European Territorial Cooperation Programme
Greece - Italy
2007-2013

INVESTING IN OUR FUTURE

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Efficient IrrigationManagement Tools forAgricultural Cultivations andUrban Landscapes

IRMA

WP6

Specialized research actions

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V.01

IRMA info

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Deliverable 6.5.4: Experiments Regarding Alternative Water Sources (Grey, Waste) For Landscaping

A knowledge harvest and experimental evaluation report

Chapter of:

WP6: Specialized research actions

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Summary

Alternative water sources have been successfully implemented for irrigation purposes in many countries world widely in the framework of water resources conservation strategies. Although Europe is not considered to be an arid continent, countries around the Mediterranean basin experience frequently water scarcity phenomena attributed to unequal distribution of precipitation during the year and large withdrawals by the agricultural sector. Landscape irrigation also requires considerable amounts of water as urbanised areas are growing and tourism sector is expanding around the basin. A field study was conducted at the Technological Educational Institute of Epirus (TEIEP, Arta, Greece) from May to October 2014 in order to assess the effects of irrigation using alternative water sources on the growth and status of plant species frequently encountered in landscaping projects at North and Western Greece. Irrigation with tertiary treated wastewater provided by the Municipal Sewage Treatment Plant and grey water captured from actual cleaning activities in TEIEP's facilities were applied to tall fescue (*Festuca arudinacea*) and six shrub species, namely: *Abelia chinensis*, *Ligustrum japonicum*, *Photinia serrulata*, *Viburnum tinus*, *Pittosporum tobira* and *Thuja occidentalis*. Irrigation with tap water provided by the municipal potable water supply network was considered to be the reference treatment. Quantitative and qualitative characteristics were evaluated by a series of measurements which included: turfgrass fresh and dry cutting weighs, solar radiation reflectance by the turfgrass canopy, fresh and dry weighs of turfgrass roots, shrub growth parameters (including height, stem diameter, growth index, fresh and dry weighs of shrub roots), chemical analysis of plants' roots and leaves, optical evaluation of shrubs, soil EC and pH. The results revealed that in overall recycled and grey water did not have any evident reverse effect on all plant species status, although there have been pointed out some variations in quantitative or qualitative characteristics when compared to tap water irrigation treatments.Turfgrass irrigated using recycled water presented no difference in growth development compared to the reference turfgrass. The grey water treatment, although that it exhibited the lowest growth rate, did not demonstrate any difference in qualitative terms as determined by the solar radiation reflectance analysis. Growth development of shrub species treated with recycled water was not significantly affected apart from *Pittosporum tobiris* plants. Optical evaluation findings differentiated some of the species (*Thuja occidentalis, Pittosporum tobira*) indicating that shrubs irrigated with either recycled or grey water exhibited lower quality performance when compared to reference treatment. There has been observed an increase in soil EC and pH values in recycled and grey water treatments, although these values did not exceed acceptable limits. In conclusion the study's findings can support the effort of utilization the assessed alternative water resources as

supplement or even when possible as complete substitute of freshwater for landscape irrigation purposes since no evident quantitative or qualitative adverse effects have been observed.

Introduction

Water is essential for sustaining ecosystems and regulating our climate(EU, 2010) while history shows a strong bidirectional link between economic development and water resources development (Katz , 2008; WWAP, 2009). The total volume of freshwater is finite (~35Mkm^3: 2.5% of the 1.4 Bnkm^3 of global water resources), remains globally constant in various forms in the water cycle and exists largely in the form of unusable glaciers and groundwater. Only ~0.6% of total natural freshwater resources (~200,000km^3) is usable by humans and ecosystems. However, a small percentage of about 2% of this potential resource is actually accessible, reliable and sustainable (SBCInstitute, 2014) while competing demands may lead to an estimated 40% global water supply shortage by 2030 (COM(2012)673).

Water scarcity is characterized by an imbalance between freshwater supply and demand in a specified domain (country, region, catchment, river basin, etc.) as a result of a high rate of demand compared with available supply (FAO, 2012; EU, 2010). Water availability which refers to the part of water resources available for use (FAO, 2012) is affected not only by natural forces but mainly by anthropogenic activities.These include, land use, economic activities such as energy production, industry, agriculture and tourism, urban development and demographic change which are mainly related to culturaland economic growth. On the other hand, climate change poses an additional stress to world's water abundance.

Although Europe is not considered to be an arid continent, water supplies are now a concern for almost half of the EU population (EU, 2010). According to the "Report on the Review of the European Water Scarcity and Droughts Policy" (COM(2012)672), in 2007 at least 11% of the EU population and 17% of the continent had experienced water scarcity while the latest years a significant number of river basins are considered to be under water stress all year round. In southern Europe water scarcity phenomena are generally evident during summer months but they are also becoming increasingly important in Northern basins, including UK and Germany(COM(2012)672). An indicator of water scarcity, the Water Exploitation Index (WEI), provides the broadest depiction of water use compared to general availability, and describes the risk posed by over exploitation (Figure 1, EEA, 2012). As it is clearly stated in EC's "Blueprint to Safeguard Europe's Water Resources" (COM(2012)673)that around the year 2030 the 50% of river basins in Europe are expected to be under water stress especially during the summer months.

The Mediterranean area raises great concern, since water scarcity is reported in nearly all its river basin districts. In two out of three groundwater bodies reported as not being in good quantitative status, abstraction is mentioned as a significant pressure. Poor or unsuitable water quality often further reduces availability, restricts use, and increases the costs of supply (UNWATER, 2009).

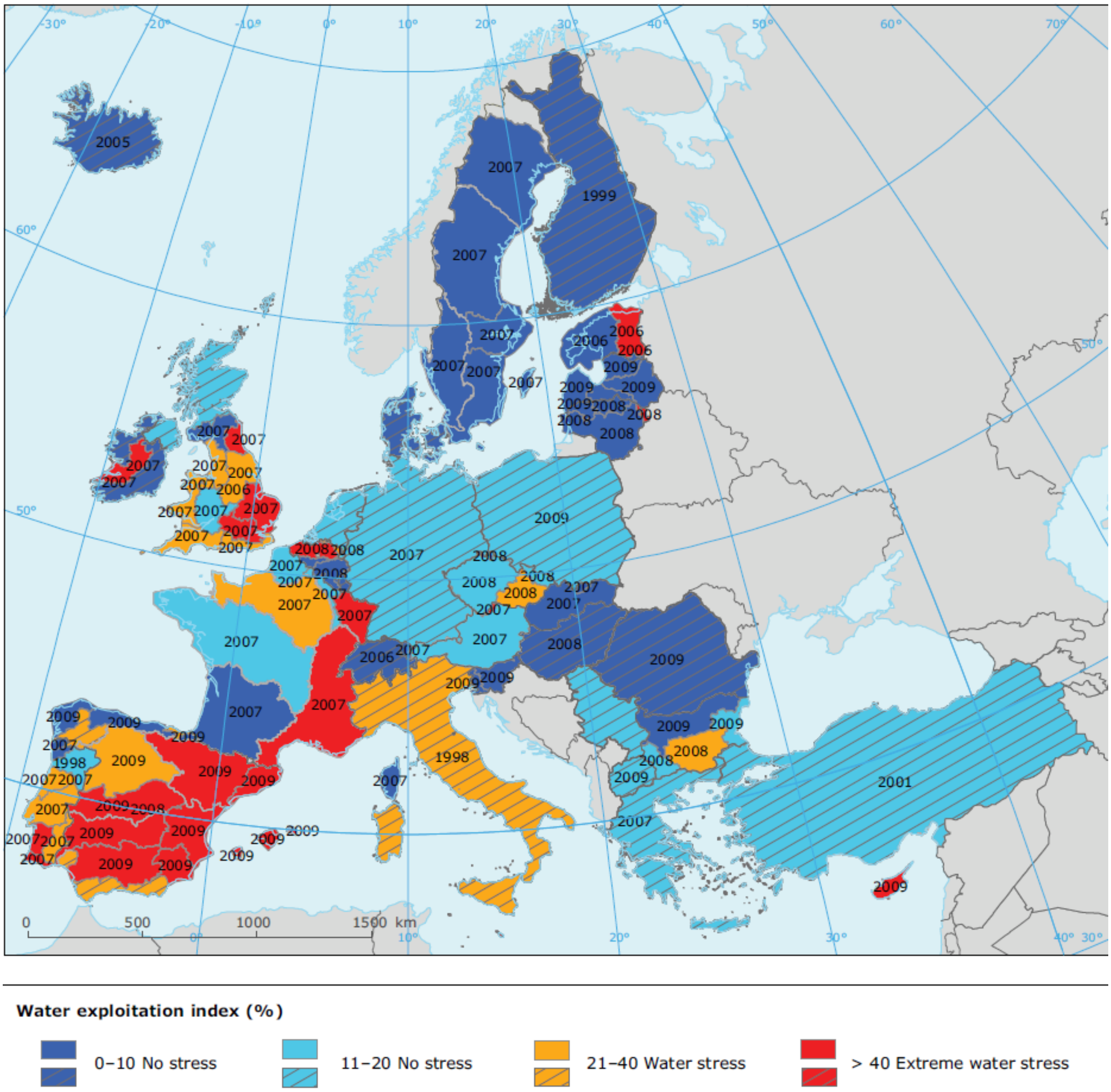

Figure 1 Water Exploitation Index in Europe in the smallest available data disaggregation (EEA, 2012).

Water scarcity has been in the EU's agenda for over thirty years and all efforts for the establishment of a water policy have contributed to water protection. In 2000, the EU Water Framework Directive (WFD) (2000/60/EC) comprehensively addressed all the challenges faced by EU waters, making it clear that water management is much more than just water distribution and treatment. It involves land-use and management that affect both water quality and quantity (COM(2012) 673). The WFD established the objective to achieve good status by 2015 and according to the EEA State of Water report (EEA, 2012) and the Commission assessment of the Member States' RBMPs (River Basin Management Plans) (COM(2012)670) developed under the WFD this objective could be achieved in slightly over half (53 %) of EU waters(COM(2012)673).

