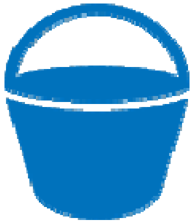
Salinity (affects crop water availability)

	Unit	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
EC	dS/m	< 0.7	0.7 – 3.0	> 3.0

Comments

D. Uniformity analysis (use separate sheet for every zone)

Zone ________ (use separate sheet for every zone)



Catch device throat diameter 0.10 m or specific cath-can: Underhill_mini

Test run time 15.00 min

Analysis

A-Z list

	V	Vi-Vμέση	PR
Αρ. δοχείου	**ml or ……..**	**ml - ml or ………**	**mm/h**
1	18	23.30	9.17
2	18	23.30	9.17
3	18	23.30	9.17
4	23	18.30	11.72
5	25	16.30	12.74
6	25	16.30	12.74
7	25	16.30	12.74
8	30	11.30	15.29
9	32	9.30	16.31
10	32	9.30	16.31
11	36	5.30	18.35
12	38	3.30	19.36
13	40	1.30	20.38
14	50	8.70	25.48
15	52	10.70	26.50
16	60	18.70	30.58
17	60	18.70	30.58
18	62	20.70	31.60
19	62	20.70	31.60
20	120	78.70	61.15
21			

1. Sort measurements in descending order
(regards measurements of catch-cans and moisture difference data)

2. Calculation of averages, totals and ratios

Attention, these formulas need to set up every time

24.60	Low_Quarter_Average_Depth (or Volume)
41.30	Low_Half_Average_Depth (or Volume)
41.30	Overall_Average_Depth (or Volume)
826.00	Σvi (ml)
21.03	PRavg (mm/h), average zone precipitation rate

Distribution Uniformity

for sprinkler systems, Dulq is more strict

Low Quarter irrigation Distribution Uniformity - DU_{lq}

DUlq= 60%

$$DU_{lq} = \frac{Low\_Quarter\_Average\_Depth}{Overall\_Average\_Depth} \times 100$$

Low Half irrigation Distribution Uniformity - DU_{lh}

DUlh= 100%

$$DU_{lh} = \frac{Low\_Half\_Average\_Depth}{Overall\_Average\_Depth} \times 100$$

Scheduling Coefficient (SC)

for sprinkler systems

SC= 2.29

$$SC = \frac{PR_{average}}{PR_{minimum}}$$

22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			

Christiansen
for micro-irrigation systems
Σ|Vi-V|= 353.8
CU= 57%

$$CU = 1 - \frac{\sum_{i=1}^{n} \left| V_i - \overline{V} \right|}{\sum_{i=1}^{n} V_i}$$

Attention, this formula need to set up every time

Maximum volume:	120.00
Minimum volume:	18.00
Average volume:	41.30
Standard deviation:	24.11
Standard error:	5.39

-17% 217%

In every case a variation of more than ±10% is probably unacceptable and suggests poor system design.

Rough cross check – pump flow rate / water supply from catch can test

No. outlets x average emitter flow rate ______ outlets x ______ lpm
Overall flow rate ______ lpm
Pump flow rate – specified ______ lpm

How does the specified compare to the overall? ______

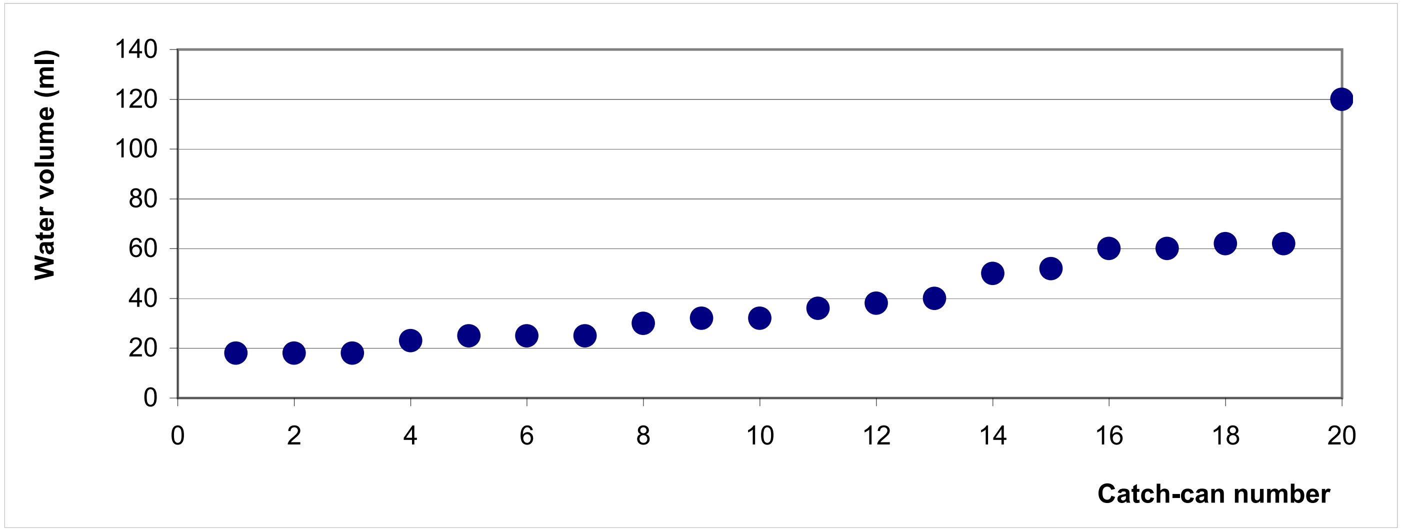
Emitter flow equation: $q=kH^x$

k	
x	
H	
q expected	#APIΘ!

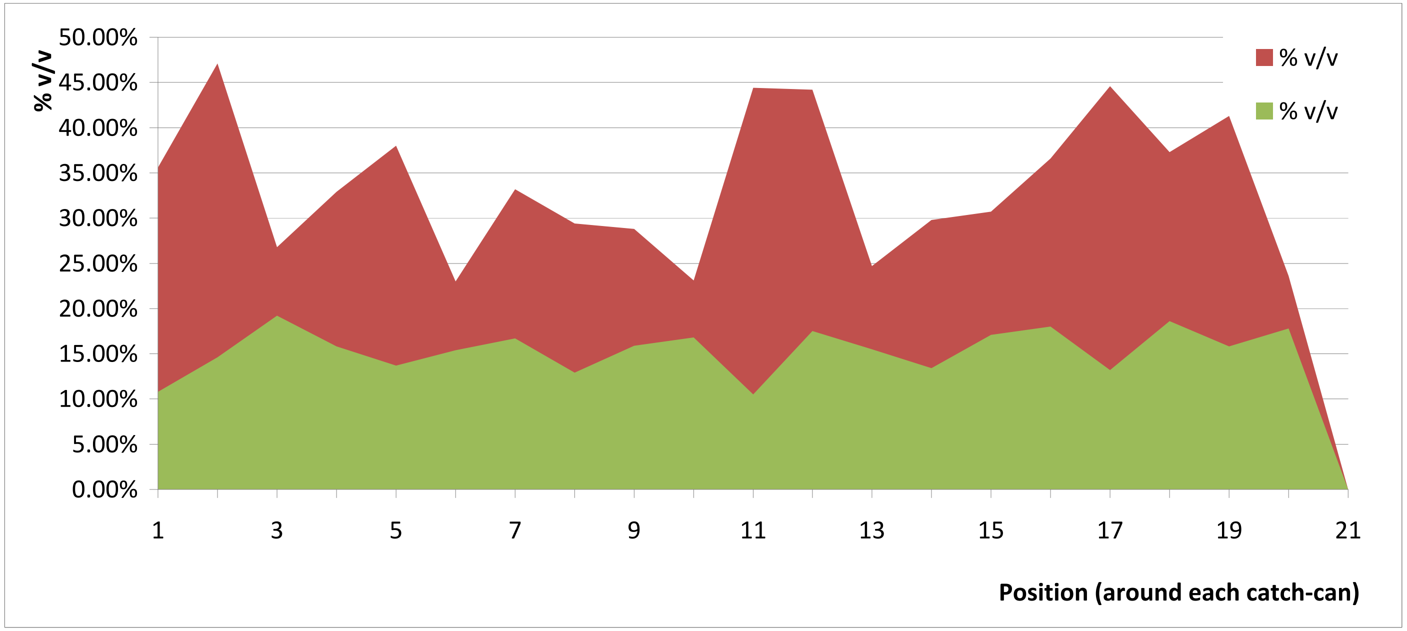
Selected alternatives for uniformity calculation:

UC Davis Biomet DU Citrus http://biomet.ucdavis.edu/irrigation_scheduling/DU%20Irrig%20of%20Citrus/IS004.htm

Water volume fluctuation in catc-cans



Substrate moisture before and after irrigation



manH and other costs

D. Climatic data, potential Evapotranspiration and Ombrothermic diagram

Constants for the calculations

G_{sk}	116.64 cal cm^{-2} h	0.082 $MJm^{-2}min^{-1}$	1 MJ m^{-2} day^{-1} = 0.408	mm day^{-1}
λ	59.50 cal cm^{-2} mm^{-1}			
φ	0.00 rad			

t greenhouse cover transmission to solar radiation (%)

Step 1. Calculation of potential / reference evapotranspiration (ETo)

	Reference period temperatures (i.e. month)			Solar radiation calculation for the characteristic day of the reference period					Rain	Open field (1)	Greenhouse (2)
Month	Representative day number	Tmin (°C)	Tmax (°C)	Tmean (°C)	dr (rad)	δ (rad)	ωs (rad)	R_a (MJ m^{-2} day^{-1})	Rain (mm/month)	ETo (mm day^{-1})	ETo (mm day^{-1})
Jan	18	5.27	13.39	8.93	1.03	-0.36	1.57	36.27	150.11	2.59	0.00
Feb	46	5.19	13.57	9.11	1.02	-0.23	1.57	37.44	171.71	2.74	0.00
Mar	75	7.26	16.44	11.69	1.01	-0.04	1.57	37.90	132.97	3.18	0.00
Apr	105	10.21	20.44	15.16	0.99	0.17	1.57	36.78	73.21	3.64	0.00
May	135	13.70	24.83	19.20	0.98	0.33	1.57	34.77	63.99	4.03	0.00
Jun	162	17.59	29.20	23.57	0.97	0.40	1.57	33.50	35.86	4.43	0.00
Jul	199	20.09	32.34	26.50	0.97	0.37	1.57	33.99	0.80	4.95	0.00
Aug	229	20.73	32.96	26.97	0.98	0.23	1.57	35.78	1.91	5.26	0.00
Sep	259	16.99	27.74	22.17	0.99	0.03	1.57	37.26	91.67	4.58	0.00
Oct	289	13.49	22.89	17.61	1.01	-0.18	1.57	37.33	211.03	3.80	0.00
Nov	318	10.17	18.97	14.03	1.02	-0.33	1.57	36.36	212.36	3.22	0.00
Dec	345	6.44	14.36	9.97	1.03	-0.40	1.57	35.64	182.06	2.61	0.00
									1327.69	45.03	0.00

Microclimatic notes (i.e. local winds etc)

1) FAO Paper56 / Hargreaves
2) Institute Nationale de la Recherche Agronomique (INRA), Avignon, France / Baille

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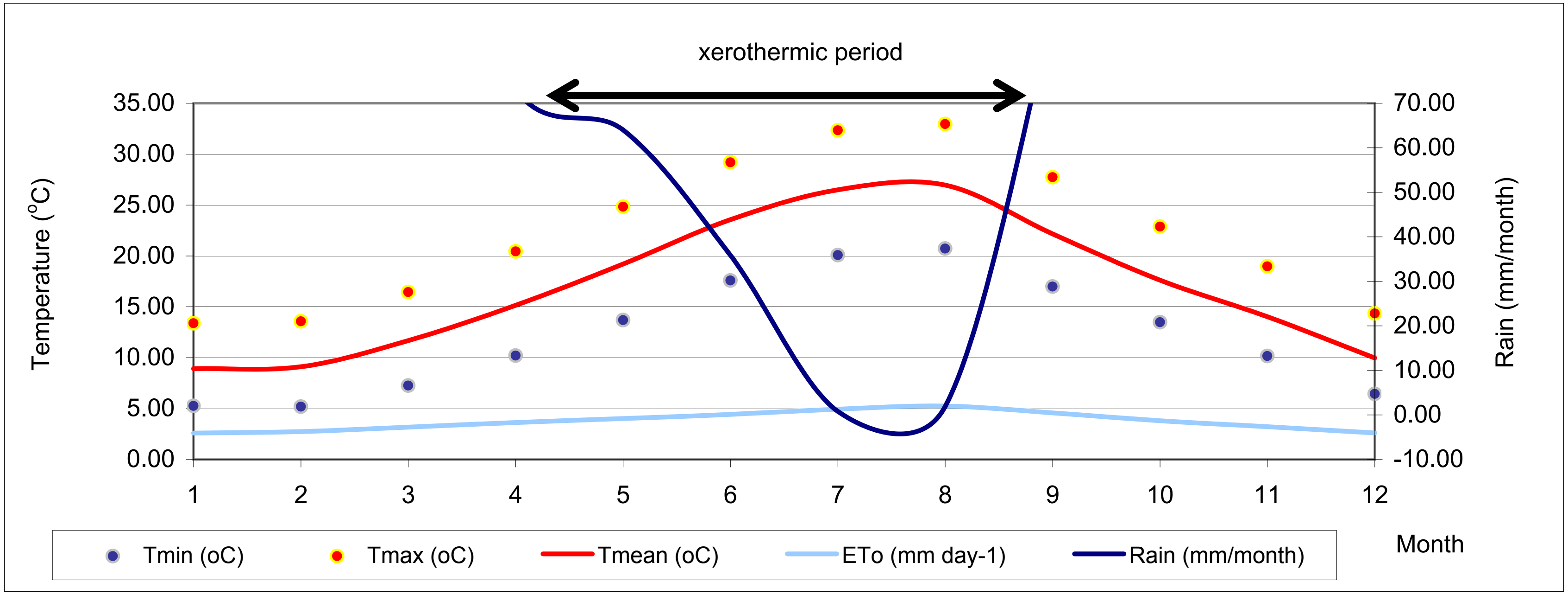
Ombrothermic diagram



manH and other costs

Reference evapotranspiration openfield
FAO - Penman - Monteith
Based on Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56

Eto according to Penman - Monteith

$$ET_o = \frac{0{,}408 \times \Delta \times (R_n - G) + \gamma \times \frac{900}{T + 273} \times u_2 \times (e_s - e_a)}{\Delta + \gamma \times (1 + 0{,}34 \times u_2)}$$

Altenrantive method, Hargreaves:

$$ET_o = 0{,}0023 \times (T_{mean} + 17{,}8) \times (T_{max} - T_{min})^{0,5} R_a$$

Constants (or practically constants) of meteorological conditions

k	4.10E-01	αδιάστατη	von Karman constant (for wind profile)
ε	6.22E-01	-	molecular weight ratio of vapour / dry air
G_{sk}	8.20E-02	$MJm^{-2}min^{-1}$	solar constant
σ	4.90E-09	$MJK^{-4}M^{-2}day$	Stefan-Boltzman constant
P	1.01E+02	kPa	atmospheric pressure (cosnidering air an ideal gas and the temperature equal to 20^oC)
λ	2.45E+00	MJ kg^{-1}	lantent heat for evaporation at 20^oC
c_p	1.01E-03	MJ kg^{-1} $^oC^{-1}$	special heat under constant pressure for mean atmospheric conditions
γ	6.73E-02	kPa $^oC^{-1}$	psychrometric constant

ET calculations mmday^{-1}

Area

	o	'	"	
Lat	39.00	33.00	58.64	
Lat	0.69	rad		latitude
z area		m		area height above sea level
z station		m		meteorological station height above sea level
Day	199			1-365
Tmin data	20.08571429	^oC		min air temperature at 2 m height
Tmax data	32.34285714	^oC		max air temperature at 2 m height
Tmean	26.5	^oC		mean air temperature at 2 m height
RH min		%		min relative humidity
RH max		%		max relative humidity
$e^o(T_{min})$	2.35	kPa		saturation vapour pressure at daily minimum temperature

$e^o(T_{max})$	4.85	kPa	saturation vapour pressure at daily maximum temperature
es	3.60	kPa	saturation vapour pressure
ea	0.00	kPa	actual vapour pressure from relative humidity data
Δ	0.20	kPa $^oC^{-1}$	slope vapour pressure curve (for the mean temp)
VPD	3.60	kPa	vapour pressure deficit (es-ea)
dr	0.97	rad	inverse relative distance Earth-Sun
δ	0.37	rad	solar decimation
ωs	1.89	rad	sunset hour angle
R_a	40.54	MJ $m^{-2}day^{-1}$	extraterrestrial radiation
$R_{s\ actual}$	10.14	MJ $m^{-2}day^{-1}$	solar or shortwave radiation (measured or estimated)
R_{so}	30.41	MJ $m^{-2}day^{-1}$	clear-sky solar radiation (n=N)
R_{ns}	7.80	MJ $m^{-2}day^{-1}$	net solar radiation for α=0,23 - reference surface
R_s/R_{so}	0.33	-	relative shortwave radiation
R_{nl}	1.34	MJ $m^{-2}day^{-1}$	net longwave radiation
R_n	6.46	MJ $m^{-2}day^{-1}$	net radiation at the crop surface
G_{day}	0	MJ $m^{-2}day^{-1}$	soil heat flux density
z windmeter		m	wind speed measurement height
uz		m s^{-1}	wind speed, z windmeter
u2	#ΑΡΙΘ!	m s^{-1}	wind speed at 2 m heightπάνω από το έδαφος

Rs: solar or shortwave radiation
n: actual duration of sunshine
N: daylight hours, maximum possible duration of sunshine or daylight hours

N=	14.45867527	h
n=		h
R_s=	10.14	MJ $m^{-2}day^{-1}$

ETo	Hargreaves	
	5.90	mm day^{-1}
	Penman-Monteith	
	#ΑΡΙΘ!	mm day^{-1}

Selected alternatives for ET and plants water needs calculation:

FAO Eto Calculator http://www.fao.org/nr/water/eto.html

FAO CropWat http://www.fao.org/nr/water/infores_databases_cropwat.html

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D. Data analysis and report generation (sprinkler system, use separate sheet for every zone)