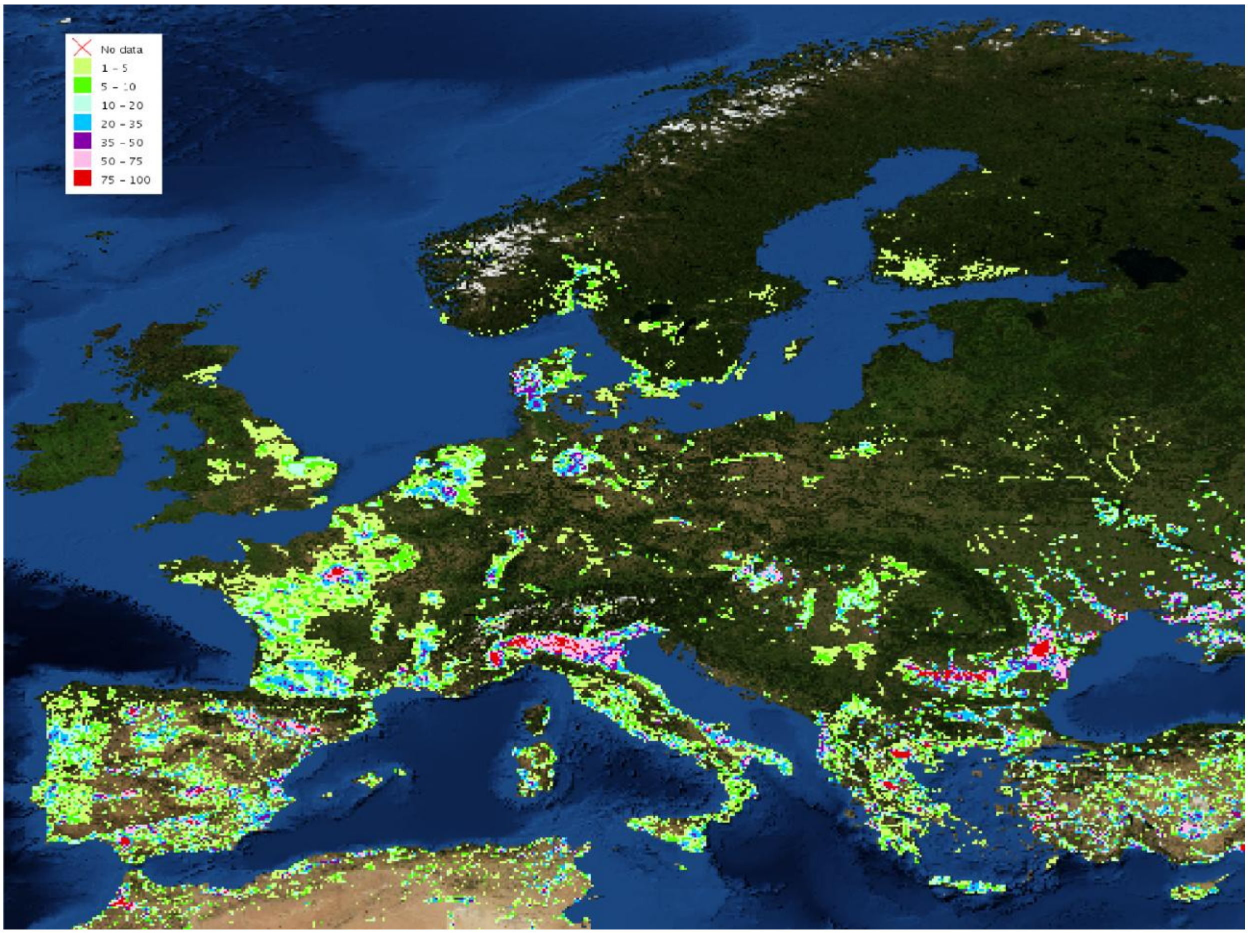

Figure 2 European map of irrigated areas (source FAO - AQUASTAT)

The major contributor to water resources exploitation globally is the agriculture sector. Over the past 50 years agricultural production has increased between 2.5-3 times while cultivated area has grown only 12%. The 40% of production's growth is attributed to irrigation. In the present agriculture uses 11% of the planet's surface for crop production and the 9% of surface water (FAO, 2011b).

According to FAO (2011b), water withdrawal in Europe by the agricultural sector represents the 29% of the total water withdrawal which is only the 6% of the total internal renewable water resources (TRWR) while globally, irrigation accounts for the 70% of the total withdrawn water (9% of the TRWR). The withdrawal rate varies significantly by country or region. The countries around the Mediterranean basin (Portugal, Spain, France, Italy and Greece) comprise the 75% of the total European agricultural land equipped for irrigation (Wriedt, 2009)and high demand for water in this section is justified by the limited availability of water resources and weather variability (Wriedt, 2009). Significant discrepancies in the water abstraction for irrigation between Mediterranean countries occur as well. In Italy the 44% of the withdrawn water goes to agriculture while the correspondent percentage in Greece reaches the 89.3% (AQUASTAT, 2015). Agriculture in Central and Northern European countries abstracts significantly less water (Belgium 0.1%, Germany 0.5%, Netherlands 0.8%)where irrigation is supplementary and compensates for water stress during dry summers, especially when crops are in a sensitive stage, in order to optimize production (Wriedt, 2009).

World’s population is expected to increase from 6.9 billion in 2010 to 8.3 billion in 2030 and 9.1 billion in 2050. Along with the population’s growth, demand in agricultural production is expected to increase about 70% which indicates a 10% increase in water withdrawal until 2050 (FAO, 2011b). This coupled with climate change that will affect hydrological inputs on which agriculture depends, will intensify competition between the major water withdrawal sectors (municipal, industrial and agricultural) leading agriculture to apply more efficient resources management policies that will include implementation of more precise irrigation systems or exploitation of alternative sources for irrigation.

Background of water reuse

Water reuse for farm practices dates back 5000 years in ancient Greece where it was applied by the Minoan civilization, has been recorded in Germany and England in the 16th and 18th century respectively and has also been reported in China and India (Vigneswaran, 2004). The first organized attempt to exploit sewage water was in 1912 in San Francisco, California for the irrigation of the Golden Gate Park (CaliforniaRecycledWaterTaskForce, 2003). Reuse of alternative water sources is usually applied as a supplementary to the existing water sources in order to compensate for water scarcity during dry periods.

The pressures on water resources in Europe have encouraged more active consideration of using alternative water sources as a strategic option to supplement water supplies and protect natural resources. In its "Blueprint to Safeguard Europe's Water Resources" (COM(2012)673), the Commission explicitly highlights the need to find solutions to water challenges in the urban, industrial and agriculture sectors(Sanz, 2014).Typical alternative sources of water are recycled water, greywater or saline water.

Recycled water refers to any water that has undergone one cycle of (human) use and then received sufficient treatment at a sewage treatment plant to be made suitable for various reuse purposes, including irrigation. Recycled water may be primary, secondary, or advanced (tertiary) treated municipal or industrial wastewater (Harivandi, 2006).

Greywater refers to water that has gone through one cycle of use, usually in homes, but not including water from toilets and dishwashers (or other kitchen water potentially contaminated by food residues), and which has not been treated (Harivandi, 2006). It refers to untreated household wastewater that has not come in contact with sewage or "black water" (namely the water that comes from toilet and contains human excreta and urine). Common domestic sources of greywater include showers, baths, sinks, and clothes washers. According to WHO (2006) greywater doesn't include wastewater from kitchen sinks and automatic dishwashers, which is usually referred to as "dark greywater" and is characterized by high concentrations of organic matter that encourage the growth of bacteria. There is a significant lack of legislative pieces regarding greywater capture and reuse in many countries, but there are many regulations and standards in several regions such as United States or Queensland in Australia that do not allow wastewater from the kitchen to be reused (Allen , Christian-Smith, & Palaniappan, 2010).

Saline or brackish water refers either to sea water or to fresh water that has been contaminated with sea water. Fresh water contamination by saline water occurs through tidal flow into coastal freshwater sources resulting in brackish water, and through intrusion along permeable subsurface layers that contaminate impounded and groundwater (Harivandi, 2006). This salt contaminated water is generally unsuitable for irrigation for the majority of plant species but there are several salt-tolerant species to which they can be applied.

Water reuse is now recognized as a strategy to compensate with foreseen water scarcity within European countries. Water reuse is the top-listed priority area in the Strategic Implementation Plan of the European Innovation Partnership on Water (EIPW, 2012), and maximization of water reuse is a specific objective of the aforementioned European Blueprint for Water (COM (2012) 673). Water reuse applications include agricultural, industrial, recreational, environmental and even in some cases potable uses (EU, 2010).

Figure 3 shows a model output for wastewater reuse potential of European countries with a project horizon of 2025. Spain shows by far the highest reuse potential, the calculations suggesting a value of over 1 200 $Mm^3\ yr^{-1}$. Italy and Bulgaria both exhibit estimated reuse potentials of approximately 500 $Mm^3\ yr^{-1}$. Wastewater reuse appraisals for Turkey amount to 287 $Mm^3\ yr^{-1}$, whereas Germany and France could potentially reuse 144 and 112 $Mm^3\ yr^{-1}$, respectively. Portugal and Greece account for reuse potentials of less than 100 Mm^3yr^{-1} (67 and 57 $Mm^3\ yr^{-1}$, respectively). Overall, the estimates suggest a wastewater reuse potential of 3 222 $Mm^3\ yr^{-1}$ (Sanz, 2014).

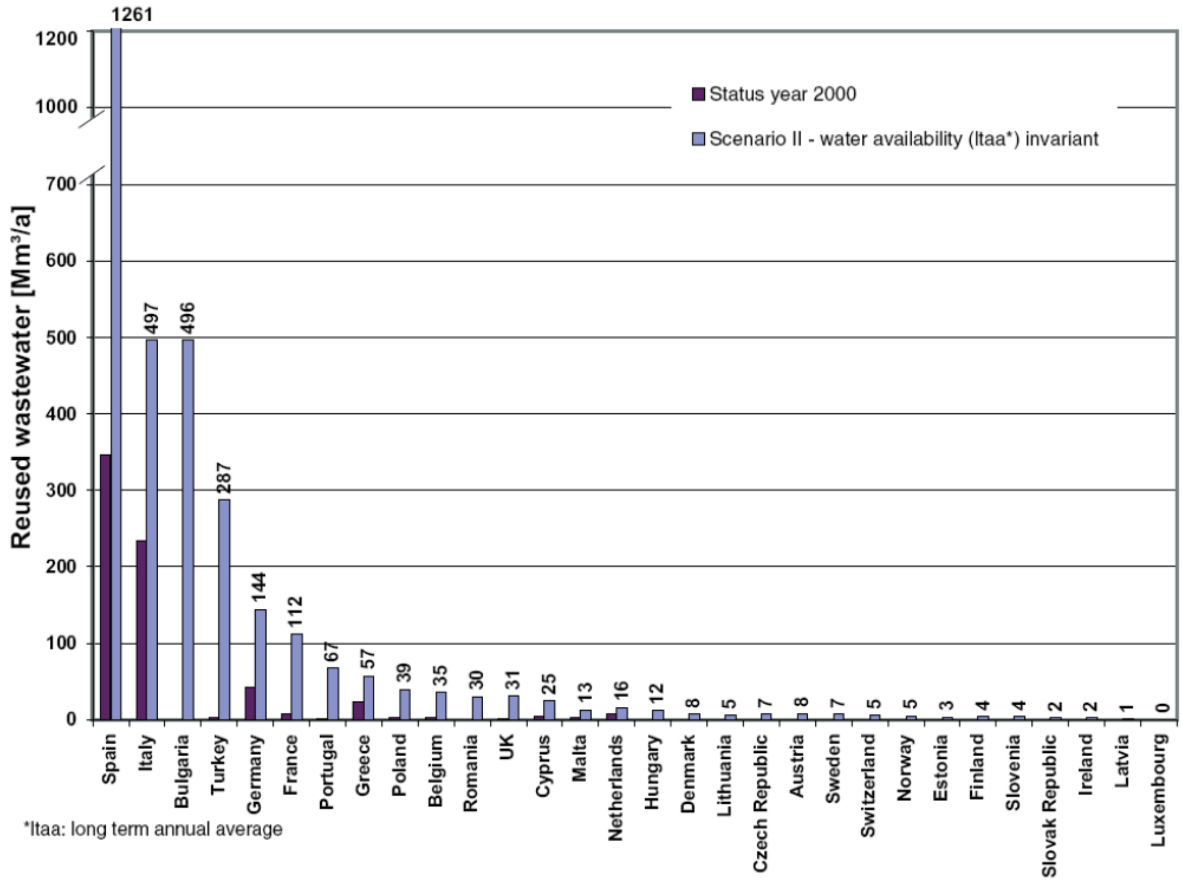

Figure 3 Model output for wastewater reuse potential of European countries with a projection horizon 2025 (Sanz, 2014)

Water reuse applications risks

Agronomic concern

Reusable water application for irrigation poses the risk of toxicity to the plants since it contains elevated concentrations of dissolved salts. Some soluble salts are nutrients and therefore beneficial to plant growth. Other soluble salts, however, may be phytotoxic or may become so when present in undesirable soil concentrations. Another important factor is sodium which when accumulated or applied directly on the leaves of several plants can cause injury. Recycled waters are prone to excessively high bicarbonate ($HC0_3$) levels. Elevated $HC0_3$ in irrigation water can increase soil pH and affect soil permeability. In addition, the $HC0_3$ ion may combine with Ca and/or Mg to precipitate as Ca and/or Mg carbonate in the root zone, causing SAR increases in the soil solution by lowering the dissolved Ca and Mg concentrations. Municipal recycled water may contain excessive residual chlorine (Cl_2), a potential plant toxin. Chlorine toxicity almost always is associated with recycled waters that have been disinfected with Cl-containing compounds. Boron although is a micronutrient essential for plants' growth, when applied in concentrations as low as 1 to 2 mg lt^{-1} can be phytotoxic. Periodical monitoring of the applied water with chemical water analysis is a key component of sound irrigation management (Harivandi, 2006).