For sprinkler systems (openfield agriculture, landscape etc)
FAO Irrigation and drainage paper 56, WUCOLS for Landscape Irrigation, FAO Irrigation Water Management: Irrigation Scheduling, FAO Effective rainfall in irrigated agriculture

Zone A

Area (A) 2.20 ha 22

Basic soil characteristics

Soil type	Si
Field capacity (FC, % v/v)	31%
Permanent wilting point (PWP, % v/v)	15%
Available water content (AWC, % v/v)	16%
Final infiltration rate (if, mm/h)	5%

Cultivation / Landscape plants (or category)

Plant species / variety	Citrus Trees
Effective depth of rootzone (de, m)	0.60
Maximum allowed depletion (MAD)	60%

Basic characteristics of irrigation system

System type		
Efficiency (IE, %)	85%	estimation using application uniformity
Precipitation rate (PR, mm/h)	21.03	from audit results

Irrigation schedule Take account of rain (y/n)? y

da, max irrigation dose (mm) 57.60

>> <<

Notes

												Calculations					
	Kc	kmc or Ks	kd or Ks	K_L	ETa	Number of days	ETa	Rain	Reff	Leaching fraction	Water needs, ED	Theoretical irrigation span, EA	Practical irrigation span, EA	Final application dose, du	Actual run time RT=du/PR	Required water volume
Month	-	-	-	-	mm day^{-1}	days	mm month^{-1}	mm month^{-1}	mm month^{-1}	%	mm day^{-1}	days	days	mm	min	m^3 month^{-1}
Jan	0.00	1.00	1.00	0.00	0.00	31	0.00	150.11	101.66	0%	0.00	0.00	**14.0**	0.00		0.00
Feb	0.00	1.00	1.00	0.00	0.00	29	0.00	171.71	103.20	0%	0.00	0.00	**14.0**	0.00		0.00
Mar	0.00	1.00	1.00	0.00	0.00	31	0.00	132.97	97.38	0%	0.00	0.00	**14.0**	0.00		0.00
Apr	0.80	1.00	1.00	0.80	2.91	30	87.32	73.21	65.48	0%	0.73	79.13	**14.0**	11.99	34	527.56
May	0.70	1.00	1.00	0.70	2.82	31	87.39	63.99	57.87	0%	0.95	60.48	**14.0**	15.69	45	690.36
Jun	0.65	1.00	1.00	0.65	2.88	30	86.44	35.86	33.54	0%	1.76	32.66	**14.0**	29.04	83	1277.76
Jul	0.65	1.00	1.00	0.65	3.22	31	99.68	0.80	0.76	0%	3.19	18.05	**14.0**	52.56	150	2312.64
Aug	0.65	1.00	1.00	0.65	3.42	31	105.91	1.91	1.82	0%	3.36	17.15	**14.0**	55.31	158	2433.64
Sep	0.80	1.00	1.00	0.80	3.67	30	110.01	91.67	110.09	0%	0.00	0.00	**14.0**	0.00		0.00
Oct	1.05	1.00	1.00	1.05	3.99	31	123.79	211.03	105.17	0%	0.60	95.87	**14.0**	9.90	28	435.60
Nov	0.00	1.00	1.00	0.00	0.00	30	0.00	212.36	105.23	0%	0.00	0.00	**14.0**	0.00		0.00
Dec	0.00	1.00	1.00	0.00	0.00	31	0.00	182.06	103.72	0%	0.00	0.00	**14.0**	0.00		0.00
																7677.56

Selected alternatives for irrigation scheduling:

FAO CropWat http://www.fao.org/nr/water/infores_databases_cropwat.html
UC Davis Biomet http://biomet.ucdavis.edu/irrigation-scheduling.html

F, Frequency:	per	**14.0**	day
RT, Run time:		**158.00**	min

ETCP GREECE-ITALY 2007-2013 www.irrigation-management.eu

IRMA

Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

Subsidy Contract No: I3.11.06

Audit No	**No3**
Date	

WP5 Irrigation Audits

Auditing team members name (chief inspector first)

Christos Myriounis
Dimitrios Myriounis

Contact information with audit team:

Tel.:	**+302665100220**
Mobile:	**+306973336140**
email:	cmyriounis@gmail.com

Irrigation system

General problems the have been noticed

Low pressures were observed

Comments regarding soil and water characteristics

Soil type Si

Comments regarding design,construction and maintenance of the system

Telescopic method

Comments regarding distribution uniformity

Uniformity DULh=60%
Needs to be improved

Comments regarding the applied irrigation schedule

Irrgation water is applied more time for improvement of the uniformity conditions

Proposed repairs / alterations and expected benefits

Sprinklers need to be vertical
Filters shoold be in the irrigation pipes

Proposed irrigation schedule and expected benefits

Irragation every 14 days for 4houres, water saving about 5% (due to low uniformity)

Drainage system

General problems the have been noticed

No problems were observed

Comments regarding design,construction and maintenance of the system

Proposed repairs / alterations and expected benefits

Attached	Analytical soil analysis results	Analytical nutrient solution analysis results

Have also in mind the following

All the entities that participated in IRMA project audits are requested to participate in IRMA stakeholders DB
http://www.irrigation-management.eu/network/stakeholders

All the entities that participated in IRMA project audits can request a relevant certificate which will testify that they are trying to contribute to water savings.

Disclaimer

IRMA project and its staff / cooperators, assume no responsibility or liability for the way that audit results and the relevant advices will be intepreted and applied. In every case it is suggested to be discussed with the relevant consultant of the audited entity before any alterations to the irrigation and drainage systems structure and management are decided and made.

Appendix III. Irrigation worksheets from a landscape

	Date	Sign
My system got audited		
I received the audit results		

ETCP GREECE-ITALY 2007-2013

IRMA Subsidy Contract No: I3.11.06

www.irrigation-management.eu

Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

fill data or circle (O) in cells colored in | manH and other costs

check (√ or O) squares □

for extra comments, number and fill info at Notes (bottom of page)

B: Bad; M: Moderate; F: Fair; E: Excellent

WP5 Irrigation Audits

Auditing team members name (chief inspector first): Christos Myriounis; Dimitrios Myriounis

Audit No: No27

A. First contact and field work plan

Organisation	Private
Name and age	Theodoridis George, 56
Position of contact person	Owner / Subcont/or / Manager / Other
Address	Plataria Thesprotias
Telephone numbers	+306974915478
Other contact information (website, email etc)	

First contact, explanation of the procedure

Try to collect as much basic information as you can during this contact

Check Have you filled an irrigation survey questionnaire of IRMA project? Yes No

If Yes, a copy should be inquired by the relevant contractor and most of the

If No, a communication with the relevant contractor should be made in order to register this system.

Provide information regarding the documents that you will need and ask for copies

			Comments
Yes	No	Topographic or a coverage diagram	
Yes	No	Plan of the irrigation and drainage system	
Yes	No	Pumping system / grid connection design	
Yes	No	Manuals of the system's basic components (i.e. pump operation diagram)	
Yes	No	Electric power accounts of the system	
Yes	No	Bills from the Local Land Reclamation Service (LLRS) or other similar	
Yes	No	Latest soil and/or water analysis available	
Yes	No	Latest statement regarding EU agricultural funding	
Yes	No	Registrations of the cultivation system (eg integrated management)	
Yes	No	Reports from previous audits	
		Set date, time, location for the audit	
		Selection of date based on weather conditions. In case of sprinkler system, it is recommended to select not intensely windy conditions. For accurate results note that collection of data should be time independent to prior irrigation of the study area.	
	□	Call the day before to confirm appointment	

Notes (use numbering for references)

A, C. Basic system characteristics

manH and other costs

Date	11/9/2014	**Time**	
		arrival at field	9:20
		departure from field	10:40

Location, type of setup, total area

Location		GLRS		LLRS
		Name		
		o	'	"
Latitude	39.40117791	39.00	24.00	4.2404724
Longitude	20.23754741			

Type of setup (√)

Open field	☐	Public	☐
Greenhouse / Nethouse	☐	Private	✓
Landscape (turfgrass, shrubs, trees)	✓		
Athletic installation	☐	Area (ha)	

System designer	Craftsman	Agricult/list	Him/Her self	Other	
System constructor	Craftsman	Agricult/list	Him/Her self	Other	
System conservator	Craftsman	Agricult/list	Him/Her self	Other	
System administrator	Craftsman	Agricult/list	Him/Her self	Other	

Operational problems reported by the system administrator

Low pressure	☐	
High pressure	☐	
Tilted sprinklers	☐	
Sunken sprinklers	☐	
Spray deflection	☐	
Arc misalignment	✓	
Drainage from low placed sprinklers	☐	
Different oulets at the same zone	☐	
Missing or broken components	☐	
Clogged components	☐	
Leaky seals or fittings	☐	
Pipe leaks	☐	
Slow drainage / ponding / surface runoff	☐	
Compaction / thatch	☐	

Other mulfactions etc: Garden near sea, strong wind in summer
Low pressures

In case of a previous audit, confirm that the proposed improvements and repairs have been made before proceed to the new audit.

Basic system use (√)

☐ Irrigation
☐ Frost protection
☐ Other

Notes (use numbering for references)

Water supply / POC (point of connection) characteristics

manH and other costs

Source type	Irrigation canal				
	Water pond / tank				
	Drilling (depth (m) and pipe diameter ("))				
	Civil water system	X			
	Other				
Irrigation rules (bans, irrigation time windows etc)					
Water meter (Y/N, characteristics)		Yes	No		
Condition of water supply / POC area (circle)		Bad	Moderate ✓	Fair	Excellent
Photos	☐				

Irrigation water usage/cost, data?	Yes	No	20..	20..	20..
If yes, irrigation water usage (last 3 years, m3)					
or how many hours per year the system irrigates					
Irrigation cost (last 3 years, € y^{-1})	Labor		Materials		

Pump identification

Ask for or find manuals of components and circle if available — Manual

Manufacturer				
Model				
Age				
Power / max RPM			HP	rpm
Typical operating flow (select or write unit)			m^3/h Lm^{-1} Lh^{-1} ….	
Typical operating pressure (select or write unit)			atm bar …	
Pressure tank (circle and note)	Yes	No	Characteristics:	
Other				
Photos ☐				

Energy source (circle, or specify)	Petrol	Gas	Electricity	…	…
Power system diagram availability (circle)		Yes	No	Notes:	
Condition of power supply system (circle)		Bad	Moderate	Fair	Excellent
Other					
Photos ☐					

Energy

cost (€ y^{-1}) ____ or typical energy consumption per hour ____

this info must be treated in combination with the applied schedule data in Zone characteristics

Filters

System head filtering system		Order	Characteristics	mesh or color
Hydrocyclone	☐			
Sand	☐			
Mesh	☐			
Disk	☐			
Reverse osmosi:	☐			
Other…	☐			

Notes (use numbering for references)

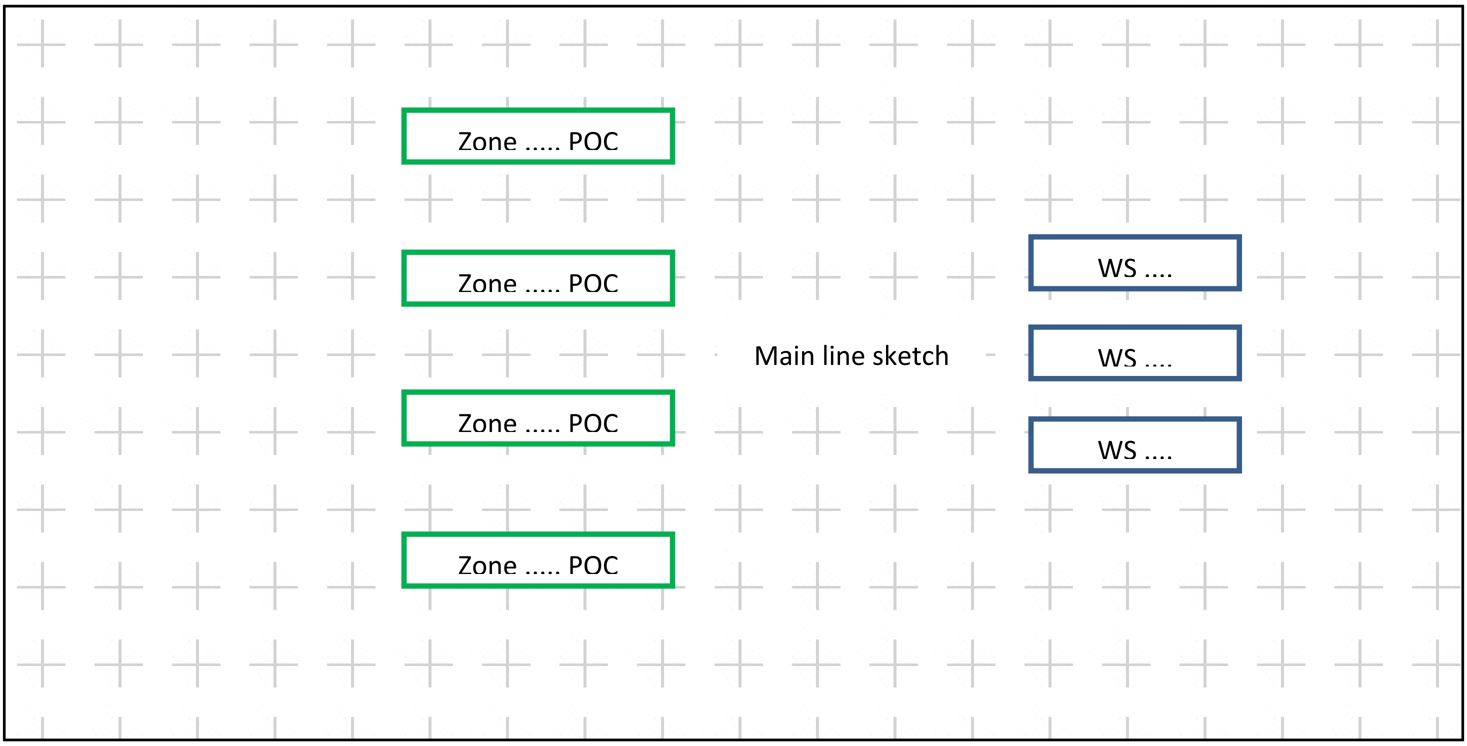
Other key components	Check	Condition (B, M, F, E)	Characteristics and comments regarding placement	manH and other costs
Check valve	□			
Backflow preventer	□			
Air valve	□			
Flush valve	□			
Other				
Other				
Other				

Type of main pipes (material, pressure range) and depth of installation

Section (initial - final length in m)	PVC (Ø mm)	PE(LDPE) (Ø mm)	PE(HDPE) (Ø mm)	(Ø mm)	Pressure (Schedule, atm))	Height (m)*
10			20		6	-0.5
-						
-						
-						

* in case of underground system enter a negative value

Basic system and surroundings that affect irrigation sketch (circle if available) Available



Show info regarding
Water supply (WS)
Mainline
Zones/Stations (A, B, C,….)
Zones' point of connection (POC)

Connection of zone control valves (circle)
Central Close to zones

Photos □

Notes (use numbering for references)

Identify irrigation system zones (stations)

Zone (A-Z and System type code)	Slope (%)	Soil sample no	Area (m^2)	Irrigation system type: Sprinkler	Micro	Other	Probability of horizontal - upward motion of water
A	0		48	□	□	□	
B				□	□	□	
C				□	□	□	
…				□	□	□	
…				□	□	□	

continued…

OF: Open field; G/N: Greenhouse / Nethouse; L: Landscape (turfgrass, shrubs, trees); A: Athletic

Zone	Plant material	Yield (kg, pieces, etc)	Crop rows dist. (m)*	Crops dist. on row (m)*	Plant material similarity (√)	Establishement year
A						2006
B						
C						
…						
…						
…						

* or planting density (plants per area unit)

Notes (use numbering for references)

manH and other costs

A, C. Irrigation zone layout and components

Zone (use separate sheet for every zone, in case of greenhouse also fill the relevant sheet)

Ask for or find manuals of components

Sampling and measurements

Soil sampling
skip in case that a recent soil analysis is available

	Pos:			Pos:
X	00-30 cm			00-30 cm
	30-60 cm			30-60 cm
	cm			cm

Notes on soil layering

Select proper template to sketch the zone arangement

Valve — Ask for or find manuals of components and circle if available — Manual

Manufacturer
Model
Flow range
Pressure range

Condition (circle)	Bad	Mediocre	Fair	Excellent

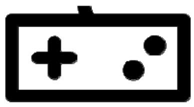
System control
Manual control
Irrigation controller

Ask for or find manuals of components and circle if available — Manual

id / Manufacturer / Model: Orbit
Age
Number of stations
Number of programs
Number of start times
Rain delay (Y/N)

Power supply □ Current □ Battery

Pump control (Y/N)	Yes	No
Water budget (Y/N)	Yes	No
Sensor(s) port (Y/N)	Yes	No
Other	Yes	No



Wiring (notes)
Sensors (check and comment regarding installation)

Rain sensor □
Soil moisture sensor □
Wind senor □
Other □

Other
Photos □

Filter (zone or line) — Ask for or find manuals of components and circle if available — Manual

Type: Mesh | Disk | Manufacturer | Model
Mesh or color
Flow range
Pressure range

Condition (circle)	Bad	Moderate	Fair	Excellent

Pressure regulator — Ask for or find manuals of components and circle if available — Manual

Manufacturer / Model
Input / output flow

Condition (circle)	Bad	Moderate	Fair	Excellent

Notes (use numbering for references)

manH and other costs

C. System operation evaluation and uniformity measurements

Zone ______ (use separate sheet for every zone)

Wind speed ______ km/h

Check and record wind speed at 2m: should be < 8 km/h (4.97 m/h)
Wind speed should be monitored also during the test if variations are sensed

Either the table or the generic or special design can be used for data keeping

Operation and measurement (in case of sprinkler systems, along with catch cans measurements)
Pressure tests must be conducted at normal operating conditions of the oulets using the appropriate pressure gauges
For pipes, at the beginning, middle, and end of every zone audited.

Outlet / Pipe-pos.	Operating pressure (bar)	Radius (for sprinklers) (m)	Pipe flow rate (….)	Comments / Observed problems
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Zone problems detected by the auditor	
Improper zoning	
Limited controller capability	
Incorrect pressure (low / high)	
Lack of adequate flows	
Improperly sized components	
Old or worn out equipment	
Dirty or teared filters	
Tilted Sprinklers	
Spray Deflection	
Sunken Sprinklers	
Plugged Equipment	
Arc Misalignment	
Low Sprinkler Drainage	
Leaky Seals or Fittings	
Lateral or Drip Line Leaks	
Missing or Broken Heads	
Slow Drainage or Ponding	
Compaction/Thatch/Runoff	
Other	

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Soil moisture sensor type:

Equation used:

Measurements

Number of catch cans 7 (at least 20)

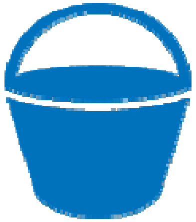
Test duration 10 min sec

Catch-can throat diameter 10 cm

or specific cath-can Underhill_mini

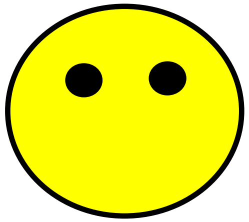
Pos / Catch Can	Measur. (select unit)	Soil moisture (v/v %)		
		Before	After	Difference
	ml	ml	ml	% v/v
1	20	33.60%	34.80%	1.20%
2	15	33.80%	36.30%	2.50%
3	25	32.50%	37.70%	5.20%
4	30	31.20%	35.80%	4.60%
5	28	30.80%	36.70%	5.90%
6	10	32.10%	37.50%	5.40%
7	14	31.70%	35.80%	4.10%
8	5	30.10%	32.10%	2.00%
9	5	29.10%	35.10%	6.00%
10				0.00%
11				0.00%
12				0.00%
13				0.00%
14				0.00%
15				0.00%
16				0.00%
17				0.00%
18				0.00%
19				0.00%
20				0.00%
21				0.00%
22				0.00%
23				0.00%
24				0.00%
25				0.00%
26				0.00%
27				0.00%
28				0.00%

Comments / Observed problems



29				0.00%	
30				0.00%	
31				0.00%	
32				0.00%	
33				0.00%	
34				0.00%	
35				0.00%	
36				0.00%	
37				0.00%	
38				0.00%	
39				0.00%	
40				0.00%	

Cooperation level (design the lips at the face)



Fittings that have been left at the audited system and must be replaced at the toolbox

Fittings	Diameter	Number
T		
Connector		
End cup		
Connection fittings		
…		
…		
…		
…		
…		
…		
…		

Notes (use numbering for references)

manH and other costs

Water sampling

Qualitative characteristics of water source

pH

Electrical conductivity (EC) ______ dS m^{-1}

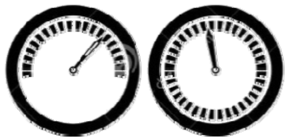
1 μ = 10^{-5} deci

Head / flowrate at water supply point

Date and time of measurement: 18/8/2014

Static pressure at the source: 15 bar

Measured flow /head couples by auditor



Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)
	11	6.5	0.39
	13	5	0.30
	14	4	0.24
	14.5	2	0.12
			0.00 Maximum available flowrate

Fill in case of more water supplies

Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)
			0.00
			0.00
			0.00
			0.00
			0.00 Maximum available flowrate

Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)
			0.00
			0.00
			0.00
			0.00
			0.00 Maximum available flowrate

Notes (use numbering for references)

manH and other costs

D. Data analysis and report generation

1 Soil characteristics estimation at the laboratory
pH
EC
Mechanical analysis for as many irrigation zones as needed
$CaCO_3$
Orgaic mater
2 Determination of irrigation period and estimation of monthly plant's water needs according to historical climatic data
3 Calculation of distribution uniformity coefficients (DU, CU, SC or other) using catch - cans and soil moisture data.
4 Development of a theoretical irrigation schedule and comparison with the applied one for each zone.
5 Development of information regarding the design and construction issues of the system.
6 Estimation of the potential savings in water, energy, labour and money after the application of the proposed mprovements.
7 Authoring of the final report regarding the system, the schedule, the efficiency etc. Proposals for improvement and expected savings.

E. Final activities

1 Presentation of the final report.
2 Ask if they would be interested for system repair, tune-up, adjustment and repair.
If no, why?
3 Do not forget to fill the internal form regarding the audit procedure.

manH and other costs

D. Soil and water analysis

Soil characteristics estimation at the laboratory

Soil texture analysis and other measurements in as many irrigation zones as needed

Mechanical classes determination method

$CaCO_3$ determination method

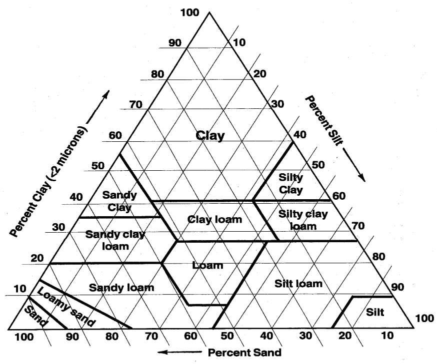
Organic mater determination method

Zone	Sand (%)	Silt (%)	Clay (%)	Soil type	pH	EC	$CaCO_3$	Organic mater
A	27.2	66.5	6.3	Sil	7.7	0.33	7.1	
B								
C								
…								
…								
…								

repeat the page in case of more than one sample

[Cick here to activate USDA soil texture calculator (web link)]

Comments



In case of hydroponic cultivations

Zone

Substrate (check or specify):

Check	Type	Manufacturer	Particles size (mm)	…	…	…	…	…
☐	Perite							
☐	Pumice							
☐	Rockwool							
☐	….							

Comments

Water characteristics

repeat the page in case of more than one sample

Field measurements

Water source		
pH	0	
Electrical conductivity (EC)	0	dS/m

pH normal range: 6.5 – 8.4

Salinity (affects crop water availability)

	Unit	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
EC	dS/m	< 0.7	0.7 – 3.0	> 3.0

Comments

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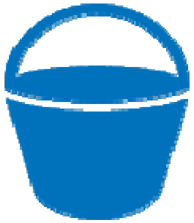


D. Uniformity analysis (use separate sheet for every zone)

Zone ______ (use separate sheet for every zone)

Catch device throat diameter 0.10 m or specific cath-can: Underhill_mini
Test run time 10 min

Analysis

A-Z list

Αρ. δοχείου	V (ml)	Vi-Vμέση (ml - ml)	PR (mm/h)
1	5	11.89	3.82
2	5	11.89	3.82
3	10	6.89	7.64
4	14	2.89	10.70
5	15	1.89	11.47
6	20	3.11	15.29
7	25	8.11	19.11
8	28	11.11	21.40
9	30	13.11	22.93
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			

1. Sort measurements in descending order
(regards measurements of catch-cans and moisture difference data)

2. Calculation of averages, totals and ratios

Attention, these formulas need to set up every time

5.00	Low_Quarter_Average_Depth (or Volume)
8.50	Low_Half_Average_Depth (or Volume)
16.89	Overall_Average_Depth (or Volume)
152.00	Σvi (ml)
12.90	PRavg (mm/h), average zone precipitation rate

Distribution Uniformity

for sprinkler systems, Dulq is more strict

Low Quarter irrigation Distribution Uniformity - DU_{lq}

DUlq= 30%

$$DU_{lq} = \frac{Low\_Quarter\_Average\_Depth}{Overall\_Average\_Depth} \times 100$$

Low Half irrigation Distribution Uniformity - DU_{lh}

DUlh= 50%

$$DU_{lh} = \frac{Low\_Half\_Average\_Depth}{Overall\_Average\_Depth} \times 100$$

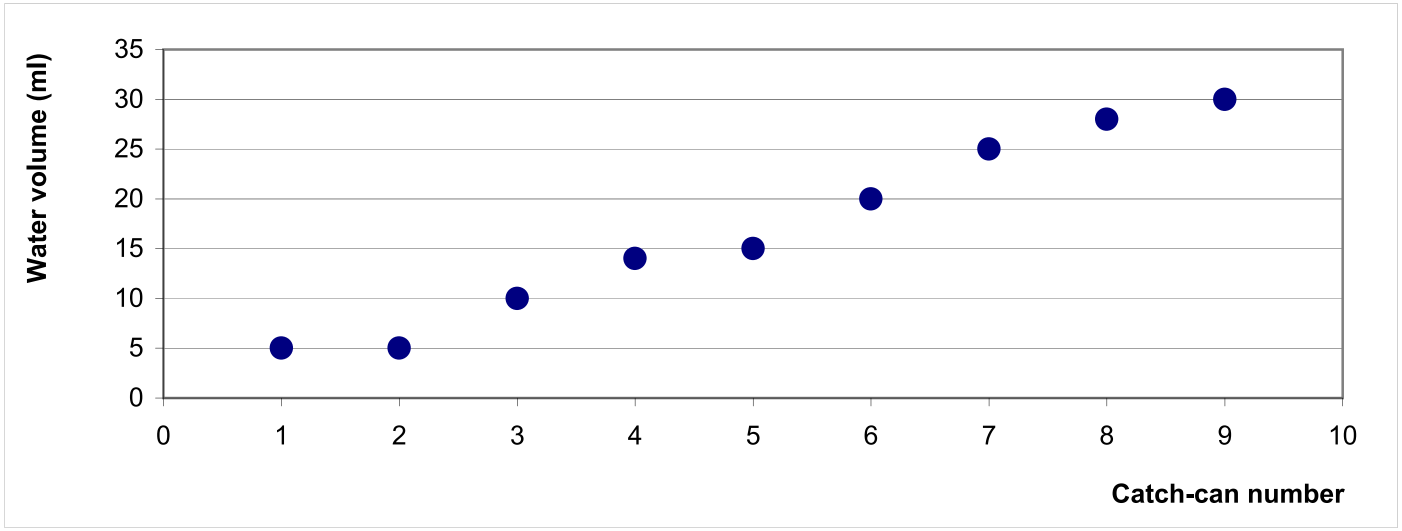
Scheduling Coefficient (SC)

for sprinkler systems

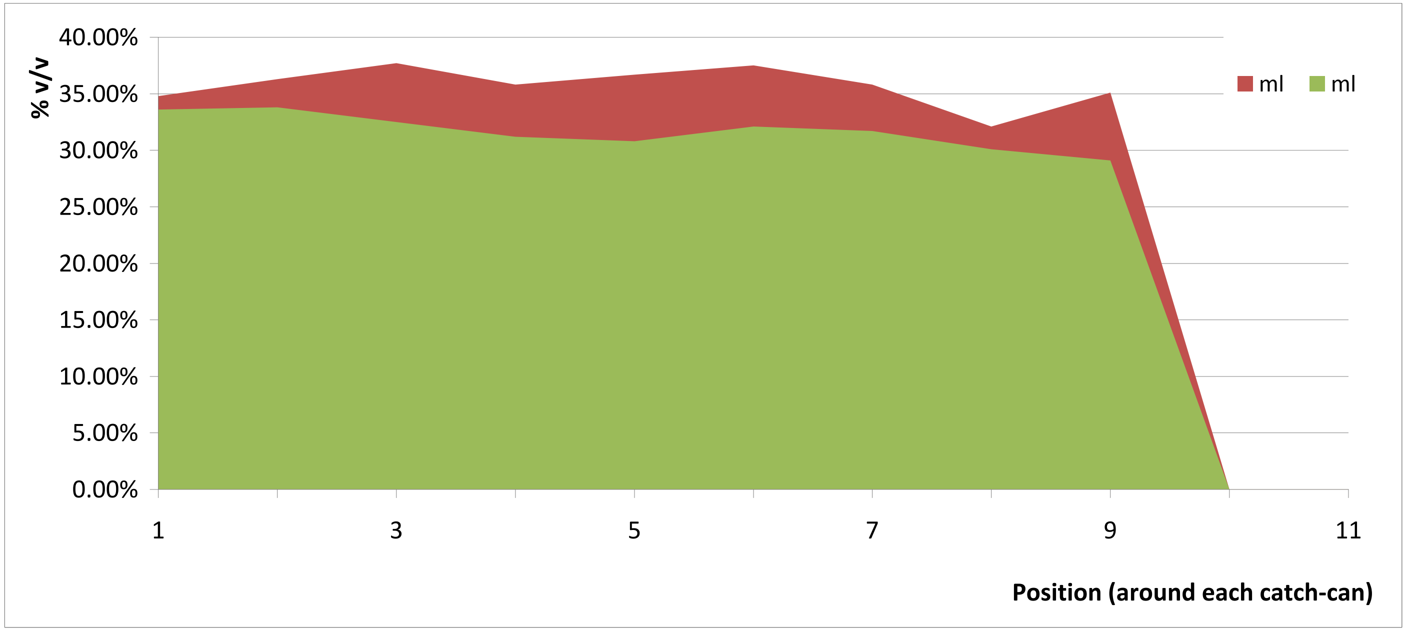
SC= 3.38

$$SC = \frac{PR_{average}}{PR_{minimum}}$$

Water volume fluctuation in catc-cans



Substrate moisture before and after irrigation



D. Data analysis and report generation (micro-irrigation system, use separate sheet for every zone)

manH and other costs

Zone | Type Open field | Take account of rain (y/n)? y

Area (A) 0.0048 ha

Basic soil characteristics

Soil type	Sil
Field capacity (FC, %v/v)	31%
Permanent wilting point (PWP. %v/v)	15%
Available water content (AWC, %v/v)	16%
Final infiltration rate (if, mm/h)	5

Cultivation / Landscape plants (or category)

Plant species / variety	lawn
Effective depth of rootzone (de, m)	0.5
Maximim allowed depletion (MAD, %)	60
Precentage of soil surgace that is shaded by plants during midday (Ps, %)	75.00%
Microirrigation ET reduction factor (r)	r 0.88

Basic characteristics of irrigation system

System type		
Percentage of weted area (%)	50.00%	
Efficiency (IE, %)	95.00%	estimation using application uniformity
Precipitation rate (PR, mm/h)	12.90	from audit results

da, max irrigation dose (mm) 2400.00 115.20 m^3

Irrigation schedule

>> <<

Month	Kc	kmc or Ks	kd or Ks	K_L	ETa	Number of days	ETa	Rain	Reff	Leaching fraction	Calculations: Water needs, ED	Theoretical irrigation span, Fth	Practical irrigation span, F	Run time, RT	Required water volume
	-	-	-	-	mm day^{-1}	days	mm $month^{-1}$	mm $month^{-1}$	mm $month^{-1}$	%	mm day^{-1}	days	**days**	**min**	m^3 $month^{-1}$
Jan	0.80	1.00	1.00	0.80	0.79	31	24.61	150.11	101.66	0%	0.00	0.00	**1.0**	0.00	0.00
Feb	0.80	1.00	1.00	0.80	1.07	29	31.02	171.71	103.20	0%	0.00	0.00	**1.0**	0.00	0.00
Mar	0.80	1.00	1.00	0.80	1.64	31	50.97	132.97	97.38	0%	0.00	0.00	**1.0**	0.00	0.00
Apr	0.80	1.00	1.00	0.80	2.43	30	72.96	73.21	65.48	0%	0.25	9632.54	**1.0**	1.22	0.38
May	0.80	1.00	1.00	0.80	3.25	31	100.77	63.99	57.87	0%	1.38	1734.21	**1.0**	6.77	2.17
Jun	0.80	1.00	1.00	0.80	3.90	30	116.93	35.86	33.54	0%	2.78	863.40	**1.0**	13.61	4.21
Jul	0.80	1.00	1.00	0.80	4.17	31	129.14	0.80	0.76	0%	4.14	579.55	**1.0**	20.27	6.49
Aug	0.80	1.00	1.00	0.80	3.78	31	117.03	1.91	1.82	0%	3.72	645.79	**1.0**	18.19	5.82
Sep	0.80	1.00	1.00	0.80	2.60	30	77.92	91.67	110.09	0%	0.00	0.00	**1.0**	0.00	0.00
Oct	0.80	1.00	1.00	0.80	1.62	31	50.28	211.03	105.17	0%	0.00	0.00	**1.0**	0.00	0.00
Nov	0.80	1.00	1.00	0.80	1.05	30	31.46	212.36	105.23	0%	0.00	0.00	**1.0**	0.00	0.00
Dec	0.80	1.00	1.00	0.80	0.00	31	0.00	182.06	103.72	0%	0.00	0.00	**1.0**	0.00	0.00

Notes

Selected alternatives for irrigation scheduling:

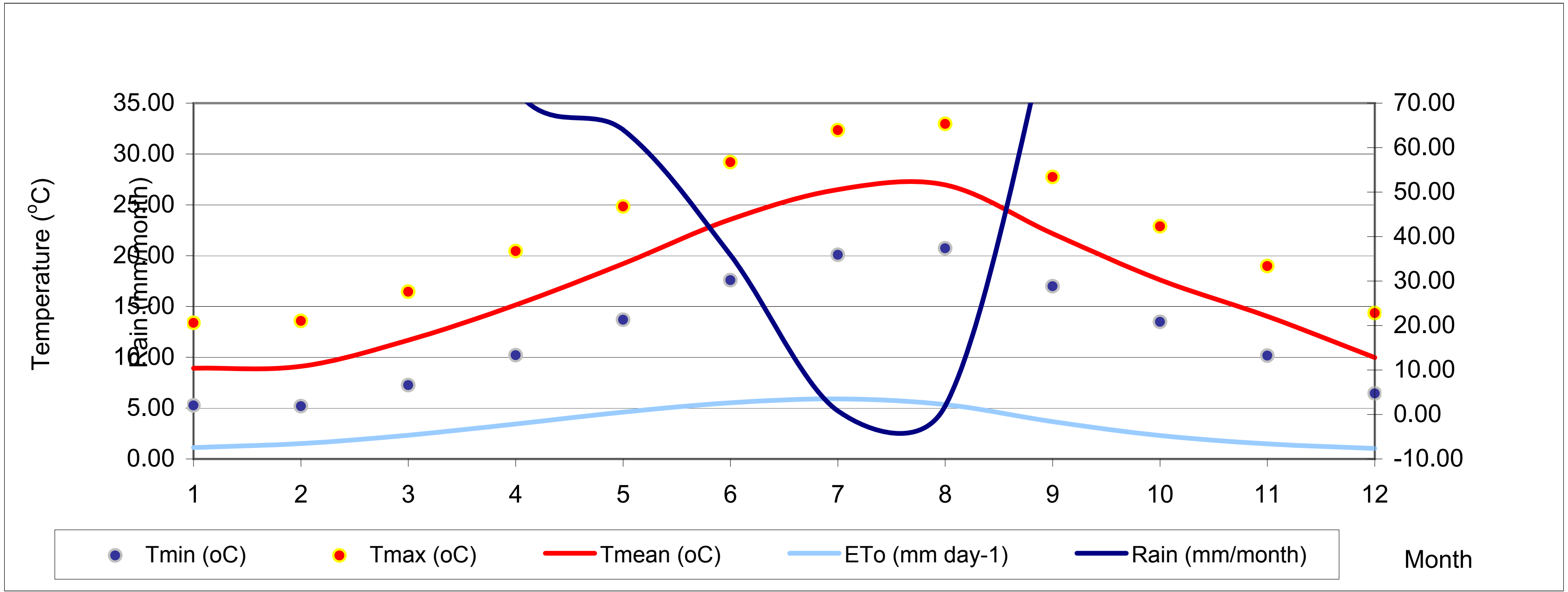
FAO CropWat http://www.fao.org/nr/water/infores_databases_cropwat.html