Human health and environmental concern

Recycled-reclaimed water due to its derivation is prone to elevated concentration of microbial and chemical agents that could pose a risk to human health and environmental matrices. In order to implement irrigation with alternative sources water, these risks is fundamental that should be managed.

Pathogens and chemical contaminants present in reclaimed water constitute the most significant health and environmental hazards. Many microbial pathogens found in reclaimed water are enteric in origin (Sanz, 2014). Table 1 lists all possible pathogens that are encountered in reused water.

Table 1 Pathogens possibly encountered in reclaimed water (Soure: Sanz, L.A. and Gawlik, B. M. (2014) (via Rowe and Abdel-Magid (1995); Yates and Gerba (1998); Haas et al. (1999))

Pathogen	Associate disease
Bacteria	
Campylobacter jejuni/coli	Gastroenteritis
Legionella spp	Respiratory disease
Salmonella typhi/paratyphi	Typhoid fever
Salmonella spp.	Gastroenteritis
Shigella spp.	Dysentery
Vibrio cholera	Cholera
Yersinia enterocolitica	Gastroenteritis
Viruses	
Adenovirus (40 y 41)	Gastroenteritis
Agente Norwalk	Gastroenteritis
Astrovirus	Gastroenteritis

Pathogen	Associate disease
Calicivirus	Gastroenteritis
Coxsackievirus	Meningitis
Viruses (continued)	
Echovirus	Meningitis
Hepatitis A virus (HAV)	Hepatitis
Hepatitis E virus (HEV)	Hepatitis
Rotavirus	Gastroenteritis
Protozoa	
Cryptosporidium parvum	Gastroenteritis
Entamoeba histolytica	Amebiasis
Giardia intestinalis	Gastroenteritis
Helminths	
Ascaris lumbricoides	Gastroenteritis
Taenia spp.	Taeniasis
Trichuris trichiura	Trichuriasis

Reused water contains elevated chemical pollutants that not only need to be considered from environmental aspect but alsoentail considerable long or short-term risks to human health. These agents have cumulative effects that most often are not assessed. In Table 2 chemical hazards with either environmental or human effects are listed.

Table 2 Chemical hazards related to reclaimed water (Source: Sanz, L.A. and Gawlik, B. M. (2014) (via USEPA, 2004; NRMMC-EPHC-AHMC, 2006)

Chemical agents	Associated disease or effect
Biodegradable organics such as proteins, carbohydrates	Eutrophication of surface water.
Oils, greases, cellulose, lignin…	Anoxic conditions in aquatic ecosystems.
Macronutrients (N, P, K)	Eutrophication of soils and surface water, plant toxicity, nutrient imbalance in plants, pest and disease in plants, loss of biodiversity.
Micronutrients (B, Ca, Cu, Fe, Mg, Na,	Plant toxicity, accumulation in soils.

Chemical agents	Associated disease or effect
Co, …)	
Metals (Cd, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Zn, …)	Toxicity to plants and aquatic biota.
Inorganic salts (chlorides, sulphurs, nitrates, …)	Soil salinity due to a plant stressed from osmotic, soils contamination, increasing salinity of groundwater and surface water risk for human health (methemoglobinemia associated with nitrates).
Industrial chemicals (PFCs, MTBE, solvents, …)	Carcinogenic, teratogenic and/or mutagenic effects, risk for human health (cyanotoxins), bioaccumulation, toxicity to plants. Various effects, often unexplored.
Pesticides, biocides and herbicides (e.g. atrazine, lindane, diuron, fipronil)	
Natural chemicals (hormones, phytoestrogens, geosmin, 2-methylisoborneol)	
Pharmaceuticals and metabolites (antibacterials (sulfamethoxazole), analgesics (acetominophen, ibuprofen),beta-blockers (atenolol), antiepileptics(phenytoin, carbamazepine), veterinaryand human antibiotics (azithromycin),oral contraceptives (ethinyl estradiol))	Carcinogenic, teratogenic and/or mutagenic effects, risk for human health (cyanotoxins), bioaccumulation, toxicity toplants. Various effects, often unexplored.
Personal care products (triclosan, sunscreen ingredients, fragrances, pigments)	
Household chemicals and food additives (sucralose, bisphenol A (BPA), dibutyl phthalate, alkylphenol polyethoxylates, flame retardants (perfluorooctanoic acid, perfluorooctane sulfonate)	
Transformation products (NDMA, HAAs, and THMs)	

Legal status regarding water reuse

Sound and safe implementation of alternative water sources for irrigation or other purposes calls for minimization of environmental and health hazards related to (present in) these sources through the development of guidelines and regulations in national or international level for the safe use of treated wastewater.

There have been developed guidelines by either international organisations such as the WHO in 2006 (WHO, 2006) or FAO in 1994 (“Water quality for agriculture” - Ayers & Westcot, 1994) or entities in national level such as the US Environmental Protection Agency –USEPA in 2004 and 2012 (“Guidelines for Water Reuse”), the Natural Resource Management Ministerial Council-NRMMC, the

Environment Protection and Heritage Council-EPHC, and the Australian Health Ministers Conference-AHMC in 2006, 2008 and 2009 ("Australian guidelines for water recycling: managing health and environmental risks" phase 1, 2, 2c). These guidelines provide the operational and monitoring framework of water reuse such as implementation, treatment process, water quality criteria, water monitoring, on-site preventive measures, environmental monitoring and communication strategies(Sanz, 2014). The State of California has established several water related laws ("Statutes Related to Recycled Water & the California Department of Public Health", State of California, 2014 and "State Water Resources Control Board Regulations Related to Recycled Water", amm. 16-07-2015 -State of California, 2016), a compilation of which, referred to as "The Purple Book" provides a basis for development of further regulations worldwide.

In Europe, there is a lack of a central legislative basis for the water reuse application. However, several environmental Directives such as Article 12 of the Urban Wastewater Treatment Directive (91/271/EEC) which requires that "treated wastewater shall be reused whenever appropriate" and "disposal routes shall minimize the adverse effects on the environment", with the objective of the protection of the environment from the adverse effects of wastewater discharge. Several Member States and autonomous regions have produced their own legislative frameworks, regulations, or guidelines for water reuse applications.

Among European countries only Spain, Portugal, Italy, France, Cyprus and Greece have enacted legislative acts or guidelines setting the basis of treated waste water reuse practices concerning the field of application, the implementation restrictions and the evaluation standards. It is worthwhile to mention that there is a variation between evaluation standards and application requirements in each of the aforementioned legislative or regulatory acts.

In Spain the RD1620/2007 issued by the Ministry of Environment, the Ministry of Agriculture, Food and Fisheries and the Ministry of Health sets the legal framework for the reuse of treated wastewater in a broad spectrum of applications including industrial, agricultural (even aquaculture), urban, environmental (aquifer recharge) and recreational uses. It also foresees the application in private gardens provided the implementation of a separate supply (pipes') network distinct from the domestic potable water pipe circuit.

In Cyprus the Water and Soil Pollution Control Law (Law106(I)2002) with its amendments and other regulatory acts such as (P.I. 270/2005) for Olive Presses Waste Disposal and (P.I. 269/2005) for the General Terms for Wastewater Disposal define the general framework for wastewater reuse and application in agriculture and green areas and for environmental uses such as aquifer recharge.

In Italy the DM185/2003 "Technical measures for reuse of wastewater" issued by the Ministry of Environment Ministry of Agriculture and the Ministry of Public Health defines the legal requirements for water reuse. The implementation spectrum includes mainly agriculture (not aquaculture), urban and industry (cleaning but not food industry) sectors. Environmental or private uses are not included.

In France JORF0153, 4 July 2014 issued by the Ministry of Public Health Ministry of Agriculture, Food and Fisheries Ministry of Ecology, Energy and Sustainability narrows waste water reuse in agriculture and green areas leaving outside industrial, urban or environmental uses.

In Greece legislative actJ.M.D.145116/2011 and its amendment J.M.D. 191002/2013 define the terms and procedures for the reuse of reclaimed water in a wide range of applications including agricultural, urban, industrial, recreational and environmental uses.

In Portugal the Portuguese Institute of Quality has developed a standard (NP4434:2005) for reuse of urban wastewater for irrigation providing guidelines for any water reuse practice implemented in agriculture and urban landscapes mainly.

Concerning monitoring requirements each of the aforementioned countries sets its own standards which differ distinctively not only in terms of analytical parameters but also in terms of limit values and frequency of analysis. A common place though is pointed out in physical and chemical parameters which in all of the above countries reflect the requirements of several European Directives such as Directive 91/271/EEC on the quality of treated effluent disposal, Directive 2008/105/EC on environmental quality standards and emission limits, and Directive 91/676/EEC on water pollution from nitrates.

It is fundamental that a convergence in legal framework of water reuse should be pursued between European countries if wastewater reuse strategies are to be largely adopted in the future. The development of central concrete policies that integrate environmental, health, economical and social standards and adapt to local needs and particularities is essential for the implementation of water reuse as a means of sustainable water resources management.

Objectives

The objective of deliverable 6.5.4 of IRMA project was to support the study of the effects of grey and recycled water on the development and status of plants that are used in landscaping projects.

After extensive literature review, a field experiment was organised and carried out at the Technological Educational Institute of Epirus (TEIEP), Kostakii Campus (Arta, Greece) from May to October of 2014 in order to assess the effect of irrigation with alternative sources water on development and status of ornamental plants such as turfgrass and other shrubs that are common in Arta's landscape.

Irrigation using tap water from the municipal drinking (potable) water supply network of Arta was used as reference. Grey water produced from TEIEP FLA building and reclaimed water from Arta's Waste Water Treatment Plant were selected as the alternative water sources to be evaluated. Both quantitative and qualitative parameters have been evaluated in order to assess the effects of irrigation with alternative water sources.