UC Davis Biomet http://biomet.ucdavis.edu/irrigation-scheduling.html

F, Frequency:	per	1.0	day
RT, Run time:		21.00	min
Water Budget (spring, fall):			

manH and other costs

Ombrothermic diagram



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Reference evapotranspiration openfield
FAO - Penman - Monteith
Based on Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56

Eto according to Penman - Monteith

$$ET_o = \frac{0,408 \times \Delta \times (R_n - G) + \gamma \times \frac{900}{T + 273} \times u_2 \times (e_s - e_a)}{\Delta + \gamma \times (1 + 0,34 \times u_2)}$$

Altenrantive method, Hargreaves:

$$ET_o = 0,0023 \times (T_{mean} + 17,8) \times (T_{\max} - T_{\min})^{0,5} R_a$$

Constants (or practically constants) of meteorological conditions

k	4.10E-01	αδιάστατη	von Karman constant (for wind profile)
ε	6.22E-01	-	molecular weight ratio of vapour / dry air
G_{sk}	8.20E-02	$MJm^{-2}min^{-1}$	solar constant
σ	4.90E-09	$MJK^{-4}M^{-2}day^{-}$	Stefan-Boltzman constant
P	1.01E+02	kPa	atmospheric pressure (cosnidering air an ideal gas and the temperature equal to 20^oC)
λ	2.45E+00	MJ kg^{-1}	lantent heat for evaporation at 20^oC
c_p	1.01E-03	MJ kg^{-1} $^oC^{-1}$	special heat under constant pressure for mean atmospheric conditions
γ	6.73E-02	kPa $^oC^{-1}$	psychrometric constant

ET calculations mmday^{-1}

Area					
	o		'	"	
Lat	39.00		24.00	4.24	
Lat	0.69	rad			latitude
z area		m			area height above sea level
z station		m			meteorological station height above sea level
Day	199				1-365
Tmin data	20.09	^oC			min air temperature at 2 m height
Tmax data	32.34	^oC			max air temperature at 2 m height
Tmean	26.50	^oC			mean air temperature at 2 m height
RH min		%			min relative humidity
RH max		%			max relative humidity
$e^o(T_{min})$	2.35	kPa			saturation vapour pressure at daily minimum temperature

$e^o(T_{max})$	4.85	kPa	saturation vapour pressure at daily maximum temperature
es	3.60	kPa	saturation vapour pressure
ea	0.00	kPa	actual vapour pressure from relative humidity data
Δ	0.20	kPa $^oC^{-1}$	slope vapour pressure curve (for the mean temp)
VPD	3.60	kPa	vapour pressure deficit (es-ea)
dr	0.97	rad	inverse relative distance Earth-Sun
δ	0.37	rad	solar decimation
ωs	1.89	rad	sunset hour angle
R_a	40.55	MJ $m^{-2}day^{-1}$	extraterrestrial radiation
$R_{s\ actual}$		MJ $m^{-2}day^{-1}$	solar or shortwave radiation (measured or estimated)
R_{so}	30.41	MJ $m^{-2}day^{-1}$	clear-sky solar radiation (n=N)
R_{ns}	0.00	MJ $m^{-2}day^{-1}$	net solar radiation for α=0,23 - reference surface
R_s/R_{so}	0.00	-	relative shortwave radiation
R_{nl}	-4.70	MJ $m^{-2}day^{-1}$	net longwave radiation
R_n	4.70	MJ $m^{-2}day^{-1}$	net radiation at the crop surface
G_{day}		MJ $m^{-2}day^{-1}$	soil heat flux density
z windmeter		m	wind speed measurement height
uz		m s^{-1}	wind speed, z windmeter
u2	#ΑΡΙΘ!	m s^{-1}	wind speed at 2 m heightπάνω από το έδαφος

Rs: solar or shortwave radiation
n: actual duration of sunshine
N: daylight hours, maximum possible duration of sunshine or daylight hours

N=	14.44376669	h
n=		h
R_s=	10.14	MJ $m^{-2}day^{-1}$

ETo	Hargreaves	
	5.90	mm day^{-1}

Penman-Monteith	
#ΑΡΙΘ!	mm day^{-1}

Selected alternatives for ET and plants water needs calculation:

FAO Eto Calculator http://www.fao.org/nr/water/eto.html
FAO CropWat http://www.fao.org/nr/water/infores_databases_cropwat.html

manH and other costs

D. Data analysis and report generation (sprinkler system, use separate sheet for every zone)

For sprinkler systems (openfield agriculture, landscape etc)
FAO Irrigation and drainage paper 56, WUCOLS for Landscape Irrigation, FAO Irrigation Water Management: Irrigation Scheduling, FAO Effective rainfall in irrigated agriculture

Zone

Area (A) ha ha/10 0.00

Basic soil characteristics
Soil type
Field capacity (FC, % v/v)
Permanent wilting point (PWP, % v/v)
Available water content (AWC, % v/v) 0.00%
Final infiltration rate (if, mm/h)

Cultivation / Landscape plants (or category)
Plant species / variety
Effective depth of rootzone (de, m)
Maximum allowed depletion (MAD)

Basic characteristics of irrigation system
System type

Efficiency (IE, %) estimation using application uniformity
Precipitation rate (PR, mm/h) from audit results

Irrigation schedule

Take account of rain (y/n)? n

da, max irrigation dose (mm) 0.00

>> <<

												Calculations					Notes
	Kc	kmc or Ks	kd or Ks	K_L	ETa	Number of days	ETa	Rain	Reff	Leaching fraction	Water needs, ED	Theoretical irrigation span, EA	Practical irrigation span, EA	Final application dose, du	Actual run time RT=du/PR	Required water volume	
Month	-	-	-	-	mm day^{-1}	days	mm month^{-1}	mm month^{-1}	mm month^{-1}	%	mm day^{-1}	days	days	mm	min	m^3 month^{-1}	RT check
Jan				0.00	0.00	31	0.00	150.11	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Feb				0.00	0.00	29	0.00	171.71	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Mar				0.00	0.00	31	0.00	132.97	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Apr				0.00	0.00	30	0.00	73.21	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
May				0.00	0.00	31	0.00	63.99	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Jun				0.00	0.00	30	0.00	35.86	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Jul				0.00	0.00	31	0.00	0.80	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Aug				0.00	0.00	31	0.00	1.91	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Sep				0.00	0.00	30	0.00	91.67	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Oct				0.00	0.00	31	0.00	211.03	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Nov				0.00	0.00	30	0.00	212.36	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
Dec				0.00	0.00	31	0.00	182.06	0.00	0%	0.00	0.00	**0.0**	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!	#ΔIAIP/0!
															#ΔIAIP/0!	#ΔIAIP/0!	

Selected alternatives for irrigation scheduling:

FAO CropWat http://www.fao.org/nr/water/infores_databases_cropwat.html
UC Davis Biomet http://biomet.ucdavis.edu/irrigation-scheduling.html

F, Frequency: per **0.0** day
#ΔIAIP/0! min
Water Budget (spring, fall): **#ΔIAIP/0!**

IRMA partner LOGO

ETCP GREECE-ITALY 2007-2013 www.irrigation-management.eu

IRMA

Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

Subsidy Contract No: I3.11.06

Audit No	No27
Date	

WP5 Irrigation Audits

Auditing team members name (chief inspector first)

Christos Myriounis
Dimitrios Myriounis

Contact information with audit team:

Tel.:	2665100220
Mobile:	+306973336140
email:	cmyriounis@gmail.com

Irrigation system

General problems the have been noticed

Strong winds

Comments regarding soil and water characteristics

Soli type Sil

Comments regarding design,construction and maintenance of the system

Low pressures

Comments regarding distribution uniformity

Low uniformity due to strong winds, and low pressures

Comments regarding the applied irrigation schedule

Proposed repairs / alterations and expected benefits

Some wind fense from the direction of the sea, for the protection of the plants, and for better irrigation

Proposed irrigation schedule and expected benefits

Irrigate every day for 17 min in each zone
for the irrigation period

Drainage system

General problems the have been noticed

Comments regarding design,construction and maintenance of the system

Proposed repairs / alterations and expected benefits

Attached	Analytical soil analysis results	Analytical nutrient solution analysis results

Have also in mind the following

All the entities that participated in IRMA project audits are requested to participate in IRMA stakeholders DB
http://www.irrigation-management.eu/network/stakeholders

All the entities that participated in IRMA project audits can request a relevant certificate which will testify that they are trying to contribute to water savings.

Disclaimer

IRMA project and its staff / cooperators, assume no responsibility or liability for the way that audit results and the relevant advices will be intepreted and applied. In every case it is suggested to be discussed with the relevant consultant of the audited entity before any alterations to the irrigation and drainage systems structure and management are decided and made.

Appendix IV. Irrigation worksheets from a Greenhouse

	Date	Sign
My system got audited		
I received the audit results		

ETCP GREECE-ITALY 2007-2013

IRMA Subsidy Contract No: I3.11.06 www.irrigation-management.eu

Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

fill data or circle (O) in cells colored in | manH and other costs

check (√ or O) squares □

for extra comments, number and fill info at Notes (bottom of page)

B: Bad; M: Moderate; F: Fair; E: Excellent

WP5 Irrigation Audits

Auditing team members name (chief inspector first): Karamani Aglaia

Audit No: PR2

A. First contact and field work plan

Organisation	Private
Name and age	Dimitrios Mprikos
Position of contact person	Owner / Subcont/or / Manager / Other
Address	Agios Minas Preveza
Telephone numbers	
Other contact information (website, email etc)	

First contact, explanation of the procedure

Try to collect as much basic information as you can during this contact

Check Have you filled an irrigation survey questionnaire of IRMA project? Yes / No

If Yes, a copy should be inquired by the relevant contractor and most of the

If No, a communication with the relevant contractor should be made in order to register this system.

Provide information regarding the documents that you will need and ask for copies — Comments

Yes	No	Topographic or a coverage diagram	
Yes	No	Plan of the irrigation and drainage system	
Yes	No	Pumping system / grid connection design	
Yes	No	Manuals of the system's basic components (i.e. pump operation diagram)	
Yes	No	Electric power accounts of the system	
Yes	No	Bills from the Local Land Reclamation Service (LLRS) or other similar	
Yes	No	Latest soil and/or water analysis available	
Yes	No	Latest statement regarding EU agricultural funding	
Yes	No	Registrations of the cultivation system (eg integrated management)	
Yes	No	Reports from previous audits	

Set date, time, location for the audit

Selection of date based on weather conditions. In case of sprinkler system, it is recommended to select not intensely windy conditions. For accurate results note that collection of data should be time independent to prior irrigation of the study area.

□ Call the day before to confirm appointment

A, C. Basic system characteristics

manH and other costs

Date	2/2/2015	**Time**	
		arrival at field	9:30
		departure from field	11:00

Location, type of setup, total area

Location		GLRS		LLRS	
		Name			
			o	'	"
Latitude	38°57°33"N				
Longitude	20°45°02"E				

Type of setup (√)

Open field	□	Public	□
Greenhouse / Nethouse	□	Private	□
Landscape (turfgrass, shrubs, trees)	□		
Athletic installation	□	Area (ha)	0.6

System designer	Craftsman	Agricult/list	Him/Her self	Other	
System constructor	Craftsman	Agricult/list	Him/Her self	Other	
System conservator	Craftsman	Agricult/list	Him/Her self	Other	
System administrator	Craftsman	Agricult/list	Him/Her self	Other	

Operational problems reported by the system administrator

Low pressure	□	
High pressure	□	
Tilted sprinklers	□	
Sunken sprinklers	□	
Spray deflection	□	
Arc misalignment	□	
Drainage from low placed sprinklers	□	
Different oulets at the same zone	□	
Missing or broken components	□	
Clogged components	□	
Leaky seals or fittings	□	
Pipe leaks	□	
Slow drainage / ponding / surface runoff	□	
Compaction / thatch	□	
Other mulfactions etc		

In case of a previous audit, confirm that the proposed improvements and repairs have been made before proceed to the new audit.

Basic system use (√)

□ Irrigation
□ Frost protection
□ Other

Notes (use numbering for references)

Water supply / POC (point of connection) characteristics

manH and other costs

Source type	
Irrigation canal	
Water pond / tank	
Drilling (depth (m) and pipe diameter ("))	
Civil water system	
Other	

Irrigation rules (bans, irrigation time windows etc)				
Water meter (Y/N, characteristics)	Yes	No		
Condition of water supply / POC area (circle)	Bad	Moderate	Fair	Excellent
Photos □				

Irrigation water usage/cost, data?	Yes	No	20..	20..	20..
If yes, irrigation water usage (last 3 years, m3)					
or how many hours per year the system irrigates					
Irrigation cost (last 3 years, € y^{-1})	Labor		Materials		

Pump identification

Ask for or find manuals of components and circle if available Manual

Manufacturer				
Model				
Age				
Power / max RPM		HP		rpm
Typical operating flow (select or write unit)		m^3/h Lm^{-1} Lh^{-1} ….		
Typical operating pressure (select or write unit)		atm bar …		
Pressure tank (circle and note)	Yes No	Characteristics:		
Other				
Photos □				

Energy source (circle, or specify)	Petrol	Gas	Electricity	…	…
Power system diagram availability (circle)		Yes	No	Notes:	
Condition of power supply system (circle)		Bad	Moderate	Fair	Excellent
Other					
Photos □					

Energy

cost (€ y^{-1}) ______ or typical energy consumption per hour ______

this info must be treated in combination with the applied schedule data in Zone characteristics

Filters

System head filtering system

		Order	Characteristics	mesh or color
Hydrocyclone	□			
Sand	□			
Mesh	□			
Disk	□			
Reverse osmosi	□			
Other…	□			

Notes (use numbering for references)

	Check	Condition (B, M, F, E)	Characteristics and comments regarding placement	manH and other costs
Other key components				
Check valve	□			
Backflow preventer	□			
Air valve	□			
Flush valve	□			
Other				
Other				
Other				

Type of main pipes (material, pressure range) and depth of installation

Section (initial - final length in m)	PVC (Ø mm)	PE(LDPE) (Ø mm)	PE(HDPE) (Ø mm)	(Ø mm)	Pressure (Schedule, atm))	Height (m)*
-						
-						
-						
-						

* in case of underground system enter a negative value

Basic system and surroundings that affect irrigation sketch (circle if available) Available

Show info regarding
Water supply (WS)
Mainline
Zones/Stations (A, B, C,….)
Zones' point of connection (POC)

Connection of zone control valves (circle)
Central Close to zones

Photos □

Notes (use numbering for references)

Identify irrigation system zones (stations)

Zone (A-Z and System type code)	Slope (%)	Soil sample no	Area (m^2)	Irrigation system type: Sprinkler	Micro	Other	Probability of horizontal - upward motion of water
A				□	□	□	
B				□	□	□	
C				□	□	□	
…				□	□	□	
…				□	□	□	

continued…

OF: Open field; G/N: Greenhouse / Nethouse; L: Landscape (turfgrass, shrubs, trees); A: Athletic

Zone	Plant material	Yield (kg, pieces, etc)	Crop rows dist. (m)*	Crops dist. on row (m)*	Plant material similarity (√)	Establishe ment year
A						
B						
C						
…						
…						
…						

* or planting density (plants per area unit)

Notes (use numbering for references)

A, C. Irrigation zone layout and components

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Zone ______ (use separate sheet for every zone, in case of greenhouse also fill the relevant sheet)

Ask for or find manuals of components

Sampling and measurements

Soil sampling	Pos:			Pos:	
skip in case that a recent		00-30 cm			00-30 cm
soil analysis is available		30-60 cm			30-60 cm
		cm			cm

Notes on soil layering

Select proper template to sketch the zone arangement

Valve Ask for or find manuals of components and circle if available Manual

Manufacturer

Model

Flow range

Pressure range

Condition (circle) Bad Mediocre Fair Excellent

System control

Manual control

Irrigation controller

Ask for or find manuals of components and circle if available Manual

id / Manufacturer / Model

Age

Number of stations — Power supply ◻ Current

Number of programs — ◻ Battery

Number of start times

Rain delay (Y/N)

Pump control (Y/N)	Yes	No
Water budget (Y/N)	Yes	No
Sensor(s) port (Y/N)	Yes	No
Other	Yes	No

Wiring (notes)

Sensors (check and comment regarding installation)

Rain sensor ◻

Soil moisture sensor ◻

Wind senor ◻

Other ◻

Other

Photos ◻

Filter (zone or line) Ask for or find manuals of components and circle if available Manual

Type Mesh Disk Manufacturer Model

Mesh or color

Flow range

Pressure range

Condition (circle) Bad Moderate Fair Excellent

Pressure regulator Ask for or find manuals of components and circle if available Manual

Manufacturer / Model

Input / output flow

Condition (circle) Bad Moderate Fair Excellent

Notes (use numbering for references)

Other key components	Check	Condition (B, M, F, E)	Characteristics
Feltilisation equipment	□		
Check valve	□		
Air valve	□		
Flush valve	□		
Other ………………	□		

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Type of pipes (material, pressure range) and depth of installation

	PVC (Ø mm)	PE(LDPE) (Ø mm)	PE(HDPE) (Ø mm)	(Ø mm)	Pressure (Schedule, atm))	Height (m)*
Zonepipes						
Application						

* in case of underground system enter a negative value

Outlets

Big guns / travelling irrigators characteristics Manual

Manufacturer

Model

Operating pressure unit:

Flow rate unit:

Condition Bad Mediocre Fair Excellent

Sprinklers and micro-sprinklers characteristics Manual

Manufacturer

Model

Nozzles (type or	90o		180o		270o	
press/flow)..units	360o		…		…	

Layout type (circle) Square Triangular

Distance between Wet radius

Condition (circle) Bad Moderate Fair Excellent

Drippers / Emitters and Driplines characteristics:

Individual emitters Driplines Height (m)

Manufacturer

Type or press/flow (units)

Distances on pipe or dripline between pipes or driplines

Pressure regulated? Yes No

Self cleaned? Yes No

Condition (circle) Bad Mediocre Fair Excellent

Applied schedule

Manual
- Month
- Number of irrigation events
- Run time (min)

Using controler

- Program
- Start times
- Frequency
- Run time
- Special sensor application (i.e. at valve common)

Using other approcah

Notes (use numbering for references)

Special cases **Greenhouse / nethouse**

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Basic characteristics

Manufacturer		**Covering material**	Glass	◻	Age: 2005
Year of construction	1990		Plastic film	✓	
			Other		

Type of structure

- ◻ Arc
- ✓ Arc with side walls
- ◻ Sloped rood

Number of rows:

Whitening / Shading Yes No

Shading percentage

Shading period

Dimensions of each row

Length	50.00	m
Width	6.5	m
Side wall height	2.0	m
Ringe hight	3.0	m

Covered area **0.00** m^2

Climate control

Roof vents	◻	Cooling system	◻
Side vents	✓	Other	
Heating system	◻		

Hydroponics

Yes

No

Fertigation

Yes

No

Photos ◻

Notes (use numbering for references)

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C. System operation evaluation and uniformity measurements

Zone ______ (use separate sheet for every zone)

Wind speed ______ km/h   Check and record wind speed at 2m: should be < 8 km/h (4.97 m/h)
Wind speed should be monitored also during the test if variations are sensed

Either the table or the generic or special design can be used for data keeping

Operation and measurement (in case of sprinkler systems, along with catch cans measurements)
Pressure tests must be conducted at normal operating conditions of the oulets using the appropriate pressure gauges
For pipes, at the beginning, middle, and end of every zone audited.