The present technical report presents the work that has been done and the relevant results, includes a discussion of the findings and provides information and practical advices regarding the implementation of such alternative water sources for landscape irrigation in residential or even municipal level.

The results will be combined with those of other relevant deliverables of the project in order to produce integrated information regarding the potentials of irrigation using alternative water sources in the programme area.

Material and methods

Experimental site (description of study area and climate data)

The experiment was conducted from May to October 2014 at the Kostakioi Campus of the Technological Educational Institute of Epirus (latitude 39° 0.7’N, longitude 20° 56’E, altitude 5m), near Arta, at the northwest coastal area of Greece.

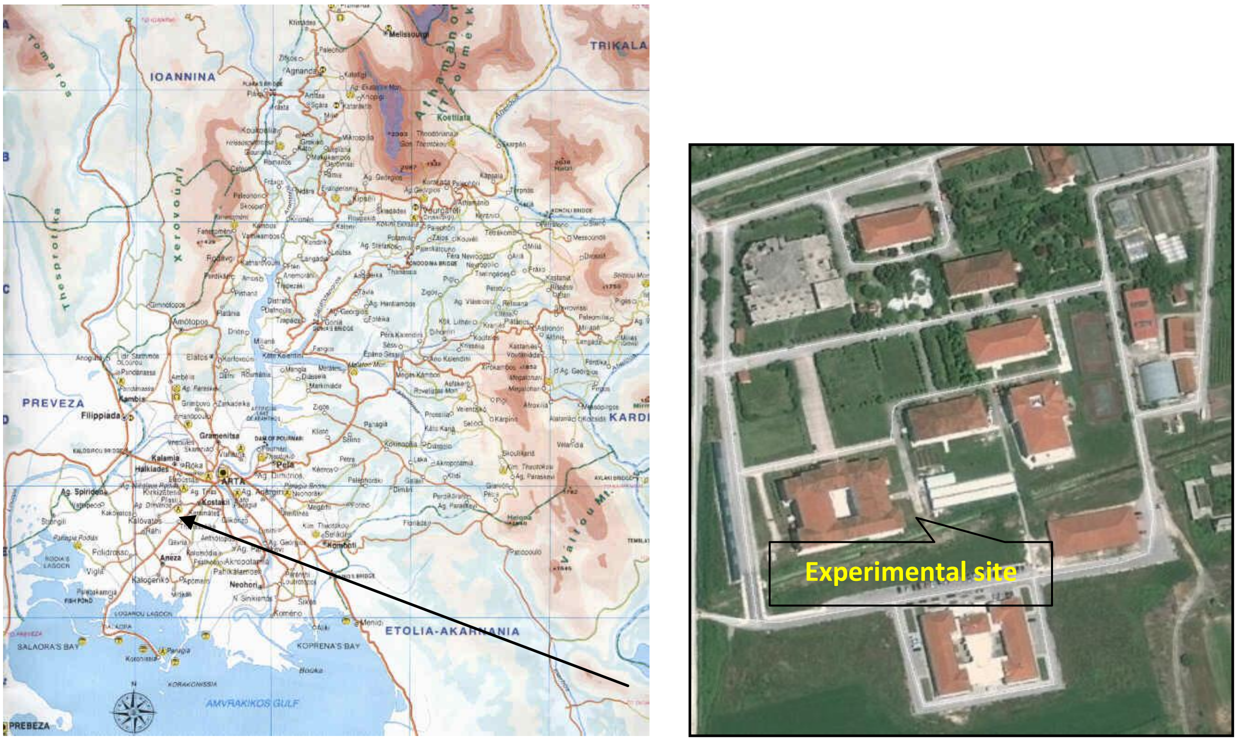

Figure 4 Location of Arta and experimental site on TEIEP Kostakioi Arta

The area is characterized by dry summers and moist but not cold winters and is classified to Mediterranean type. The summer of 2014 was characterized as extremely wet summer. Figure 5 shows the ombrothermic diagram of Arta using climatic data (20 years averages; HNMS, 2014).

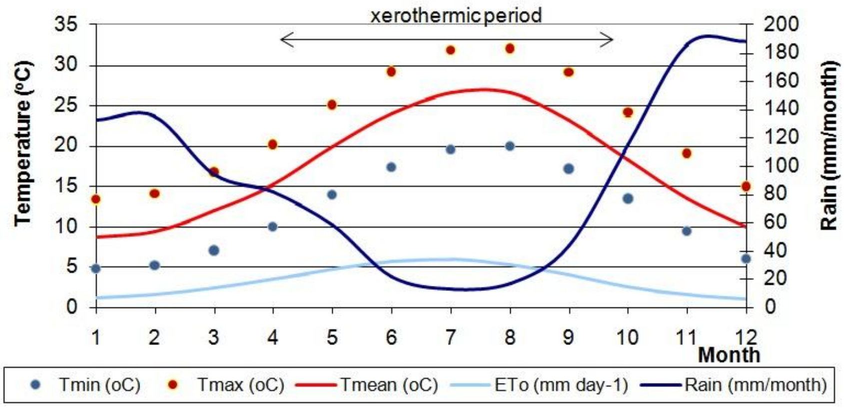

Figure 5 Ombrothermic diagram of Arta

Standards followed

The following standards where followed during the experiment:

- Laying readymade lawn turf (sod) - Hellenic Technical Specification TP 1501-10-05-02-02 (ELOT, 2009a)
- Construction of plant irrigation networks - Hellenic Technical Specification TP 1501-10-08-01-00 (ELOT, 2009b)
- Electric motor pumps for water supply and irrigation pumping stations - Hellenic Technical Specification TP 1501-08-08-02-00 (ELOT, 2009c)
- Irrigation of plants - Hellenic Technical Specification TP 1501-10-06-02-01 (ELOT, 2009d)
- Irrigation of lawn, ground cover plants and slope cover plants - Hellenic Technical Specification TP 1501-10-06-02-02 (ELOT , 2009e)
- Application of fertilizers - Hellenic Technical Specification TP 1501-10-06-03-00 (ELOT, 2009f)
- Lawn mowing - Hellenic Technical Specification TP 1501-10-06-04-03 (ELOT , 2009g)
- Plant protection - Hellenic Technical Specification TP 1501-10-06-05-00 (ELOT , 2009h)
- Weed control methods - Hellenic Technical Specification TP 1501-10-06-06-00 (ELOT , 2009i.)
- Lawn improvement - Hellenic Technical Specification TP 1501-10-06-08-00 (ELOT, 2009k)
- Determination of minimum and maximum limits of the necessary quantities for the sustainable use of water for irrigation (GMA, 1989)
- Modernisation of the methodology used for the calculation of plants water needs in the framework of relevant studies and adaptation to Greek conditions (GMA, 1992)
- Determination of terms and procedures for the reuse of treated wastewater(J.M.D. 145116, 2011)
- Amendment of J.M.D. 145116/2011 "Determination of terms and procedures for the reuse of treated wastewater" (J.M.D.191002/2013)

Also the guidelines from manufacturers (sod, fertilisers, plant protection materials and irrigation system components) were taken into account too.

Preparation activities

Soil and Soil analysis

The soil that was used in the experiment was uniformly mixed local soil. Soil analysis classified the soil as loamy sand (Figure 6) (86.40% sand, 11.64% clay and 2.36% silt) and its physical properties are described as:

- Field Capacity: 15%
- Permanent Wilting Point: 6%
- Available Water Capacity: 9%
- Infiltration Capacity: 23mm/h.

Figure 6 Classification of soil used in the experiment

Experimental design

Treatments

The experiment studies the effect of irrigation with alternative water sources on both turfgrass and shrub growth and condition. The experimental design used three different kinds of water sources: a) tap water, b) grey water and c) recycled water and two categories of plants: i) turfgrass and ii) shrubs. All treatments had three replications. The experimental design is presented in Figure 10.
Treatments were coded as following:

1. Treatment 1_1: Turfgrass irrigated with Tap water as control (TW_C)
2. Treatment 1_2: Turfgrass irrigated with Grey water (GW)
3. Treatment 1_3: Turfgrass irrigated with Recycled water (RW)
4. Treatment 2_1: Shrubs irrigated with Tap water as control (TW_C)
5. Treatment 2_2: Shrubs irrigated with Grey water (GW)
6. Treatment 2_3:Shrubs irrigated with Recycled water (RW)

Figure 7 Indicative stages from the construction of the experimental setup

Eighteen containers (Figure 7) hosted the experimental plots. Each container was framed by 2x2x0.22m wooden lined trays and was covered inside with a plastic film in order to hamper the water leakage to the adjacent experimental plots (container). At the bottom of each container a 0.8m of height layer of gravel was formed, while the rest of it was filled until the top with soil. Characteristics of soil used in the experiment are described in the relevant paragraph. Each treatment's replicates were hosted in experimental plots that were put adjacently forming a bigger container of three sections while groups of experimental plots that hosted replications of different treatments were put at a distance of 0.6m forming corridors between them covered with groundcover fabric and gravel over it in order to suppress weed growth. Additionally two 1.5x3x0.22m containers hosted the backup shrubs and turfgrass.

Figure 8 Construction of the irrigation system head (initial placement)

Labeling is a very important issue when applying irrigation with alternative sources water and most significantly a legal requirement (J.M.D.145116/2011, 2011). Appropriate labeling was applied to each experimental group of plots indicating the treatment and on tanks that contained alternative sources water (Figure 9).

Figure 9 Construction of the experimental setup and a view of the experimental plots

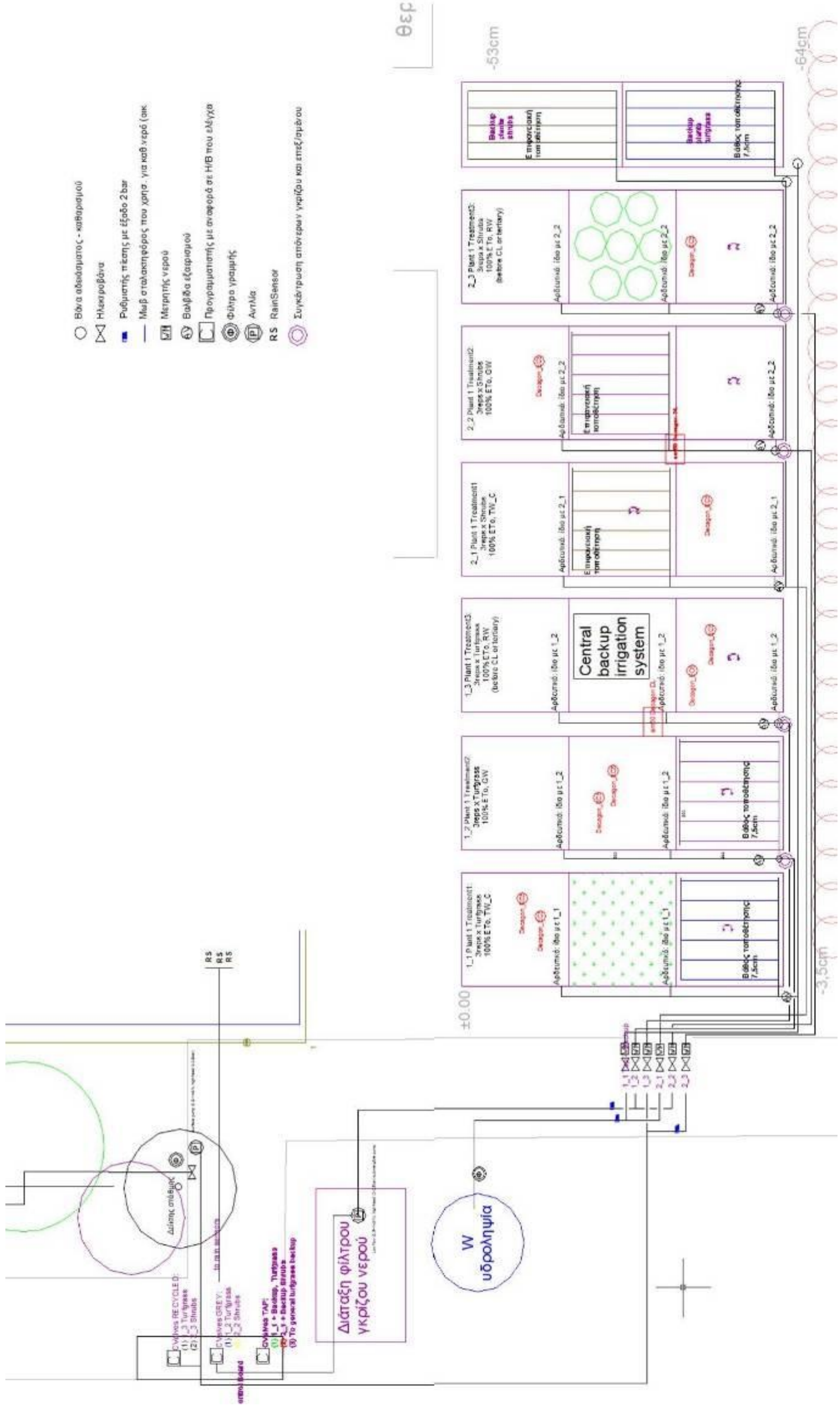

Figure 10 Experimental design

Plant material

Turfgrass

Turfgrass Festuca “Heraklis” (Hellasod) used in the experiment was a mixture of selected *Festuca Arundinaceae* varieties (hybrids F1 & F2). This sod is a cool season variety, tolerant to xerothermic conditions and low temperatures (and EC up to 3000 μS cm^{-1}(3 dS m^{-1})). Turfgrass was installed and maintained (soil preparation, fertilization, initial irrigation, establishment period precautions and care etc) according to nursery supervisor’s instructions and relevant standards (mentioned above). Selection of turfgrass was based on market popularity criteria. According to the nursery it is suggested to be mowed every 7 days to 3-5 cm (or 6cm for shady places).
The sod was installed on 10/4/2014 and it was considered fully established on 10/5/2014.

Shrubs

Shrub species used in the experience were selected based on their landscape occurrence (popularity in Arta’s landscape) and their medium (moderate) water needs (WUCOLS, 2000). Table 3 lists the plants that were selected for the experiment and their growth characteristics.

Table 3 Shrub species used in the experiment

Species	**Max Height (m)***	**Max Width (m)***
Ligustrum japonicum (Com.Japanese privet or wax-leaf privet)	6 2.5-3	4 1-1.5
Photinia serrulata (Com.Chinese photinia)	5 2.5-3	4 2
Viburnum tinus (Com.Laurustinus Viburnum)	3 2-2.5	3 2
Pittosporum tobira “Wheelers dwarf” (Com. Dwarf pittosporum)	4 2.5-3	3 2.5-3
Thuja occidentalis (Com. American arbovitae)	4 2.5-3	2
Abelia chinensis (Com. Chinese Abelia)	2	4
Hibiscus syriacus (Com. Rose of Sharon)	4 2-3	3 1-1.5

*Natura Media (2010) & MillePlante (2000)

Water resources

Tap water

TEIEP’s tap water is supplied by the municipal drinking (potable) water supply network. Tap water physical properties are summarized as: pH=7.63 and EC=0.58 dS m^{-1}.

Grey water

Grey water consisted of water collected through an appropriate plumbing arrangement (Figure 13) from a TEIEP's hand washstand in which water from certain cleaning activities was discharged (hand washing and moping). This water flew through a greywater diversion device (Aqua2use®,Figure 11). This device consists of a rectangular plastic pump well with a sequence (arrangement) of four different porosities filter mats of increasing density (Matala®), through which water flows and impurities are being retained. Disinfection of grey water was achieved with the help of a chlorinating device adjusted at the exit of the filter device (Figure 12). This device was a plastic container into which a chlorine tablet was inserted. Filtered grey water passed through the chlorinating device and was collectedin a 200lt cylindrical plastic tank (collection tank). Residual chlorine's concentration of treated grey water stored in the collection tank was monitored on a daily basis with a free chlorine checker (HANNA HI701, Figure 14). Treated grey water's chlorine concentration was regulated by an additional arrangement. This included a pipes loop forming a bypass so that filtered grey water could deviate from the chlorinating device and end up directly in the collection tank. This procedure decreased treated grey water's total chlorine concentration preventing chlorine accumulation in the field. Collection tank was connected to the irrigation system of the experimental plots.

Figure 11 Aqua2use filter

Figure 12 Chlorinating device

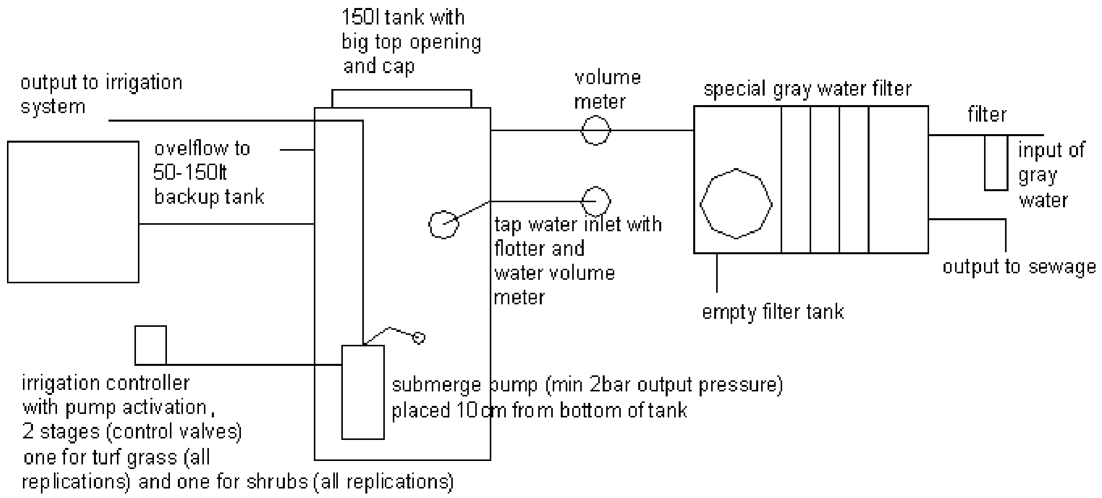

Figure 13 Arrangement of grey water capture and management system

Figure 14 Free chlorine checker

Recycled water

Recycled water was provided every week or ten days by the Waste Water Treatment Plant of Arta (Figure 16 , Figure 17). The recycled water was stored in a 6m^3 cylindrical tank (d:2m, H:3m) where it remained for maximum 10 days so as to maintain microbial load suppressed according to legislation's requirements. A light construction made by wooden frame wrapped by plastic sheet was placed on the top of the tank and fastened on peripheral metal loops was used as a detachable cover. The tank was placed in a shady and protected from solar radiation spot at the experimental site (Figure 15). Before every reload the remaining water was being pumped out and the tank was being washed.

Figure 15 Site of storage of recycled water

Figure 16 Municipal Wastewater Treatment Plant's tank during recharge

Figure 17 Recharge of recycled water tank

Irrigation system

According to national legislation (JMD 145116/8.3.11), reclaimed water should only be used in a drip irrigation system.

Turfgrass treatments were irrigated using a subsurface microirrigation system which was installed at a depth of 7cm. The dripline that was used conformed to legislation's requirements (J.M.D.145116/2011, 2011) having purple color and being coated inside with an anti-bacteria layer and pressure compensated emitters (Netafim Ø17, 1.6lph@0.30m). It must be noted that the suggested by the manufacturer antiroot chemical filter, to protect the emitter against root intrusion, was not installed. The lateral spacing of driplines was 0.35m. The system's precipitation rate was $18mmh^{-1}$.

The dripline that was used for tap water, was of brown color, impervious to sunlight so as to keep temperature to low levels and prevent bacterial (microbial) enhancement and had pressure compensated emitters (Netafim Ø16, 2.3lph@0.33m AS UNITECHLIN BROWN). The lateral spacing of driplines was 0.35m. The system's precipitation rate was $23mmh^{-1}$.

For fiscal savings reasons turfgrass tap water treatment was irrigated with purple driplines since the system was underground and there was an excess regarding purple driplines.

Screen line filters (mesh 120) were placed in order to prevent drippers' clogging. Additionally air vacuum relief valves were placed at the highest point of each zone in order to allow the flow of the air out of the driplines during irrigation and flush valves were placed at the lowest end point of every zone drove the excess of water out of the driplines after the irrigation event had finished. The excess water of the alternative water treatments was collected in buckets and disposed at sewage (the Waste Treatment Plant of Arta). Irrigation was managed electronically by controllers as will be analytically described in the relevant paragraph. All controllers were placed in closed boards.

Irrigation schedule

Irrigation scheduling is based on water requirements of plants, the plant species, climatic and soil characteristics. According to FAO-Paper 56 (Allen et al., 1998) water requirements are estimated using available historical climatic data (solar radiation, air temperature and relative humidity, wind speed etc) of the area.

The Hargreaves method (Allen et al., 1998) was used in order to estimate the reference evapotranspiration (ETo) which was then multiplied by the landscape coefficient (K_L) (UCCE and CDWR, 2000) in order to result the landscape evapotranspiration (ET_L). That was the estimation of water needs according to which irrigation was scheduled. Landscape coefficient K_L is defined as the product of a species factor (ks), a density factor (kd), and a microclimate factor (kmc). According to UCCE and CDWR (2000), the coefficients of species (ks), density (kd) and microclimate (kmc) for the turfgrass used in the experiment, were estimated to be about 0.8, 1 and 1 respectively. Concerning shrub species, the corresponding values were: 0.8, 1 and 0.5.

Table 4 summarizes reference evapotranspiration and species evapotraspiration ($ET_{L(TURFGRASS)}$) and $ET_{L(SHRUBS)}$.

Table 4 Calculation of reference evapotranspiration (ETo) using climatic data and turfgrass and shrubs landscape evapotranspiration (ETL) using estimated coefficients

Month	**ETo (mm day^{-1})**	**$ET_{L(TURFGRASS)}$ (mm day^{-1})**	**$ET_{L(SHRUBS)}$ (mm day^{-1})**	**Period characterisation**
April	3.45	2.76	1.384	cool
May	4.69	3.75	1.872	
June	5.62	4.50	2.248	warm
July	5.91	4.73	2.368	
August	5.27	4.22	2.112	
September	3.97	3.18	1.592	cool
October	2.52	2.01	1.008	

Irrigation duration is estimated as:

- For driplines Ø17: RTfc = 60 x 50% x 90mm m^{-1} x 0.25m x (0.3m x 0.3m) / 1.6lh^{-1} x 90% = 42 min and
- For driplines Ø16: RTfc = 60 x 50% x 90mm m^{-1}x 0.25m x (0.3m x 0.33m) / 2.3l h^{-1} x 90% = 33 min.