Outlet / Pipe pos.	Operating pressure bar	Radius (for sprinklers) m	Pipe flow rate ….	Comments / Observed problems
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Zone problems detected by the auditor

Problem	
Improper zoning	
Limited controller capability	
Incorrect pressure (low / high)	
Lack of adequate flows	
Improperly sized components	
Old or worn out equipment	
Dirty or teared filters	
Tilted Sprinklers	
Spray Deflection	
Sunken Sprinklers	
Plugged Equipment	
Arc Misalignment	
Low Sprinkler Drainage	
Leaky Seals or Fittings	
Lateral or Drip Line Leaks	
Missing or Broken Heads	
Slow Drainage or Ponding	
Compaction/Thatch/Runoff	
Other	

Soil moisture sensor type:
Equation used:

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Measurements

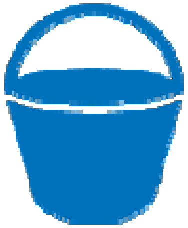
Number of catch cans 20 (at least 20)

Test duration 10 min sec

Catch-can throat diameter 8 cm

or specific cath-can Underhill_mini

Pos / Catch Can	Measur. (select unit) ml	Soil moisture (v/v %) Before % v/v	After % v/v	Difference % v/v	Comments / Observed problems
1	173	18.10%	29.80%	11.70%	
2	208	17.60%	34.50%	16.90%	
3	173	16.80%	30.50%	13.70%	
4	116	20.70%	30.50%	9.80%	
5	150	22.10%	28.50%	6.40%	
6	196	20.20%	26.30%	6.10%	
7	173	20.20%	35.80%	15.60%	
8	173	18.60%	30.50%	11.90%	
9	196	18.60%	31.50%	12.90%	
10	196	16.50%	32.40%	15.90%	
11	138	20.20%	35.40%	15.20%	
12	150	20.10%	32.60%	12.50%	
13	185	19.50%	36.50%	17.00%	
14	116	16.20%	32.80%	16.60%	
15	185	19.70%	34.20%	14.50%	
16	161	17.90%	32.70%	14.80%	
17	116	20.00%	39.20%	19.20%	
18	185	21.50%	38.10%	16.60%	
19	185	21.80%	37.00%	15.20%	
20	208	20.50%	36.50%	16.00%	
21				0.00%	
22				0.00%	
23				0.00%	
24				0.00%	
25				0.00%	
26				0.00%	
27				0.00%	



28				0.00%	
29				0.00%	
30				0.00%	
31				0.00%	
32				0.00%	
33				0.00%	
34				0.00%	
35				0.00%	
36				0.00%	
37				0.00%	
38				0.00%	
39				0.00%	
40				0.00%	

Cooperation level (design the lips at the face)

Fittings that have been left at the audited system and must be replaced at the toolbox

Fittings	Diameter	Number
T		
Connector		
End cup		
Connection fittings		
…		
…		
…		
…		
…		
…		
…		

Notes (use numbering for references)

Energy consumption indication at end

Longitudinal speed uniformity test (SI)
Optional

id	D (m)	SI (min)	Speed (m/h)
	10		#ΔIAIP/0!
	10		
	10		
	10		
	10		

Notes (use numbering for references)

Water sampling

Qualitative characteristics of water source

pH

Electrical conductivity (EC) dS m^{-1}

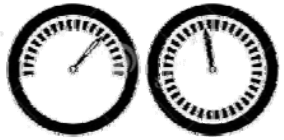
1 μ = 10^{-5} deci

Head / flowrate at water supply point

Date and time of measurement

Static pressure at the source bar

Measured flow /head couples by auditor



Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)
			0.00
			0.00
			0.00
			0.00
			0.00 Maximum available flowrate

Fill in case of more water supplies

Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)
			0.00
			0.00
			0.00
			0.00
			0.00 Maximum available flowrate

Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)
			0.00
			0.00
			0.00
			0.00
			0.00 Maximum available flowrate

Notes (use numbering for references)

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D. Uniformity analysis (use separate sheet for every zone)

Zone ________ (use separate sheet for every zone)

Catch device throat diameter 0.08 m or specific cath-can: Underhill_mini

Test 10 min

Analysis

A-Z list

	V	Vi-Vμέση	PR
Αρ. δοχεί ου	**ml or ....**	**ml - ml or ....**	**mm/h**
1	116.00	53.15	138.46
2	116.00	53.15	138.55
3	116.00	53.15	138.55
4	138.00	31.15	164.82
5	150.00	19.15	179.16
6	150.00	19.15	179.16
7	161.00	8.15	192.29
8	173.00	3.85	206.63
9	173.00	3.85	206.63
10	173.00	3.85	206.63
11	173.00	3.85	206.63
12	185.00	15.85	220.96
13	185.00	15.85	220.96
14	185.00	15.85	220.96
15	185.00	15.85	220.96
16	196.00	26.85	234.10
17	196.00	26.85	234.10
18	196.00	26.85	234.10
19	208.00	38.85	248.43
20	208.00	38.85	248.43
21			

1. Sort measurements in descending order
(regards measurements of catch-cans and moisture difference data)

2. Calculation of averages, totals and ratios

Attention, these formulas need to set up every time

146.60	Low_Quarter_Average_Depth (or Volume)
169.15	Low_Half_Average_Depth (or Volume)
169.15	Overall_Average_Depth (or Volume)
3383.00	Σvi (ml)
201.91	PRavg (mm/h), average zone precipitation rate

Distribution Uniformity

for sprinkler systems, Dulq is more strict

Low Quarter irrigation Distribution Uniformity - DU_{lq}Low Quarter irrigation Distribution Uniformity - DUlqLow Quarter irrigation Distribution Uniformity - DUlq

DUlq= 87%

$$DU_{lq} = \frac{Low\_Quarter\_Average\_Depth}{Overall\_Average\_Depth} \times 100$$

Low Half irrigation Distribution Uniformity - DU_{lh}Low Half irrigation Distribution Uniformity - DUlhLow Half irrigation Distribution Uniformity - DUlh

DUlh= 100%

$$DU_{lh} = \frac{Low\_Half\_Average\_Depth}{Overall\_Average\_Depth} \times 100$$

Scheduling Coefficient (SC)

for sprinkler systems

SC= 1.46

$$SC = \frac{PR_{average}}{PR_{minimum}}$$

22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			

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Christiansen
for micro-irrigation systems
Σ|Vi-V|= 474.1
CU= 86%

$$CU = 1 - \frac{\sum_{i=1}^{n} \left| V_i - \overline{V} \right|}{\sum_{i=1}^{n} V_i}$$

Attention, this formula need to set up every time

Maximum volume:	208.00
Minimum volume:	116.00
Average volume:	169.15
Standard deviation:	29.46
Standard error:	6.59

65% 135%

In every case a variation of more than ±10% is probably unacceptable and suggests poor system design.

Rough cross check – pump flow rate / water supply from catch can test

No. outlets x average emitter flow rate		outlets	x	lpm
Overall flow rate		lpm		
Pump flow rate – specified		lpm		

How does the specified compare to the overall?

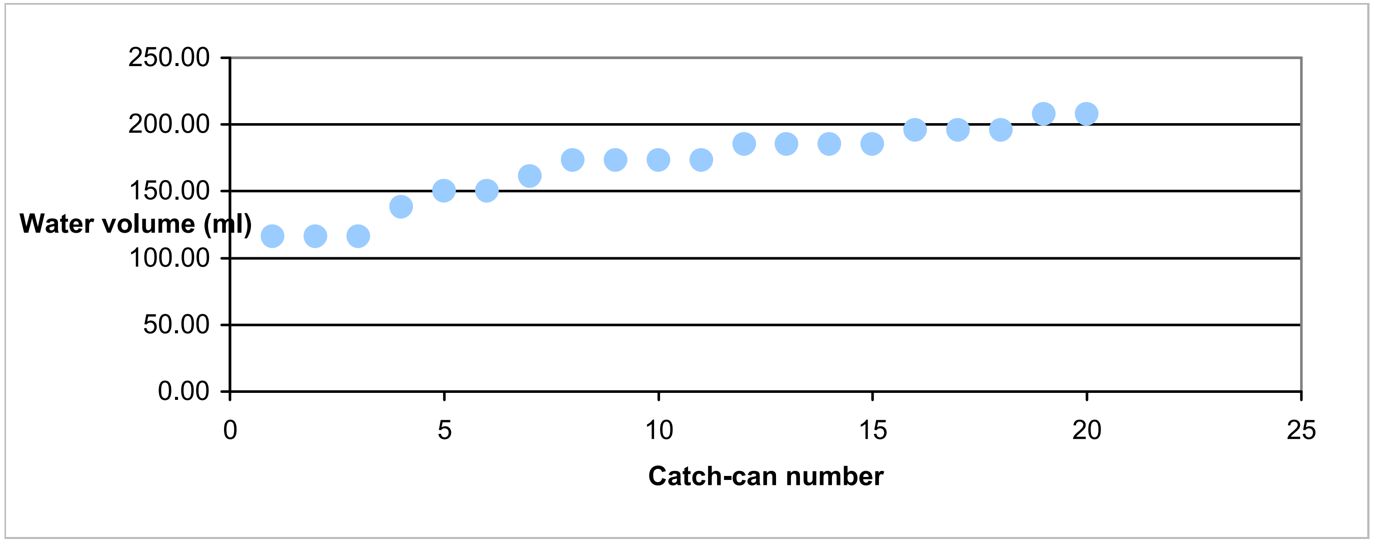
Emitter flow equation: $q=kH^x$

k		
x		
H		bar
q expected	#APIΘ!	l/h

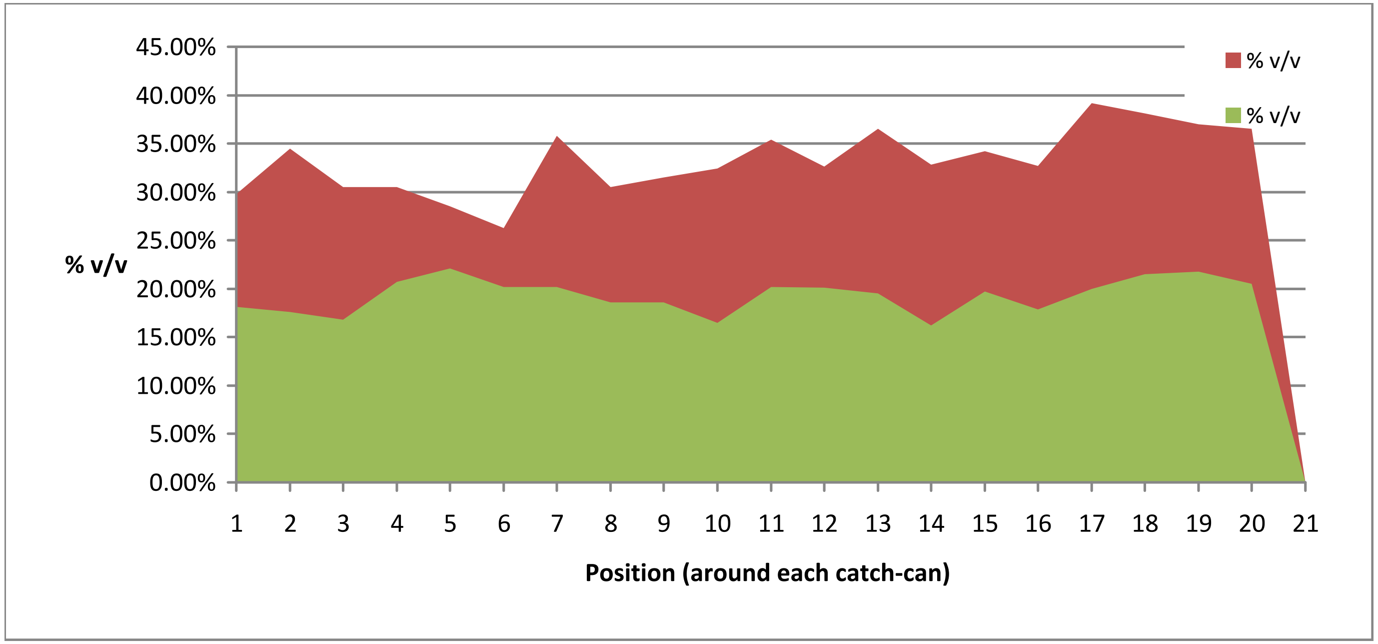
Selected alternatives for uniformity calculation:

UC Davis Biomet DU Citrus http://biomet.ucdavis.edu/irrigation_scheduling/DU%20Irrig%20of%20Citrus/IS004.htm

Water volume fluctuation in catc-cans



Substrate moisture before and after irrigation



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D. Climatic data, potential Evapotranspiration and Ombrothermic diagram

Constants for the calculations

G_{sk}	116.64	cal cm^{-2} h	0.082	MJm^{-2}min^{-1}	1 MJ m^{-2} day^{-1} =	0.408 mm day^{-1}
λ	59.50	cal cm^{-2} mm^{-1}				
φ	0.00	rad				

t 50% greenhouse cover transmission to solar radiation (%)

Step 1. Calculation of potential / reference evapotranspiration (ETo)

Month	Reference period temperatures (i.e. month)			Solar radiation calculation for the characteristic day of the reference period					Rain	Open field (1)	Greenhouse (2)
	Representative day number	Tmin (°C)	Tmax (°C)	Tmean (°C)	dr (rad)	δ (rad)	ωs (rad)	R_a (MJ m^{-2} day^{-1})	Rain (mm/month)	ETo (mm day^{-1})	ETo (mm day^{-1})
Jan	18	9.10	15.00	11.60	1.03	-0.36	1.57	36.27	187.60	2.43	4.96
Feb	46	8.10	15.60	11.40	1.02	-0.23	1.57	37.44	122.60	2.81	5.12
Mar	75	8.70	17.10	12.40	1.01	-0.04	1.57	37.90	136.40	3.11	5.18
Apr	105	11.00	19.30	14.90	0.99	0.17	1.57	36.78	158.40	3.25	5.03
May	135	14.00	22.10	18.00	0.98	0.33	1.57	34.77	46.40	3.32	4.75
Jun	162	18.10	27.30	22.70	0.97	0.40	1.57	33.50	17.20	3.86	4.58
Jul	199	20.30	29.00	24.90	0.97	0.37	1.57	33.99	12.60	4.02	4.65
Aug	229	20.40	29.40	25.10	0.98	0.23	1.57	35.78	2.20	4.32	4.89
Sep	259	18.00	26.40	22.10	0.99	0.03	1.57	37.26	94.40	4.04	5.09
Oct	289	14.70	22.50	18.20	1.01	-0.18	1.57	37.33	273.00	3.52	5.10
Nov	318	11.50	18.70	14.70	1.02	-0.33	1.57	36.36	101.60	2.98	4.97
Dec	345	8.60	15.40	11.40	1.03	-0.40	1.57	35.64	226.20	2.55	4.87
									1378.60	40.22	59.18

Microclimatic notes (i.e. local winds etc)

1) FAO Paper56 / Hargreaves
2) Institute Nationale de la Recherche Agronomique (INRA), Avignon, France / Baille

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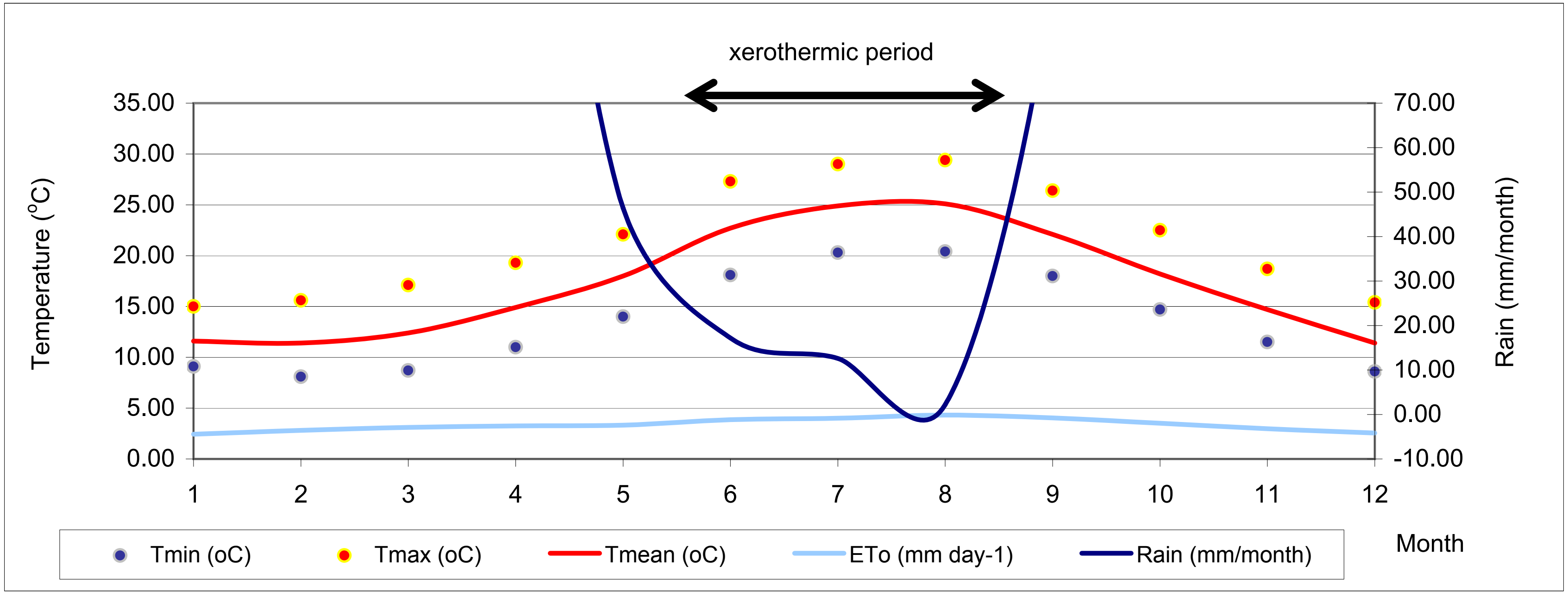
Ombrothermic diagram



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Reference evapotranspiration openfield
FAO - Penman - Monteith
Based on Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56

Eto according to Penman - Monteith

$$ET_o = \frac{0,408 \times \Delta \times (R_n - G) + \gamma \times \frac{900}{T + 273} \times u_2 \times (e_s - e_a)}{\Delta + \gamma \times (1 + 0,34 \times u_2)}$$

Altenrantive method, Hargreaves:

$$ET_o = 0,0023 \times (T_{mean} + 17,8) \times (T_{\max} - T_{\min})^{0,5} R_a$$

Constants (or practically constants) of meteorological conditions

k	4.10E-01	αδιάστατη	von Karman constant (for wind profile)
ε	6.22E-01	-	molecular weight ratio of vapour / dry air
G_{sk}	8.20E-02	$MJm^{-2}min^{-1}$	solar constant
σ	4.90E-09	$MJK^{-4}M^{-2}day^{-}$	Stefan-Boltzman constant
P	1.01E+02	kPa	atmospheric pressure (cosnidering air an ideal gas and the temperature equal to 20°C)
λ	2.45E+00	$MJ\ kg^{-1}$	lantent heat for evaporation at 20°C
c_p	1.01E-03	$MJ\ kg^{-1}\ {}^oC^{-1}$	special heat under constant pressure for mean atmospheric conditions
γ	6.73E-02	$kPa\ {}^oC^{-1}$	psychrometric constant

ET calculations $mmday^{-1}$

Area				
	o	'	"	
Lat	38.00	59.00	35.00	
Lat	0.68	rad		latitude
z area		m		area height above sea level
z station		m		meteorological station height above sea level
Day	199			1-365
Tmin data	20.30	°C		min air temperature at 2 m height
Tmax data	29.00	°C		max air temperature at 2 m height
Tmean	24.90	°C		mean air temperature at 2 m height
RH min		%		min relative humidity
RH max		%		max relative humidity
$e^o(T_{min})$	2.38	kPa		saturation vapour pressure at daily minimum temperature

$e^o(T_{max})$	4.01	kPa	saturation vapour pressure at daily maximum temperature
es	3.19	kPa	saturation vapour pressure
ea	0.00	kPa	actual vapour pressure from relative humidity data
Δ	0.19	kPa $^oC^{-1}$	slope vapour pressure curve (for the mean temp)
VPD	3.19	kPa	vapour pressure deficit (es-ea)
dr	0.97	rad	inverse relative distance Earth-Sun
δ	0.37	rad	solar decimation
ωs	1.89	rad	sunset hour angle
R_a	40.56	MJ $m^{-2}day^{-1}$	extraterrestrial radiation
$R_{s\ actual}$		MJ $m^{-2}day^{-1}$	solar or shortwave radiation (measured or estimated)
R_{so}	30.42	MJ $m^{-2}day^{-1}$	clear-sky solar radiation (n=N)
R_{ns}	0.00	MJ $m^{-2}day^{-1}$	net solar radiation for α=0,23 - reference surface
R_s/R_{so}	0.00	-	relative shortwave radiation
R_{nl}	-4.60	MJ $m^{-2}day^{-1}$	net longwave radiation
R_n	4.60	MJ $m^{-2}day^{-1}$	net radiation at the crop surface
G_{day}		MJ $m^{-2}day^{-1}$	soil heat flux density
z windmeter		m	wind speed measurement height
uz		m s^{-1}	wind speed, z windmeter
u2	#ΑΡΙΘ!	m s^{-1}	wind speed at 2 m heightπάνω από το έδαφος

Rs: solar or shortwave radiation
n: actual duration of sunshine
N: daylight hours, maximum possible duration of sunshine or daylight hours

N=	14.4072565	h
n=		h
R_s=	10.14	MJ $m^{-2}day^{-1}$

ETo	Hargreaves	
	4.79	mm day^{-1}
	Penman-Monteith	
	#ΑΡΙΘ!	mm day^{-1}

Selected alternatives for ET and plants water needs calculation:

FAO Eto Calculator http://www.fao.org/nr/water/eto.html

FAO CropWat http://www.fao.org/nr/water/infores_databases_cropwat.html

D. Data analysis and report generation (micro-irrigation system, use separate sheet for every zone)

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Zone | Type Greenhouse | Take account of rain (y/n)? n

Area (A) 0.6 ha

Basic soil characteristics

Soil type	
Field capacity (FC, %v/v)	31%
Permanent wilting point (PWP. %v/v)	15%
Available water content (AWC, %v/v)	16%
Final infiltration rate (if, mm/h)	10

Cultivation / Landscape plants (or category)

Plant species / variety	Cucumbers
Effective depth of rootzone (de, m)	0.5
Maximim allowed depletion (MAD, %)	50.00%
Precentage of soil surgace that is shaded by plants during midday (Ps, %)	100.00%
Microirrigation ET reduction factor (r)	r 1.00

Basic characteristics of irrigation system

System type		
Percentage of weted area (%)	100.00%	
Efficiency (IE, %)	86%	estimation using application uniformity
Precipitation rate (PR, mm/h)	202	from audit results

da, max irrigation dose (mm) 40.00 240.00 m^3

Irrigation schedule

>> <<

Month	Kc	kmc or Ks	kd or Ks	K_L	ETa	Number of days	ETa	Rain	Reff	Leaching fraction	Calculations: Water needs, ED	Theoretical irrigation span, Fth	Practical irrigation span, F	Run time, RT	Required water volume	Notes
	-	-	-	-	mm day^{-1}	days	mm $month^{-1}$	mm $month^{-1}$	mm $month^{-1}$	%	mm day^{-1}	days	**days**	**min**	m^3 $month^{-1}$	RT check
Jan	1.00	1.00	1.00	1.00	4.96	31	153.69	187.60	0.00	0%	4.96	8.07	**0.0**	1.68	151.21	ok
Feb	1.00	1.00	1.00	1.00	2.81	29	81.48	122.60	0.00	0%	2.81	14.24	**0.0**	1.94	163.13	ok
Mar	1.00	1.00	1.00	1.00	3.11	31	96.50	136.40	0.00	0%	3.11	12.85	**0.0**	2.15	193.64	ok
Apr	1.00	1.00	1.00	1.00	3.25	30	97.55	158.40	0.00	0%	3.25	12.30	**0.0**	2.25	202.29	ok
May	1.00	1.00	1.00	1.00	3.32	31	103.06	46.40	0.00	0%	3.32	12.03	**0.0**	2.30	206.80	ok
Jun	1.00	1.00	1.00	1.00	3.86	30	115.87	17.20	0.00	0%	3.86	10.36	**0.0**	2.67	240.26	ok
Jul	1.00	1.00	1.00	1.00	4.02	31	124.53	12.60	0.00	0%	4.02	9.96	**0.0**	2.78	249.90	ok
Aug	1.00	1.00	1.00	1.00	4.32	31	133.95	2.20	0.00	0%	4.32	9.26	**0.0**	2.99	268.79	ok
Sep	1.00	1.00	1.00	1.00	4.04	30	121.29	94.40	0.00	0%	4.04	9.89	**0.0**	2.79	251.51	ok
Oct	1.00	1.00	1.00	1.00	3.52	31	109.17	273.00	0.00	0%	3.52	11.36	**0.0**	2.43	219.08	ok
Nov	1.00	1.00	1.00	1.00	2.98	30	89.26	101.60	0.00	0%	2.98	13.44	**0.0**	2.06	185.08	ok
Dec	1.00	1.00	1.00	1.00	2.55	31	78.95	226.20	0.00	0%	2.55	15.71	**0.0**	1.76	158.42	ok
														2.99	2490.12	

Selected alternatives for irrigation scheduling:

FAO CropWat http://www.fao.org/nr/water/infores_databases_cropwat.html

UC Davis Biomet http://biomet.ucdavis.edu/irrigation-scheduling.html

F, Frequency:	per	0.0	days
RT, Run time:		3.00	min
Water Budget (spring, fall):		**63%**	

IRMA partner
LOGO

ETCP GREECE-ITALY 2007-2013

www.irrigation-management.eu

IRMA

Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

Subsidy Contract No: I3.11.06

Audit No	PR2
Date	

WP5 Irrigation Audits

Auditing team members name (chief inspector first)

Karamani Aglaia

Contact information with audit team:

Tel.:	
Mobile:	6979442437
email:	karamaniaglaia@gmail.com

Irrigation system

General problems the have been noticed

No problems were observed

Comments regarding soil and water characteristics

Irrigation canal

Comments regarding design,construction and maintenance of the system

Good management

Comments regarding distribution uniformity

High uniformity

Comments regarding the applied irrigation schedule

Irrigation in every 2 days for 15min

Proposed repairs / alterations and expected benefits

Proposed irrigation schedule and expected benefits

The applied programm

Drainage system

General problems the have been noticed

Not observed

Comments regarding design,construction and maintenance of the system

-

Proposed repairs / alterations and expected benefits

-

Attached	Analytical soil analysis results	Analytical nutrient solution analysis results

Have also in mind the following

All the entities that participated in IRMA project audits are requested to participate in IRMA stakeholders DB
http://www.irrigation-management.eu/network/stakeholders

All the entities that participated in IRMA project audits can request a relevant certificate which will testify that they are trying to contribute to water savings.

Disclaimer

IRMA project and its staff / cooperators, assume no responsibility or liability for the way that audit results and the relevant advices will be intepreted and applied. In every case it is suggested to be discussed with the relevant consultant of the audited entity before any alterations to the irrigation and drainage systems structure and management are decided and made.

Appendix V. Irrigation worksheets from a football stadium

	Date	Sign
My system got audited		
I received the audit results		

ETCP GREECE-ITALY 2007-2013

IRMA Subsidy Contract No: I3.11.06 www.irrigation-management.eu

Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

fill data or circle (O) in cells colored in | manH and other costs
check (√ or O) squares ◻
for extra comments, number and fill info at Notes (bottom of page)
B: Bad; M: Moderate; F: Fair; E: Excellent

WP5 Irrigation Audits

Auditing team members name (chief inspector first)

Audit No No81

A. First contact and field work plan

Organisation	Public
Name and age	Petratos Ioannis, 30
Position of contact person	Owner Subcont/or Manager Other
Address	
Telephone numbers	
Other contact information (website, email etc)	

First contact, explanation of the procedure
Try to collect as much basic information as you can during this contact

Check Have you filled an irrigation survey questionnaire of IRMA project? Yes No
If Yes, a copy should be inquired by the relevant contractor and most of the
If No, a communication with the relevant contractor should be made in order to register this system.

Provide information regarding the documents that you will need and ask for copies

			Comments
Yes	No	Topographic or a coverage diagram	
Yes	No	Plan of the irrigation and drainage system	
Yes	No	Pumping system / grid connection design	
Yes	No	Manuals of the system's basic components (i.e. pump operation diagram)	
Yes	No	Electric power accounts of the system	
Yes	No	Bills from the Local Land Reclamation Service (LLRS) or other similar	
Yes	No	Latest soil and/or water analysis available	
Yes	No	Latest statement regarding EU agricultural funding	
Yes	No	Registrations of the cultivation system (eg integrated management)	
Yes	No	Reports from previous audits	

Set date, time, location for the audit
Selection of date based on weather conditions. In case of sprinkler system, it is recommended to select not intensely windy conditions. For accurate results note that collection of data should be time independent to prior irrigation of the study area.

◻ Call the day before to confirm appointment

Notes (use numbering for references)

A, C. Basic system characteristics

manH and other costs

Date 7/10/2014

Time
arrival at field 8:00
departure from field 10:30

Location, type of setup, total area

Location	Patra, Roikou 2	GLRS		LLRS	
		Name			
			o	'	"
Latitude	21.74572577		21.00	44.00	44.612776
Longitude	38.26156814				

Type of setup (√)

Open field	□	Public	□
Greenhouse / Nethouse	□	Private	□
Landscape (turfgrass, shrubs, trees)	□		
Athletic installation	□	Area (ha)	

System designer	Craftsman	Agricult/list	Him/Her self	Other	
System constructor	Craftsman	Agricult/list	Him/Her self	Other	
System conservator	Craftsman	Agricult/list	Him/Her self	Other	
System administrator	Craftsman	Agricult/list	Him/Her self	Other	

Operational problems reported by the system administrator

Low pressure	□	
High pressure	□	
Tilted sprinklers	□	
Sunken sprinklers	□	
Spray deflection	□	
Arc misalignment	□	
Drainage from low placed sprinklers	□	
Different oulets at the same zone	□	
Missing or broken components	□	
Clogged components	□	
Leaky seals or fittings	□	
Pipe leaks	□	
Slow drainage / ponding / surface runoff	□	
Compaction / thatch	□	

Other mulfactions etc: Problems involving wrong desing of the irrigation system

In case of a previous audit, confirm that the proposed improvements and repairs have been made before proceed to the new audit.

Basic system use (√)

V	Irrigation
□	Frost protection
□	Other

Notes (use numbering for references)

Water supply / POC (point of connection) characteristics

manH and other costs

Source type	Irrigation canal				
	Water pond / tank				
	Drilling (depth (m) and pipe diameter ("))				
	Civil water system	X			
	Other				
Irrigation rules (bans, irrigation time windows etc)					
Water meter (Y/N, characteristics)		Yes	No		
Condition of water supply / POC area (circle)		Bad	Moderate	Fair	Excellent
Photos □					

Irrigation water usage/cost, data?	Yes	No	20..	20..	20..
If yes, irrigation water usage (last 3 years, m3)					
or how many hours per year the system irrigates					
Irrigation cost (last 3 years, € y^{-1})	Labor		Materials		

Pump identification

Ask for or find manuals of components and circle if available — Manual

Manufacturer					
Model					
Age					
Power / max RPM			HP		rpm
Typical operating flow (select or write unit)			m^3/h Lm^{-1} Lh^{-1} ….		
Typical operating pressure (select or write unit)			atm bar …		
Pressure tank (circle and note)	Yes	No	Characteristics:		
Other					
Photos □					

Energy source (circle, or specify)	Petrol	Gas	Electricity	…	…
Power system diagram availability (circle)		Yes	No	Notes:	
Condition of power supply system (circle)		Bad	Moderate	Fair	Excellent
Other					
Photos □					

Energy

cost (€ y^{-1}) ______ or typical energy consumption per hour ______

this info must be treated in combination with the applied schedule data in Zone characteristics

Filters

			Order	Characteristics	mesh or color
System head filtering system	Hydrocyclone	□			
	Sand	□			
	Mesh	□			
	Disk	□			
	Reverse osmosi:	□			
	Other…	□			

Notes (use numbering for references)