Irrigation Interval was estimated as:

- For driplines Ø17 applied to turfgrass: Theoretical I.I. =(18mm h^{-1} x 42min / 60) / 4.7 mm day^{-1}= 2.6 days,while practical decided irrigation interval was 1 event per day 16 min duration
- For driplines Ø17 applied to shrubs: Theoretical I.I. =(18mm h^{-1} x 42min / 60) / 2.9 mm day^{-1}= 4.34 days (practical decided irrigation interval was 1 event per day with duration of 10 min).
- For driplines Ø16 applied to shrubs: Theoretical I.I. =(23mm h^{-1} x 42min / 60) / 2.9 mm day^{-1}= 4.34 days (practical decided irrigation interval was 1 event per day with duration of 17 min).

Taking into consideration the above, irrigation schedule applied was finally formed as shown in the Table 5.

Table 5 Applied irrigation schedule

	1_1	2_1	1_2 και 2_2	1_3 και 2_3
Start time	8:30 am		8:30 am	9:00 am
Frequency	1	1	1	1
Duration	24min	17min	24min	24min

Weather data from the meteorological station of the TEIEP's nearby greenhouse and periodical soil moisture measurements helped in irrigation dose adjustment when needed.

Furthermore irrigation with tap water was applied every 30 days (if there was not any raining event in meantime) to alternative water treatments in order to avoid salt and microbial accumulation in soil.

On September 16th the irrigation schedule was modified to 60% of water budget so irrigation schedule was altered as described in Table 6.

Table 6 Irrigation schedule based on 60% of water budget

	1_1	2_1	1_2 και 2_2	1_3 και 2_3
Start time	8:30 am		8:30 am	9:00 am
Frequency	1	1	1	1
Duration	14min	10min	14min	14min

Compliance with the irrigation schedule was managed with the help of three controllers as described at the relevant paragraph.

Controllers

Irrigation schedule was applied using three Orbit sprinkler timers Model 91054 (Orbit, 2014) (Figure 18). This type of controller is simple yet accurate and provides the possibility of running automatic, semi-automatic or manual watering programs. It has four stations and two programs that can be applied to irrigation system. Each controller managed irrigation schedule applied to each different treatment (tap water, grey water and recycled water) for both evaluated type of plants (turfgrass and shrubs) (i.e.: 1_1 & 2_1, 1_2 & 2_2, 1_3 & 2_3). Every group of plots that represented one treatment with its replications was managed with one station of the same program. That means for example in the case of controller 1 which managed tap water treatment irrigation (1_1 and 2_1) when start time for station one of program A was 8:30 and duration time was 24 min plots 1_1 where irrigated and 24 minutes later, on 8:54 the second station started giving order to irrigate plots of 2_1 treatment. Additionaly an adjacently placedHunter Mini-Click Rain Sensor (Hunter Industries, USA) adjusted to 13 mm of rain was connected to each controller.

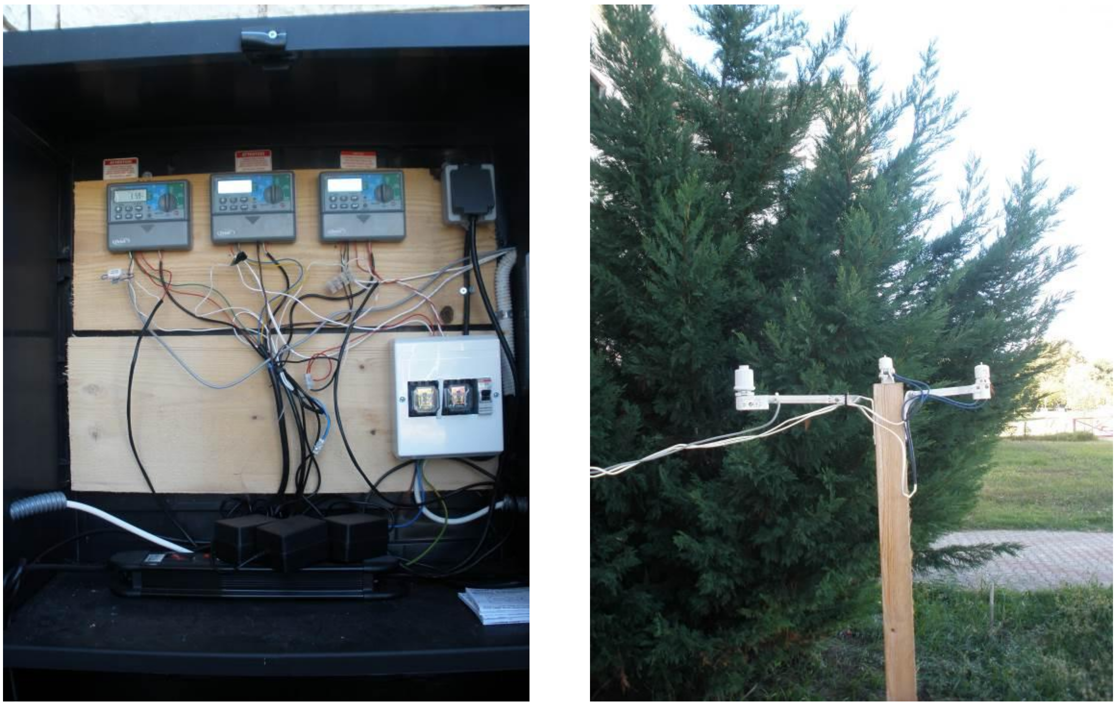

Figure 18 Controllers and rain sensor

Plant protection

During establishment of turfgrass 1kg of Pyrinex (Group 1B organophosphate insecticide) was applied.

During the experimental period plant protection was applied for the control of pest and diseases. Table 7 summarizes pest occurrence incidents and consequent actions.

Table 7 Plant protection activities

Date	**Species**	**Enemy**	**Action**
22/4/14	Shrubs (*Pittosporum tobiris, Photinia serrulata, Abelia chinensis, Viburnum tinus)*	Aphids , Whiteflies, thrips	profil (acetamiprid) 20SG (0.25 gr lt^{-1}) + poleci 2.5 EC (Deltamethrin) (0.25 gr lt^{-1})
22/5/14	Shrubs *(Photinia serrulata*, *Ligustrum japonicum, Viburnum tinus)*	Aphids , Whiteflies	profil (acetamiprid) 20SG (0.25gr lt^{-1})
5/6/14	Shrubs *(Thuja occidentalis)*	Fungus (*Pestalotiopsis funerea*)	aliette (fosetyl-Al 80%) 2.5gr lt^{-1}

Date	Species	Enemy	Action
13/6/14	Shrubs (*Thuja occidentalis*)	Fungus (*Pestalotiopsis funerea*)	aliette (fosetyl-Al 80%) (2.46 grlt^{-1}) + neotopsin (Thiophanate methyl 70%) 0.66gr lt^{-1} + decis 0.66cc lt^{-1} (deltamethrine 2.5%)
	Turfgrass	Fungi *Rhizoctonia solani*, *Helminthosporium* sp., *Agaricus* sp.,*Armillaria mellea*	
5/7/14	Turfgrasss	Fungi *Rhizoctonia solani*, *Helminthosporium* sp., *Agaricus* sp., *Armillaria mellea*	Neotopsin (1 gr lt^{-1}) (Thiophanate methyl) και Flint (0.14 gr lt^{-1}) (trifloxystrobin)
18/7/14	Turfgrass	Fungi *Rhizoctonia solani*, *Helminthosporium* sp., *Agaricus* sp., *Armillaria mellea*	Neotopsin (1.3gr lt^{-1}) (Thiophanate methyl) και Flint (0.33gr lt^{-1}) (trifloxystrobin)
24/8/14	Shrubs (Thuja occidentalis)	Fungus *Pestalotiopsis funerea*	alliette (fosetyl-Al 80%) (5gr lt^{-1})

Fertilization

Along sodding, fertilizer 4kg (55 gr m^{-2}) of COMPO Complesal Supra 21-5-10 +3MgO+B+Fe+Zn was applied.

After this there was an almost monthly application of fertilizers on turfgrass:

- 29/4, Nitrophoska special 12-12-17 (+2+8)[1], 50gr m^{-2} (EuroChem Agro Hellas S.A.)
- 29/5,ENTEC 24-8-7[2], 25gr m^{-2}(EuroChem Agro Hellas S.A.)
- 30/6, Nitrophoska special 24-8-7 & 12-12-17 (+2+8), 25gr m^{-2}(EuroChem Agro Hellas S.A.)
- 26/7, Nitrophoska special 24-8-7 & 12-12-17 (+2+8), 25gr m^{-2}(EuroChem Agro Hellas S.A.)

[1]Nitrophoska special 12-12-17: 4.8 % N-NO_3, 7.2 % N-NH_4, neutral ammonium citrate and 7.8 % P_2O_5, 17 % K_2O
[2] ENTEC 24-8-7: 10.8% N-NO_3, 13.3% N-NH_4, neutral ammonium citrate and 5.2 % P_2O_5, 7% K_2O.

- 14/8, Nitrophoska perfect (15+5+20(+2+8))[3], 25gr m^{-2} (EuroChem Agro Hellas S.A.)
- 31/8, Nitrophoskaperfect (15+5+20(+2+8)), 25gr m^{-2} (EuroChem Agro Hellas S.A.)
- 23/9, Nitrophoska perfect (15+5+20(+2+8)), 25gr m^{-2} (EuroChem Agro Hellas S.A.)
- 21/10, Nitrophoska perfect (15+5+20(+2+8)), 30gr m^{-2} (EuroChem Agro Hellas S.A.)

Application of fertilizers on shrubs is described below:

- 30/6, Nitrophoska special 24-8-7 & 12-12-17 (+2+8), 15grper shrub (26.25 gr m^{-2}) (EuroChem Agro Hellas S.A.)
- 12/7, foliar application withHumaGro IRON Fe 12-0-0 (+6)[4] 0.26 ml lt^{-1}(Intrachem Hellas)
- 26/7, foliar application with Fe 0.26 ml lt^{-1}(Intrachem Hellas)
- 6/8, Nitrophoska special 12-12-17 (+2+8)[5], 15grper shrub (26.25 gr m^{-2}) (EuroChem Agro Hellas S.A.)
- 10/8, foliar application with Fe 0.26 ml lt^{-1} (Intrachem Hellas)
- 14/8, Nitrophoska perfect (15+5+20(+2+8)), 15grper shrub (26.25 gr m^{-2}) (EuroChem Agro Hellas S.A.)
- 24/8, foliar application with Fe 0.26 ml lt^{-1}(Intrachem Hellas)
- 31/8, Nitrophoska perfect (15+5+20(+2+8)), 15grper shrub (26.25 gr m^{-2}) (EuroChem Agro Hellas S.A.)