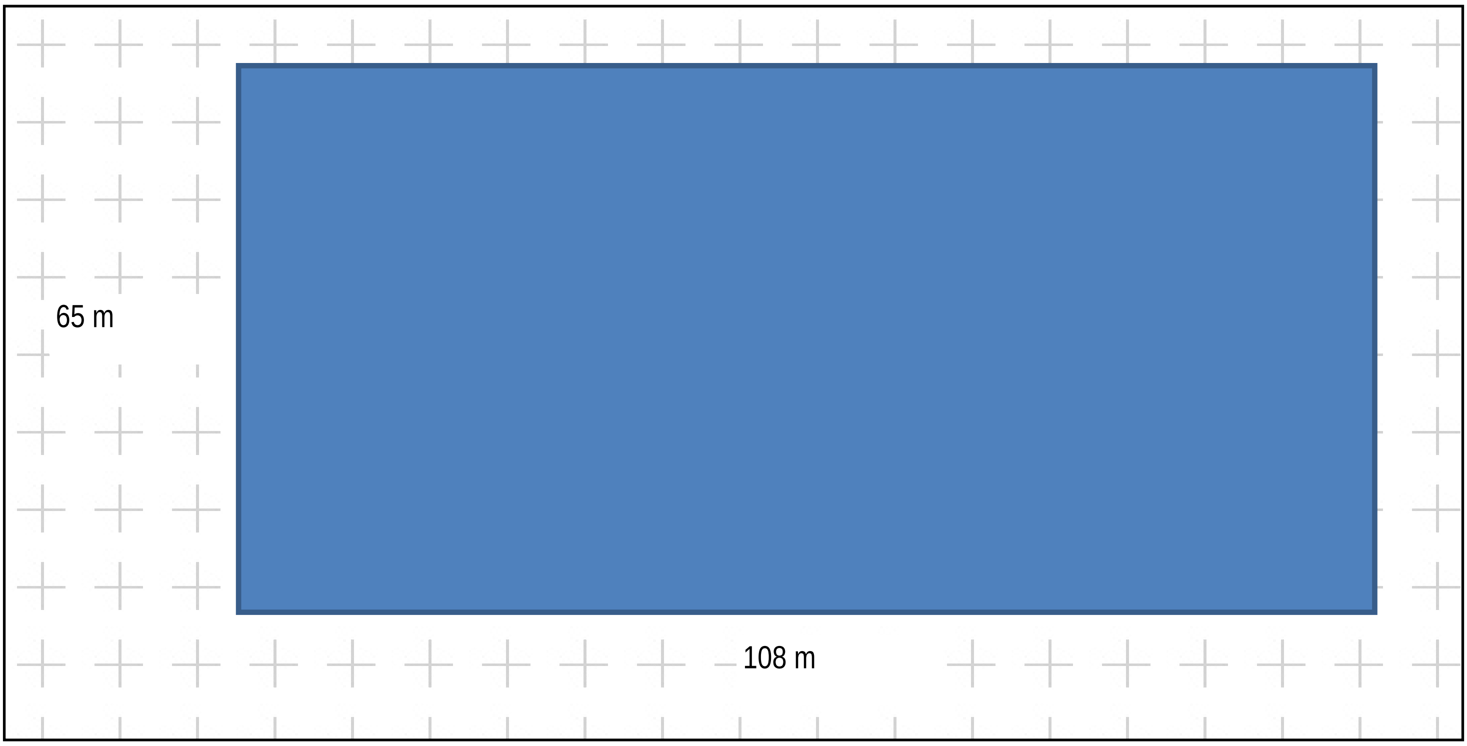
Other key components	Check	Condition (B, M, F, E)	Characteristics and comments regarding placement	manH and other costs
Check valve	□			
Backflow preventer	□			
Air valve	□			
Flush valve	□			
Other				
Other				
Other				

Type of main pipes (material, pressure range) and depth of installation

Section (initial - final length in m)	PVC (Ø mm)	PE(LDPE) (Ø mm)	PE(HDPE) (Ø mm)	(Ø mm)	Pressure (Schedule, atm))	Height (m)*
-						
-						
-						
-						

* in case of underground system enter a negative value

Basic system and surroundings that affect irrigation sketch (circle if available) Available



Show info regarding
Water supply (WS)
Mainline
Zones/Stations (A, B, C,….)
Zones' point of connection (POC)

Connection of zone control valves (circle)
Central Close to zones

Photos □

Notes (use numbering for references)

Identify irrigation system zones (stations)

Zone (A-Z and System type code)	Slope (%)	Soil sample no	Area (m^2)	Irrigation system type: Sprinkler	Micro	Other	Probability of horizontal - upward motion of water
A	lawn	82	7000	V	□	□	
B				□	□	□	
C				□	□	□	
…				□	□	□	
…				□	□	□	

continued…

OF: Open field; G/N: Greenhouse / Nethouse; L: Landscape (turfgrass, shrubs, trees); A: Athletic

Zone	Plant material	Yield (kg, pieces, etc)	Crop rows dist. (m)*	Crops dist. on row (m)*	Plant material similarity (√)	Establishement year
A						1990
B						
C						
…						
…						
…						

* or planting density (plants per area unit)

Notes (use numbering for references)

manH and other costs

A, C. Irrigation zone layout and components

Zone (use separate sheet for every zone, in case of greenhouse also fill the relevant sheet)

Ask for or find manuals of components

Sampling and measurements

Soil sampling	Pos:		Pos:	
skip in case that a recent	X	00-30 cm		00-30 cm
soil analysis is available		30-60 cm		30-60 cm
		cm		cm

Notes on soil layering

Select proper template to sketch the zone arangement

Valve Ask for or find manuals of components and circle if available Manual

Manufacturer

Model

Flow range

Pressure range

Condition (circle) Bad Mediocre Fair Excellent

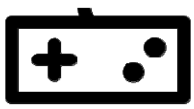
System control

Manual control

Irrigation controller

Ask for or find manuals of components and circle if available Manual

id / Manufacturer / Model	Hunter EC			
Age	2001	0		
Number of stations	8		Power supply	□ Current
Number of programs	3			□ Battery
Number of start times	12			
Rain delay (Y/N)				
Pump control (Y/N)	Yes	No		
Water budget (Y/N)	Yes	No		
Sensor(s) port (Y/N)	Yes	No		
Other	Yes	No		



Wiring (notes)

Sensors (check and comment regarding installation)

Rain sensor □

Soil moisture sensor □

Wind senor □

Other □

Other

Photos □

Filter (zone or line) Ask for or find manuals of components and circle if available Manual

Type Mesh Disk Manufacturer Model

Mesh or color

Flow range

Pressure range

Condition (circle) Bad Moderate Fair Excellent

Pressure regulator Ask for or find manuals of components and circle if available Manual

Manufacturer / Model

Input / output flow

Condition (circle) Bad Moderate Fair Excellent

Notes (use numbering for references)

Other key components

	Check	Condition (B, M, F, E)	Characteristics
Feltilisation equipment	◻		
Check valve	◻		
Air valve	◻		
Flush valve	◻		
Other ………………	◻		

manH and other costs

Type of pipes (material, pressure range) and depth of installation

	PVC (Ø mm)	PE(LDPE) (Ø mm)	PE(HDPE) (Ø mm)	(Ø mm)	Pressure (Schedule, atm))	Height (m)*
Zonepipes	40				10	-1
Application						

* in case of underground system enter a negative value

Outlets

Big guns / travelling irrigators characteristics Manual

Manufacturer

Model

Operating pressure unit:

Flow rate unit:

Condition: Bad / Mediocre / Fair / Excellent

Sprinklers and micro-sprinklers characteristics Manual

Manufacturer: Rain bird 9

Model

Nozzles (type or press/flow)..units						
	90o	X	180o		270o	
	360o	X	…		…	

Layout type (circle): Square / Triangular

Distance between ______ Wet radius ______

Condition (circle): Bad / Moderate / Fair / Excellent

Drippers / Emitters and Driplines characteristics:

Individual emitters ______ Driplines ______ Height (m) ______

Manufacturer

Type or press/flow (units)

Distances: on pipe or dripline ______ between pipes or driplines ______

Pressure regulated? Yes / No

Self cleaned? Yes / No

Condition (circle): Bad / Mediocre / Fair / Excellent

Applied schedule

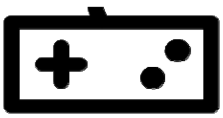
Manual

Month

Number of irrigation events

Run time (min)

Using controler



Program: April to Octomber

Start times

Frequency: 4 days per week

Run time: 15 in each zone 8 zones

Special sensor application (i.e. at valve common)

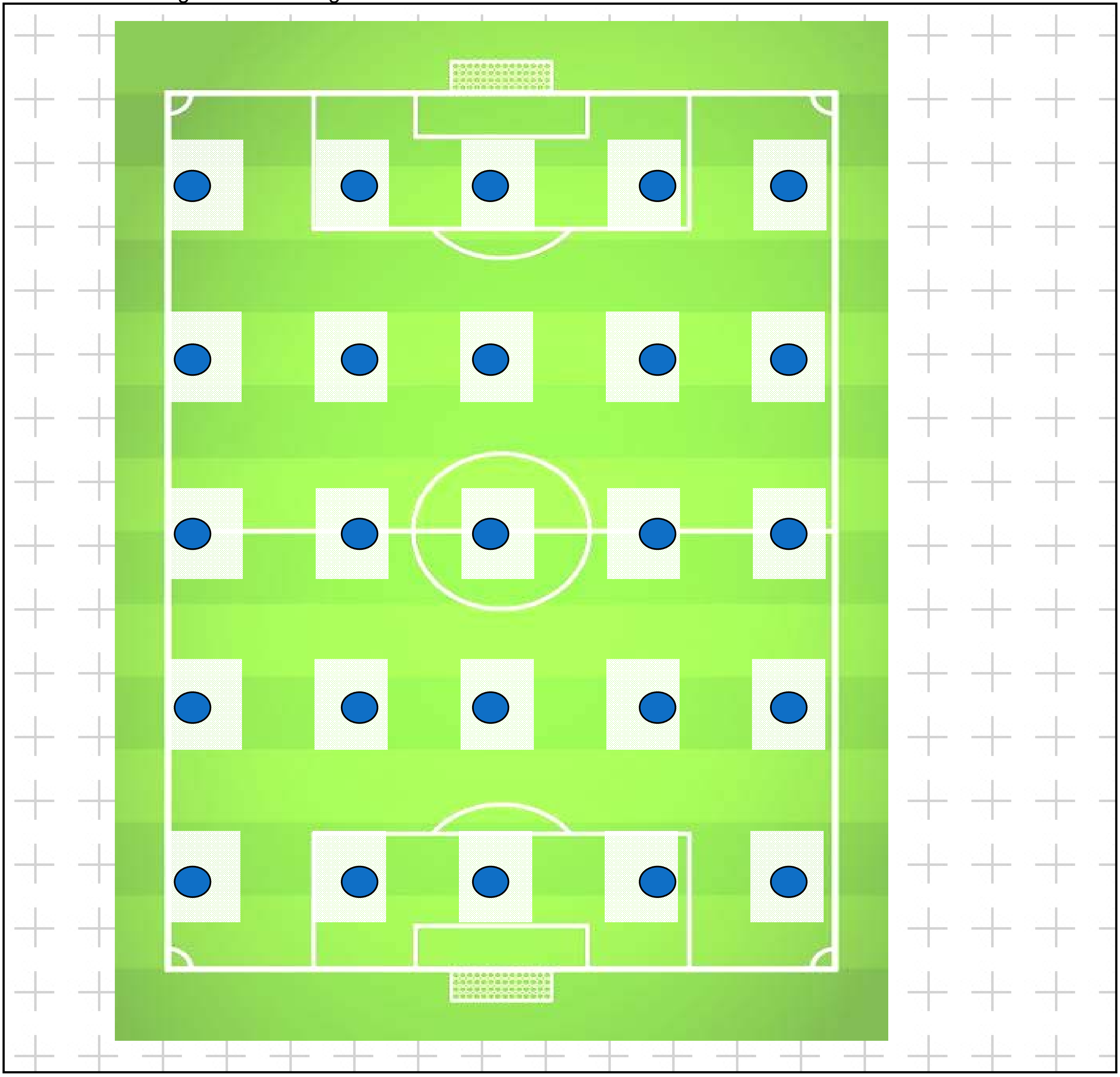
Using other approcah

Notes (use numbering for references)

Generic **Zone sketch (system zoomed in at zone scale)**

Irrigation & Drainage

manH and other costs



Mark
North direction (N)
Borders

Irrigation system layout with basic technical information
head components, pipes, pos and number of outlets, other comp.
number of outlets per lateral
Drainage system layout with basic technical information

Information regarding drainage system

Type (circle an Drainage ditches / canals
Underground pipeline system
Layering with coarse grained materials
Other

Are there any problems of inadequate drainage?

Where does the runoff terminates?

Photos □

Notes (use numbering for references)

C. System operation evaluation and uniformity measurements

manH and other costs

Zone ________ (use separate sheet for every zone)

Wind speed ________ km/h

Check and record wind speed at 2m: should be < 8 km/h (4.97 m/h)
Wind speed should be monitored also during the test if variations are sensed

Either the table or the generic or special design can be used for data keeping

Operation and measurement (in case of sprinkler systems, along with catch cans measurements)

Pressure tests must be conducted at normal operating conditions of the oulets using the appropriate pressure gauges
For pipes, at the beginning, middle, and end of every zone audited.

Outlet / Pipe-pos.	Operating pressure (bar)	Radius (for sprinklers) (m)	Pipe flow rate (….)	Comments / Observed problems
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Zone problems detected by the auditor

Improper zoning	
Limited controller capability	
Incorrect pressure (low / high)	
Lack of adequate flows	
Improperly sized components	
Old or worn out equipment	
Dirty or teared filters	
Tilted Sprinklers	
Spray Deflection	
Sunken Sprinklers	
Plugged Equipment	
Arc Misalignment	
Low Sprinkler Drainage	
Leaky Seals or Fittings	
Lateral or Drip Line Leaks	
Missing or Broken Heads	
Slow Drainage or Ponding	
Compaction/Thatch/Runoff	
Other	

Soil moisture sensor type:

Equation used:

manH and other costs

Measurements

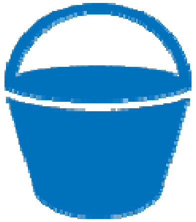
Number of catch cans 25 (at least 20)

Test duration 5 min sec

Catch-can throat diameter 10 cm

or specific cath-can Underhill_mini

Pos / Catch Can	Measur. (select unit)	Soil moisture (v/v %) Before	After	Difference	Comments / Observed problems
	ml	% v/v	% v/v	% v/v	
1	7	37.10%	39.20%	2.10%	
2	7	45.70%	51.20%	5.50%	
3	13	44.40%	47.90%	3.50%	
4	19	57.00%	57.20%	0.20%	
5	5	41.50%	43.10%	1.60%	
6	7	40.30%	45.50%	5.20%	
7	5	40.80%	46.70%	5.90%	
8	5	47.10%	54.40%	7.30%	
9	10	44.60%	52.50%	7.90%	
10	20	48.20%	50.80%	2.60%	
11	5	39.00%	46.20%	7.20%	
12	7	44.60%	55.10%	10.50%	
13	14	32.70%	35.80%	3.10%	
14	20	39.60%	50.70%	11.10%	
15	5	42.00%	45.10%	3.10%	
16	10	44.60%	54.40%	9.80%	
17	5	42.60%	42.90%	0.30%	
18	5	33.70%	42.40%	8.70%	
19	20	43.70%	50.10%	6.40%	
20	11	41.10%	42.50%	1.40%	
21	5	36.80%	44.30%	7.50%	
22	5	44.90%	49.00%	4.10%	
23	5	42.80%	43.70%	0.90%	
24	5	45.60%	46.70%	1.10%	
25	10	42.30%	47.40%	5.10%	
26				0.00%	
27				0.00%	
28				0.00%	



manH and other costs

Water sampling

Qualitative characteristics of water source

pH ______

Electrical conductivity (EC) ______ dS m^{-1}

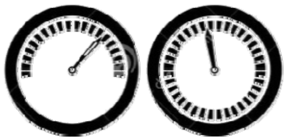
$1\ \mu = 10^{-5}$ deci

Head / flowrate at water supply point

Date and time of measurement ______

Static pressure at the source ______ bar

Measured flow /head couples by auditor



Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)	
			0.00	
			0.00	
			0.00	
			0.00	
			0.00	Maximum available flowrate

Fill in case of more water supplies

Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)	
			0.00	
			0.00	
			0.00	
			0.00	
			0.00	Maximum available flowrate

Water supply	Pres. (bar)	Flow (L/min)	Flowrate (m^3/h)	
			0.00	
			0.00	
			0.00	
			0.00	
			0.00	Maximum available flowrate

Notes (use numbering for references)

manH and other costs

D. Data analysis and report generation

1 Soil characteristics estimation at the laboratory
pH
EC
Mechanical analysis for as many irrigation zones as needed
$CaCO_3$
Orgaic mater
2 Determination of irrigation period and estimation of monthly plant's water needs according to historical climatic data
3 Calculation of distribution uniformity coefficients (DU, CU, SC or other) using catch - cans and soil moisture data.
4 Development of a theoretical irrigation schedule and comparison with the applied one for each zone.
5 Development of information regarding the design and construction issues of the system.
6 Estimation of the potential savings in water, energy, labour and money after the application of the proposed mprovements.
7 Authoring of the final report regarding the system, the schedule, the efficiency etc. Proposals for improvement and expected savings.

E. Final activities

1 Presentation of the final report.
2 Ask if they would be interested for system repair, tune-up, adjustment and repair.
If no, why?
3 Do not forget to fill the internal form regarding the audit procedure.

manH and other costs

D. Soil and water analysis

Soil characteristics estimation at the laboratory

Soil texture analysis and other measurements in as many irrigation zones as needed

Mechanical classes determination method	
$CaCO_3$ determination method	
Organic mater determination method	

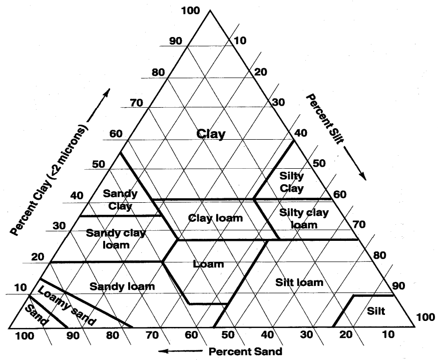
Zone	Sand	% Silt	Clay	Soil type	pH	EC	$CaCO_3$	Organic mater
A	73.2	24	2.8	LS	7.3	0,24	16.8	
B								
C								
…								
…								
…								

repeat the page in case of more than one sample

[Cick here to activate USDA soil texture calculator (web link)]

USDA

Comments



In case of hydroponic cultivations

Zone

Substrate (check or specify):

Check	Type	Manufacturer	Particles size (mm)	…	…	…	…	…
☐	Perite							
☐	Pumice							
☐	Rockwool							
☐	….							