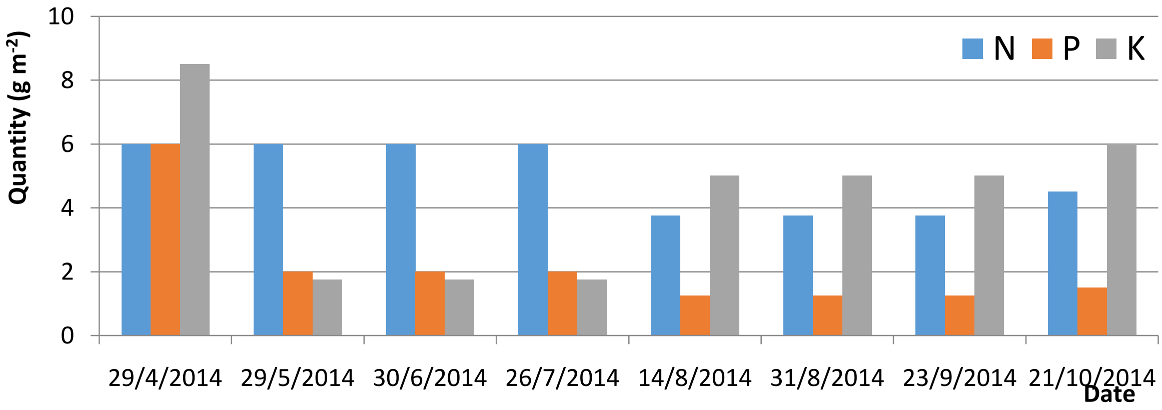

Figure 19 Applied quantities of N, P and K on turfgrass

[3]Nitrophoska perfect: 7% N-NO_3, 8% N-NH_4, neutral ammonium citrate and 3.5 % P_2O_5, 20% K_2O
[4] HumaGro IRON 12-0-0: 12% N-NH_4, 6% $FeSO_4$
[5]Nitrophoska special 12-12-17: 4.8 % N-NO_3, 7.2 % N-NH_4, neutral ammonium citrate and 7.8 % P_2O_5, 17 % K_2O

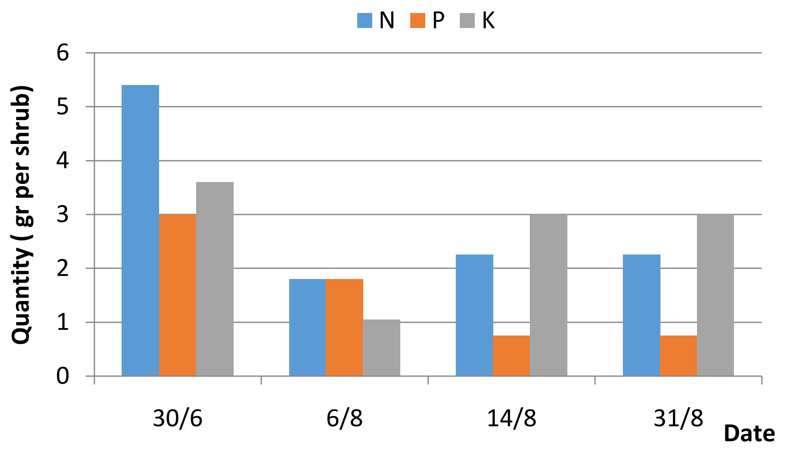

Figure 20 Applied quantities of N,P,K on shrubs (gr per shrub)

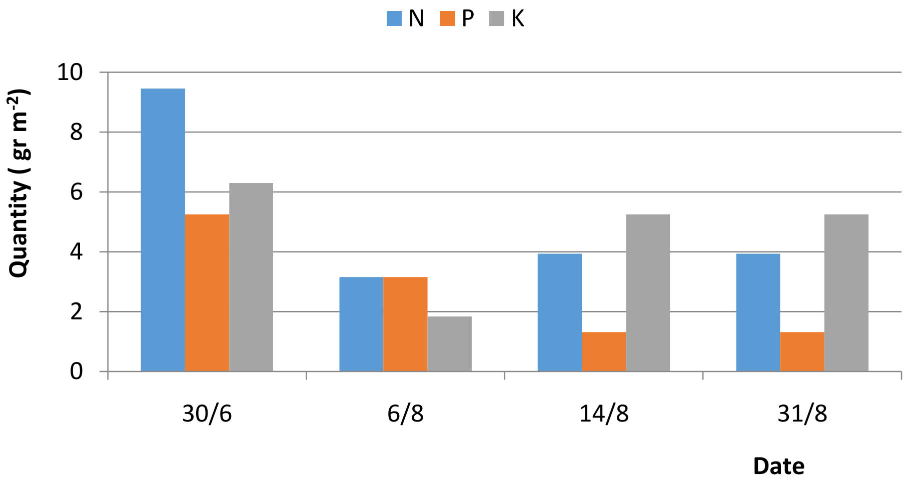

Figure 21 Applied quantities of N,P,K on shrubs (grm^{-2})

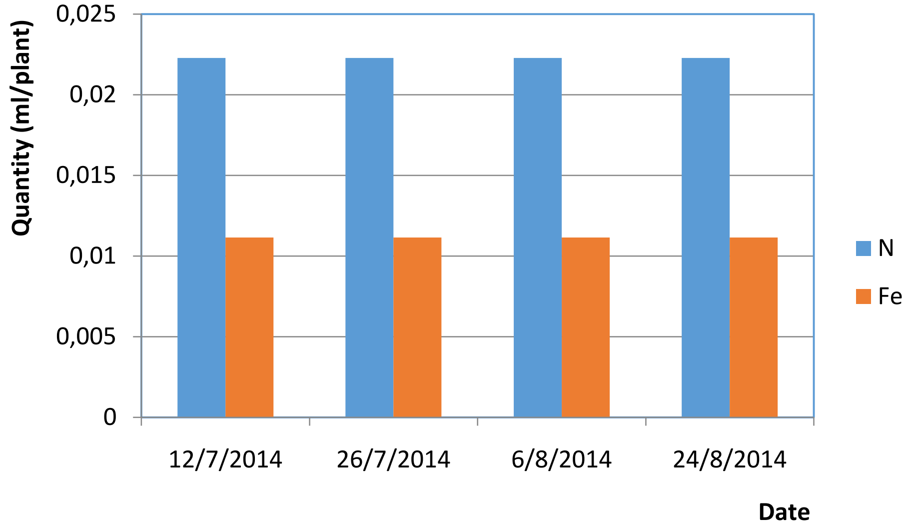

Figure 22 Applied quantities of N,Fe on shrubs (gr plant^{-1})

Mowing

From June 1st, the plots were mowed to a height of 4.5 cm every ten days using a Rotak37LI battery powered mower (Robert Bosch GmBh, DE(Bosch, 2014)).

Measuring and calculation of evaluation parameters

Meteorological data

Meteorological data, namely air temperature and relative humidity (Tair,^{o}C and RHair, %), solar radiation (RS, Wm^{-2}), wind speed (W ms^{-1}) and direction at 2m height as well as rain height (R, mm), were recorded every 30 min by means of a nearby station (HOBO Weather Station, ONSET instruments, USA). These data were used for evapotranspiration (ET) calculations according to Allen et al. (1998).

Figure 23 Meteorological station

Soil Moisture monitoring

According to (Campbell, 2013) more than two sensors are needed to compute reliable water balance: the shallower sensors monitor root zone moisture and the deeper sensors can provide drainage loss data. At the other hand (McCready & Dukes, 2011), in a turfgrass irrigation experiment, suggest the use of only one sensor placed vertically in order to measure the average moisture between 8 and 18cm.

The volumetric water content (VWC) of the soil was continuously monitored using capacitance sensors EC-5 (Decagon Devices Inc., USA). This sensor has 2 prongs of 5cm length and use Frequency Domain Reflectometry (FDR) to measure VWC from 0 to 100%. According to the manufacturer

(Cobos, 2008; Decagon Devices, 2012) the generic linear conversion equation for all mineral soil types with electrical conductivities from 0.1 to 10 dS m^{-1}, provide a ±0.03 m^3m^{-3} accuracy (for a maximum of ~60% VWC). This could be improved up to ±0.01 to ±0.02 m^3m^{-3} if calibrated (using linear or upper grade equations) for a specific soil (Cobos & Chambers, 2010; Decagon Devices, 2011 and 2012) and in order to achieve this improvement, a relevant calibration was performed. Also a SWAT calibration was found for this sensor (IA, 2008b). According to that, a number of equations for converting the sensor output to actual moisture content are provided.

According to our analysis VWC (θ %v/v) for the given soil is given by:

a) $\theta = 8.5 \cdot 10^{-4} \cdot \text{RAW} - 0.48$

b) $\theta = 6.1 \cdot 10^{-4} \cdot \text{RAW} - 0.35$

c) $Y = 0.8238 \cdot X + 0.0646$

Equation 1 EC-5 VWC equations: a) Decagon's generic equation for mineral soils; b) specific soil equation after laboratory calibration and c) SWAT response function for soils at 20°C

where RAW is the output from the Decagon data logger; X is the sensor output and Y the actual soil moisture

In every case the soil specific calibration is not a very practical approach but it is probably unavoidable as the differences are considerable Figure 24.

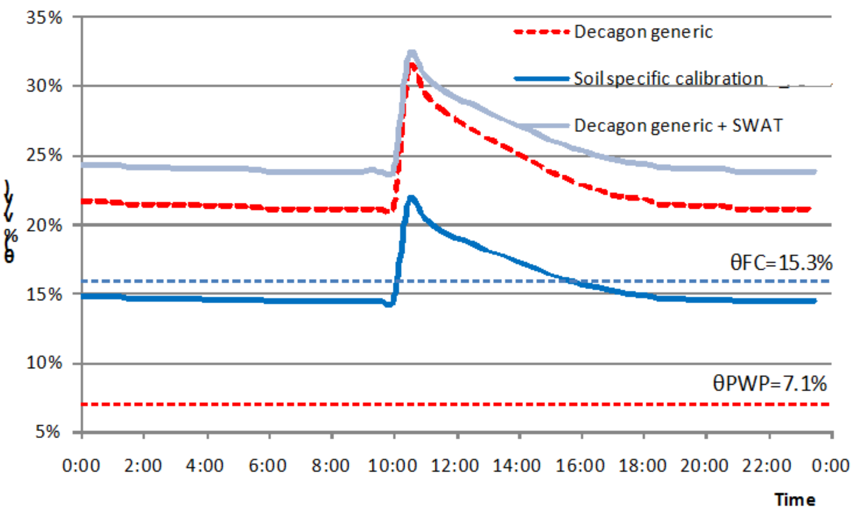

Figure 24 Indicative differences between signal and soil moisture reading when different equations are used

For treatments 1_1a, 1_2b, 1_3c EC-5 sensors were placed at two depths (6 and 17cm) with their plane perpendicular to the soil surface (as proposed by the manufacturer; Decagon Devices, 2010). For treatments 2_1c, 2_2a, 2_3c the EC-5 sensor was placed vertically with the edges of its prongs at 10cm.