Comments

Water characteristics

repeat the page in case of more than one sample

Field measurements

Water source		
pH	0	
Electrical conductivity (EC)	0	dS/m

pH normal range: 6.5 – 8.4

Salinity (affects crop water availability)

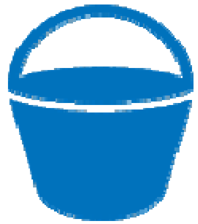
	Unit	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
EC	dS/m	< 0.7	0.7 – 3.0	> 3.0

Comments

manH and other costs

D. Uniformity analysis (use separate sheet for every zone)

Zone (use separate sheet for every zone)



Catch device throat diameter 0.10 m or specific cath-can: Underhill_mini

Test run time 5 min

Analysis

A-Z list

Αρ. δοχείου	V ml or ……..	Vi-Vμέση ml - ml or ………	PR mm/h
1	5.00	4.20	7.64
2	5.00	4.20	7.64
3	5.00	4.20	7.64
4	5.00	4.20	7.64
5	5.00	4.20	7.64
6	5.00	4.20	7.64
7	5.00	4.20	7.64
8	5.00	4.20	7.64
9	5.00	4.20	7.64
10	5.00	4.20	7.64
11	5.00	4.20	7.64
12	7.00	2.20	10.70
13	7.00	2.20	10.70
14	7.00	2.20	10.70
15	7.00	2.20	10.70
16	10.00	0.80	15.29
17	10.00	0.80	15.29
18	10.00	0.80	15.29
19	11.00	1.80	16.82
20	13.00	3.80	19.87
21	14.00	4.80	21.40

1. Sort measurements in descending order
(regards measurements of catch-cans and moisture difference data)

2. Calculation of averages, totals and ratios

Attention, these formulas need to set up every time

5.00	Low_Quarter_Average_Depth (or Volume)
5.17	Low_Half_Average_Depth (or Volume)
9.20	Overall_Average_Depth (or Volume)
230.00	Σvi (ml)
13.37	PRavg (mm/h), average zone precipitation rate

Distribution Uniformity

for sprinkler systems, Dulq is more strict

Low Quarter irrigation Distribution Uniformity - DU_{lq}

DUlq= 54%

$$DU_{lq} = \frac{Low\_Quarter\_Average\_Depth}{Overall\_Average\_Depth} \times 100$$

Low Half irrigation Distribution Uniformity - DU_{lh}

DUlh= 56%

$$DU_{lh} = \frac{Low\_Half\_Average\_Depth}{Overall\_Average\_Depth} \times 100$$

Scheduling Coefficient (SC)

for sprinkler systems

SC= 1.75

$$SC = \frac{PR_{average}}{PR_{minimum}}$$

22	19.00	9.80	29.05
23	20.00	10.80	30.58
24	20.00	10.80	30.58
25	20.00	10.80	30.58
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			

manH and other costs

Christiansen
for micro-irrigation systems
Σ|Vi-V|= 110
CU= 52%

$$CU = 1 - \frac{\sum_{i=1}^{n} \left| V_i - \overline{V} \right|}{\sum_{i=1}^{n} V_i}$$

Attention, this formula need to set up every time

Maximum volume:	20.00
Minimum volume:	5.00
Average volume:	9.20
Standard deviation:	5.41
Standard error:	1.08

-18% 218%

In every case a variation of more than ±10% is probably unacceptable and suggests poor system design.

Rough cross check – pump flow rate / water supply from catch can test

No. outlets x average emitter flow rate ____ outlets x ____ lpm
Overall flow rate ____ lpm
Pump flow rate – specified ____ lpm

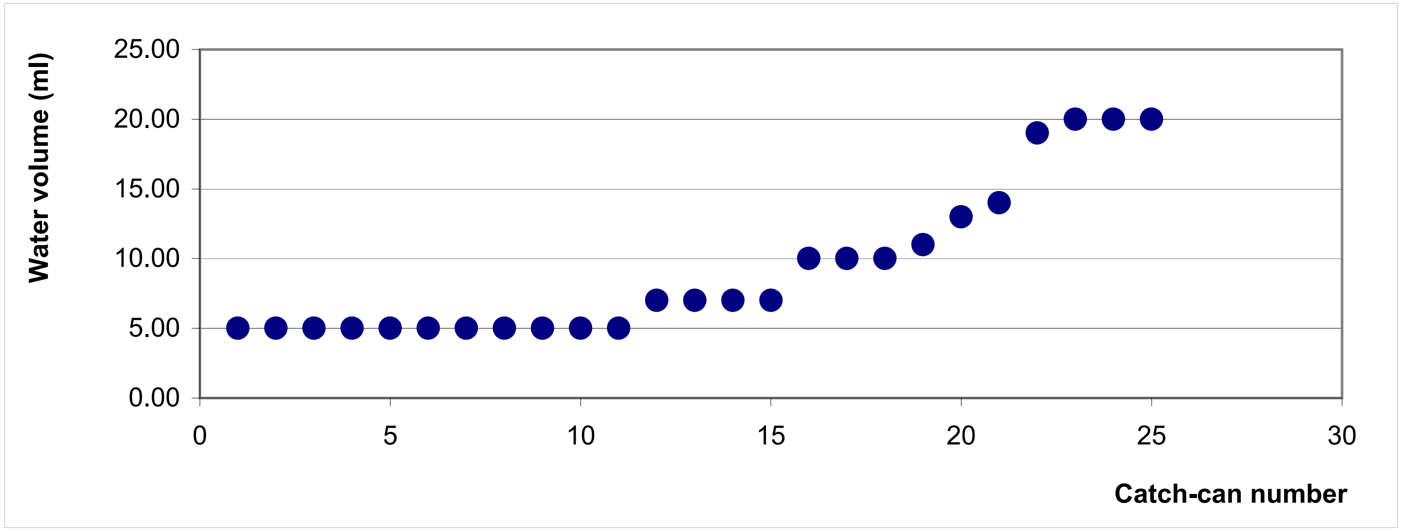
How does the specified compare to the overall? ____

Emitter flow equation: $q=kH^x$
k ____
x ____
H ____ bar
q expected #APIΘ! l/h

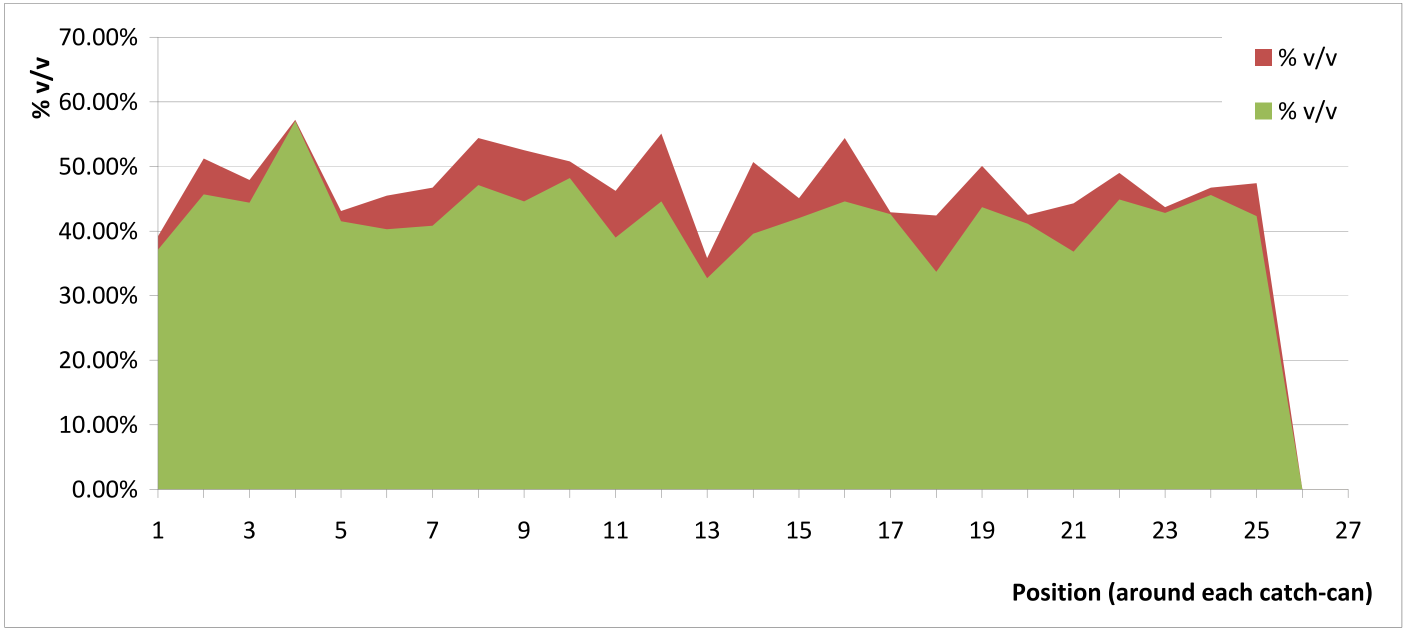
Selected alternatives for uniformity calculation:

UC Davis Biomet DU Citrus http://biomet.ucdavis.edu/irrigation_scheduling/DU%20Irrig%20of%20Citrus/IS004.htm

Water volume fluctuation in catc-cans



Substrate moisture before and after irrigation



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D. Climatic data, potential Evapotranspiration and Ombrothermic diagram

Constants for the calculations

G_{sk}	116.64 cal cm^{-2} h	0.082	$MJm^{-2}min^{-1}$	1 MJ m^{-2} day^{-1}	=	0.408	mm day^{-1}
λ	59.50 cal cm^{-2} mm^{-1}						
φ	0.38 rad						

t greenhouse cover transmission to solar radiation (%)

Step 1. Calculation of potential / reference evapotranspiration (ETo)

	Reference period temperatures (i.e. month)			Solar radiation calculation for the characteristic day of the reference period					Rain	Open field (1)	Greenhouse (2)
Month	Representative day number	Tmin (°C)	Tmax (°C)	Tmean (°C)	dr (rad)	δ (rad)	ωs (rad)	R_a (MJ m^{-2} day^{-1})	Rain (mm/month)	ETo (mm day^{-1})	ETo (mm day^{-1})
Jan	18	11.30	15.60	13.40	1.03	-0.36	1.42	26.11	128.80	1.59	0.00
Feb	46	11.10	15.20	13.10	1.02	-0.23	1.48	29.82	78.80	1.75	0.00
Mar	75	11.40	16.80	14.00	1.01	-0.04	1.55	34.31	65.20	2.38	0.00
Apr	105	13.60	18.60	16.00	0.99	0.17	1.64	37.82	81.30	2.68	0.00
May	135	16.70	22.00	19.10	0.98	0.33	1.71	39.50	27.20	3.15	0.00
Jun	162	21.00	26.70	23.40	0.97	0.40	1.74	39.88	12.40	3.68	0.00
Jul	199	23.10	28.00	25.50	0.97	0.37	1.72	39.51	13.60	3.55	0.00
Aug	229	24.00	29.00	26.20	0.98	0.23	1.66	38.19	0.00	3.53	0.00
Sep	259	21.40	25.80	23.70	0.99	0.03	1.58	35.26	76.60	2.88	0.00
Oct	289	17.10	22.30	19.60	1.01	-0.18	1.50	30.91	115.20	2.47	0.00
Nov	318	13.70	19.10	16.30	1.02	-0.33	1.43	26.82	64.20	1.99	0.00
Dec	345	11.90	16.20	13.90	1.03	-0.40	1.40	24.73	156.80	1.53	0.00
									820.10	31.18	0.00

Microclimatic notes (i.e. local winds etc)

1) FAO Paper56 / Hargreaves
2) Institute Nationale de la Recherche Agronomique (INRA), Avignon, France / Baille

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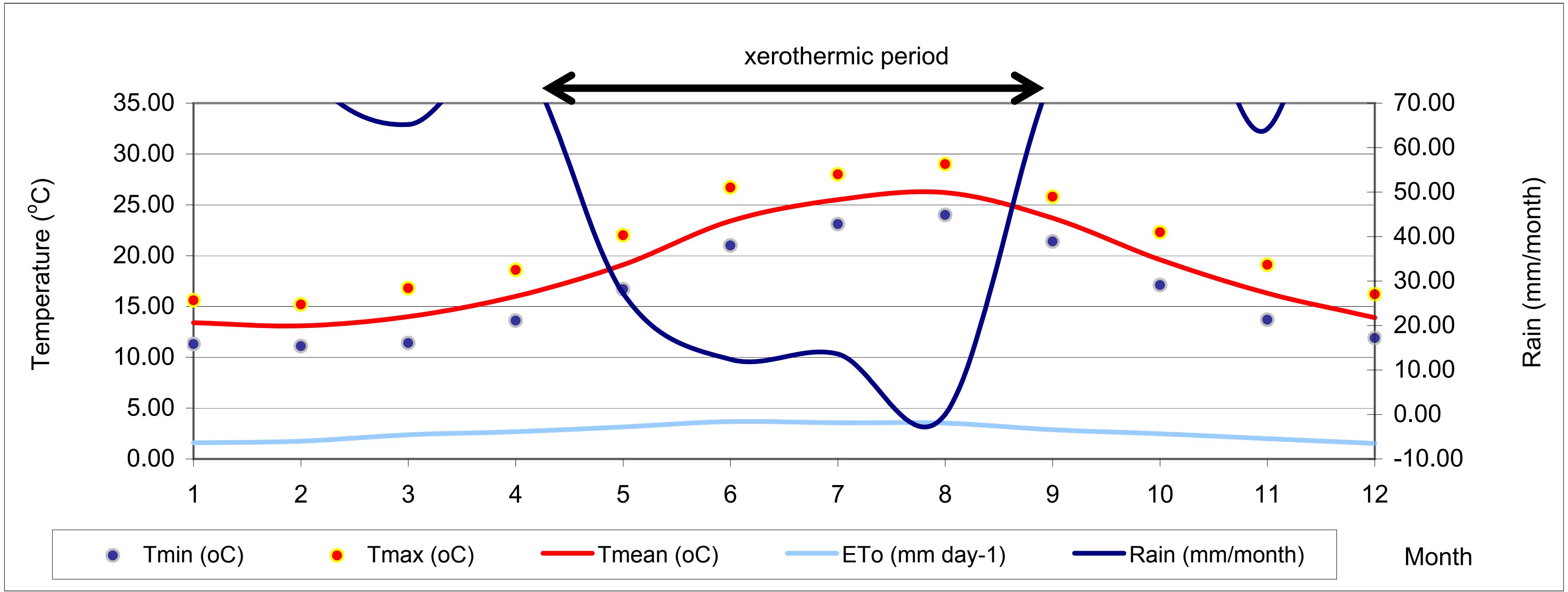
Ombrothermic diagram



D. Data analysis and report generation (micro-irrigation system, use separate sheet for every zone)

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Zone | Type Open field | Take account of rain (y/n)? y

Area (A) 0.7 ha

Basic soil characteristics

Soil type	LS
Field capacity (FC, %v/v)	12%
Permanent wilting point (PWP. %v/v)	5%
Available water content (AWC, %v/v)	7%
Final infiltration rate (if, mm/h)	30

Cultivation / Landscape plants (or category)

Plant species / variety	Lawn
Effective depth of rootzone (de, m)	0.5
Maximim allowed depletion (MAD, %)	60.00%
Precentage of soil surgace that is shaded by plants during midday (Ps, %)	85.00%
Microirrigation ET reduction factor (r)	r 1.00

Basic characteristics of irrigation system

System type	Microirrigation	
Percentage of weted area (%)	50.00%	
Efficiency (IE, %)	92%	estimation using application uniformity
Precipitation rate (PR, mm/h)	13.37	from audit results

da, max irrigation dose (mm) 10.50 73.50 m^3

Irrigation schedule

>> <<

											Calculations					Notes
	Kc	kmc or Ks	kd or Ks	K_L	ETa	Number of days	ETa	Rain	Reff	Leaching fraction	Water needs, ED	Theoretical irrigation span, Fth	Practical irrigation span, F	Run time, RT	Required water volume	
Month	-	-	-	-	mm day^{-1}	days	mm $month^{-1}$	mm $month^{-1}$	mm $month^{-1}$	%	mm day^{-1}	days	**days**	**min**	m^3 $month^{-1}$	
Jan	0.80	1.00	1.00	0.80	1.27	31	39.31	128.80	96.34	0%	0.00	0.00	**2.0**	0.00	0.00	ok
Feb	0.80	1.00	1.00	0.80	1.40	29	40.62	78.80	97.22	0%	0.00	0.00	**2.0**	0.00	0.00	ok
Mar	0.80	1.00	1.00	0.80	1.90	31	59.01	65.20	58.87	0%	0.00	2310.85	**2.0**	0.04	497.86	ok
Apr	0.80	1.00	1.00	0.80	2.15	30	64.38	81.30	99.72	0%	0.00	0.00	**2.0**	0.00	0.00	ok
May	0.80	1.00	1.00	0.80	2.52	31	78.09	27.20	25.75	0%	1.69	6.22	**2.0**	16.44	497.86	ok
Jun	0.80	1.00	1.00	0.80	2.95	30	88.35	12.40	11.78	0%	2.55	4.11	**2.0**	24.86	497.86	ok
Jul	0.80	1.00	1.00	0.80	2.84	31	88.14	13.60	12.92	0%	2.43	4.33	**2.0**	23.63	497.86	ok
Aug	0.80	1.00	1.00	0.80	2.82	31	87.44	0.00	0.00	0%	2.82	3.72	**2.0**	27.47	497.86	ok
Sep	0.80	1.00	1.00	0.80	2.30	30	69.12	76.60	95.02	0%	0.00	0.00	**2.0**	0.00	0.00	ok
Oct	0.80	1.00	1.00	0.80	1.98	31	61.34	115.20	90.58	0%	0.00	0.00	**2.0**	0.00	0.00	ok
Nov	0.80	1.00	1.00	0.80	1.60	30	47.86	64.20	58.05	0%	0.00	0.00	**2.0**	0.00	0.00	ok
Dec	0.80	1.00	1.00	0.80	1.22	31	37.83	156.80	102.46	0%	0.00	0.00	**2.0**	0.00	0.00	ok

Selected alternatives for irrigation scheduling:

FAO CropWat http://www.fao.org/nr/water/infores_databases_cropwat.html

UC Davis Biomet http://biomet.ucdavis.edu/irrigation-scheduling.html

F, Frequency:	per	2.0	days
RT, Run time:		28.00	min
Water Budget (spring, fall):			

IRMA partner LOGO

Subsidy Contract No: I3.11.06

WP5 Irrigation Audits **System manager diary up to next audit**

Zone

Remember to archive any design, manual, bill etc that is relevant to the system

Month	Schedule: Frequency (d)	Schedule: Duration (min)	Resources consumption: Energy (electric power, petrol etc)	Resources consumption: Water volume (m^3)	Problems encountered (code and/or description)	Solutions applied	Concerns	Yield (kg or pieces)
Jan								
Feb								
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								

Problem codes

1. Low pressure
2. High pressure
3. Tilted sprinklers
4. Sunken sprinklers
5. Spray deflection
6. Arc misalignment
7. Drainage from low placed sprinklers
8. Different oulets at the same zone
9. Missing or broken components
10. Clogged components
11. Leaky seals or fittings
12. Pipe leaks
13. Slow drain / ponding / surface runoff
14. Compaction / thatch