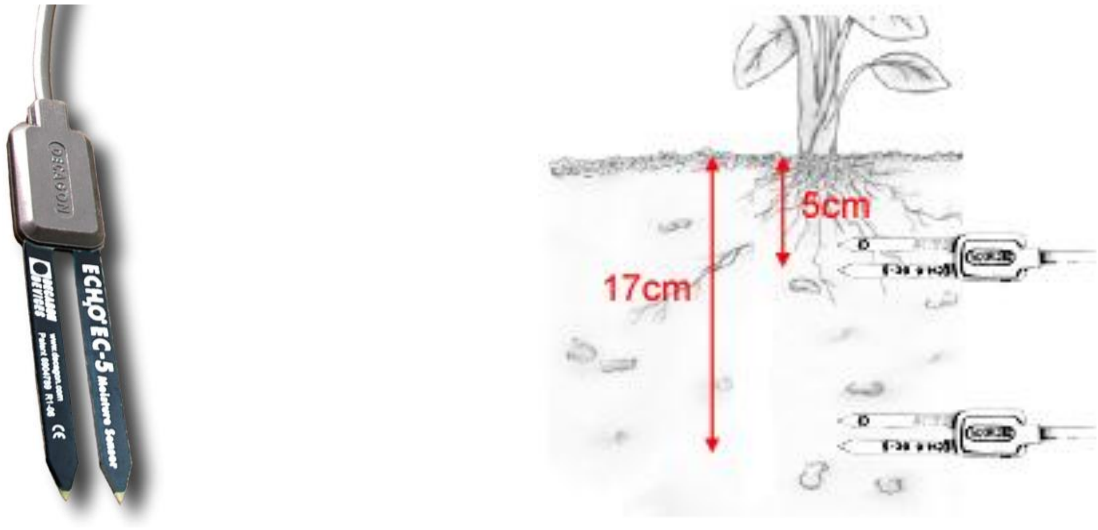

Figure 25 The EC-5 VWC sensor and the installation depth

The sensors were plunged to Em50 dataloggers (Decagon Devices Inc., USA).

Also, as a backup measurement, soil moisture readings from 0 to 6 cm depth were recorded manually every day by means of a hand-held TDR soil moisture meter (ThetaProbe ML3, Delta-T Devices Ltd, UK).

Water consumption measurement

1'' volumetric dry dial water meters (1L resolution) were used for the measurement of the water consumption during the evaluation period. One meter was installed for each treatment, and the measurements were registered manually every day.

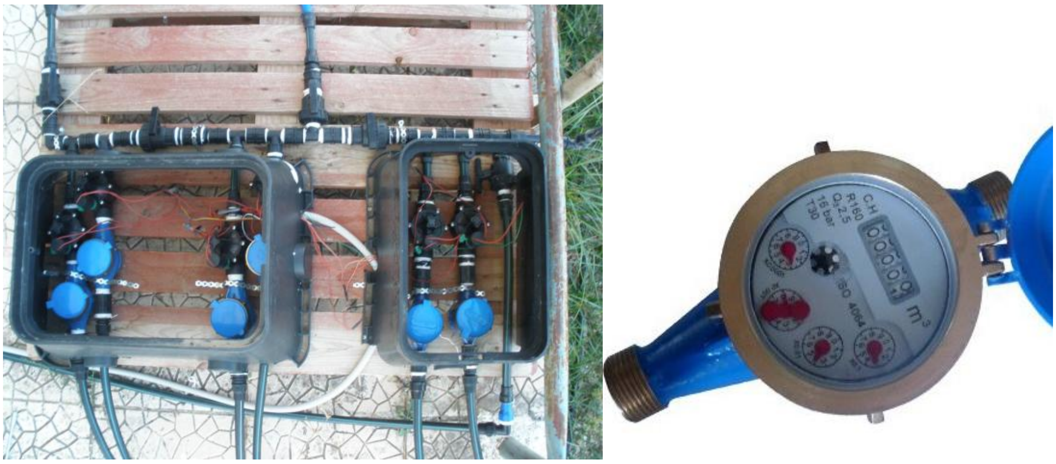

Figure 26 Volumetric dry dial water meters

Soil monitoring

Determination of soil pH and EC, nutrients such as N, P, K and ratio SAR and organic matter (OM) was carried out on monthly basis. Soil samples (Figure 27) were obtained with the help of a soil probe. Determination of EC was conducted in soil solvent (soil:water= 1:2.5) with an ECmeter (HANNA 98304), while pH was measured in soil solvent (soil:water= 1:5) with a pHmeter (HANNA HI98205).

Figure 27 A typical soil sample (soil core)

Water monitoring - Chemical and microbiological analysis of water

Grey water samples were collected biweekly and analyzed for: Total Suspended Solids (TSS) by XN 28 In house method based in APHA: 2005, 2540D, 2-58 method, Total Nitrogen (TN) by Kjeldahl method, Total Phosphorus (TP) by XN-10 In house APHA 4500-P method, BOD5 by XN-11 IN HOUSE METHOD-APHA 5280D and turbidity by XN 31 In house based APHA 2130 A & B method. Total Coliforms were determined in the above samples by M 03 ISO 9308-1 / 2000 method. Residual chlorine was determined in daily basis with a free chlorine checker (HANNA HI701).

Recycled water samples were collected every 10 days during every supply by the Waste Water Treatment Plant of Arta, and analyzed for: Total Suspended Solids (TSS) by XN 28 In house method based in APHA: 2005, 2540D, 2-58 method, Total Nitrogen (TN) by Kjeldahl method, Total Phosphorus (TP) byXN-10 In house APHA 4500-P method, BOD5 by XN-11 IN HOUSE METHOD-APHA 5280D and turbidity byXN 31 In house based APHA 2130 A & B method. Total Coliforms were determined in the above samples by M 03 ISO 9308-1 / 2000 method.

Plant status and growth

Evaluation of turfgrass growth

Dry weight of shoot and leaf after each cutting

For the evaluation of turfgrass growth the dry weight of leaves and shoots after cutting over a specified height has been estimated periodically every ten days. The sample has been acquired after cutting over 4.5 cm from ground from an area of 0.9 m^2 with the help of a metal frame (30x30 cm) as a guide (Figure 28). The frame was placed in the center of each plot in order to obtain a representative sample. The samples were collected with the help of a vacuum, placed in aluminum traces and dried in an oven (MEEMERT DO6061 model 500 MEMMERT GmbH + CO.KG) at 70^{o}C for

48h. Dried leaves were weighed on a laboratory scale (KERN EW2200-2NM, D72336, KERN & SON GmbH). After each sampling the plot area was mowed at the same height of 4.5 cm. Figure 28 shows the sampling apparatus and the sampling procedure.

Chemical analysis of leaves

Chemical analysis of leaves was conducted on monthly basis for the determination of nutrients such

Figure 28 Turfgrass sampling procedure

as N, P, K, Ca, Mg, Mn, Fe by dry-ash method. The samples were obtained as described above and were sent for the analyses to the TEIWG (Soil Laboratory).

Dry weight of roots

The sampling has been conducted periodically on monthly basis. The samples have been obtained with the help of a soil probe diameter, until depth of 30cm. The upper part of the core sample was cut off and the roots were rinsed with tap water until all visible soil particles were removed. The samples were weighed, placed in aluminum trays and dried in an oven at 70^{o}C for 48h. Dried roots were weighed on a laboratory scale (KERN EW2200-2NM, D72336, KERN & SON GmbH).

Evaluation of turfgrass quality

There have been developed several methods for the evaluation of turfgrass quality. The most commonly used method is the 1 (lowest quality) to 9 (highest quality) visual rating of turfgrass by trained evaluators as it is described at the National Turfgrass Evaluation Program (NTEP, Richardson, Karcher, & Purcell, 2001). This method although is not a labour intensive or time consuming method it has the disadvantage to be very subjective, not reproducible and there is significant variations among the evaluations (Ghali, 2011).Color variation evaluation can be estimated by colorimeters but it can be aplied only in a small turf area (less than 20 cm^2). Canopy Spectral Reflectance methods can provide objective evaluation.

Multispectral radiometry measures reflectance from turfcanopies in visible and infrared ranges and can provide objective information about water and leaf pigment content. According to what is being investigated several indexes have been calculated such as the Photochemical Reflectance Index (P.R.I.) which originally was used for the estimation of rapid changes in the epoxidation state of xanthophyll pigments but has been increasingly used to detect photosynthetical activity at different scales from plant biochemistry to the canopy level (Sun, et al., 2014). PRI is computed as: PRI= ((R_X - R_{Ref}) / (R_X + R_{Ref}))) which equals to (R_{560} – R_{510}) / (R_{560} + R_{510}). Another index, the Normalized Difference Vegetation Index (NDVI)is a typical vegetation index and is most often corellates with canopy features such as canopy coverage, biomass or Leaf Area Index (LAI) (Gamon & Field, 1992). Radiance from different wavelength bands can be used for the estimation of NDVI and various sensors have been developed comparing the reflectance off a surface of a wavelength that absorbs chrorophyl (measurement wavelength) with one that doesn't absorb chlorophyl (reference waveband).

Digital Image Analysis (DIA) is an alternative method for measuring reflectance from vegetative surfaces and it has been used in order to quantify canopy coverage or canopy color. Through digital photography millions of bits of information on a large canopy can be obtained since any pixel contains independent color information, therefore with subsequent image analysis quantification of turfgrass color on fields can be achieved. Image analysis includes the quantification of RGB colors (not only green colors) or the conversion of RGB values to HSB values that indicate human perception of color (Karcher & Richardson, 2003).

Figure 29 Crop Scan measurement

Radiation reflectance – PRI –NDVI

To determine irradiance from turfgrass covers, a multispectral radiometer (MSR87, CropScan Inc., Rochester, USA) was used which measures in 8, 10nm broad, bands centered at the following wavelengths: 460, 510, 560, 610, 660, 710, 760 and 810 nm. Due to the instrument's constrictions only data from two wavelength bands (510nm and 560nm) were used in order to estimate a similar to PRI index: PRIcropscan = (R560 – R510) / (R560 + R510). The measurements (Figure 29) were taken between two mowing events (three days after each mowing event, unless prevented by inclement weather, in which case measurements were made the following day), during solar noon. Additionally NDVI for the wavelength bands (660nm and 810nm) was estimated. Reflectance measurements over the turfgrass canopy were collected with the sensor placed at 1 m above ground level which according to the manufacturer corresponds to a circular measuring area of Ø 0.5m.

Digital Image Analysis (D.I.A.)

A preliminary pilot assessment of turf quality by the Digital Image Analysis process (Richardson et al, 2001; Karcher and Richardson, 2003) for the determination the Dark Green Color Index (DGCI) and the Percent green coverage (PCov) was attempted. Photographs were taken from the center of each plot. The image covered an area of about 1.57m^2. In order to achieve standardized and uniform lighting conditions, a box (Figure 30), equipped on the inside with four, 12.5 watt lamps, was constructed. The base diameter of the box was 0.90 m, the upper diameter was 0.52m while the height was 140m.The photos were taken periodically every 10 days, prior to the sampling and mowing events, from the same sampling spot. A G6 PowerShot, CANON camera was set to a shutter speed of 1/10, an aperture of f/2.0, and automatic focal lens. The initial resolution of the images was 2048 x 1536 pixels but the images were cropped to the size of 1200x1200 pixels with the GIMP 2.8 program. Percent green coverage (PCov) and Dark green color index (DGCI) was intended to be computed using SigmaScan Pro 5 software package (Systat Software Inc., San Jose, CA).

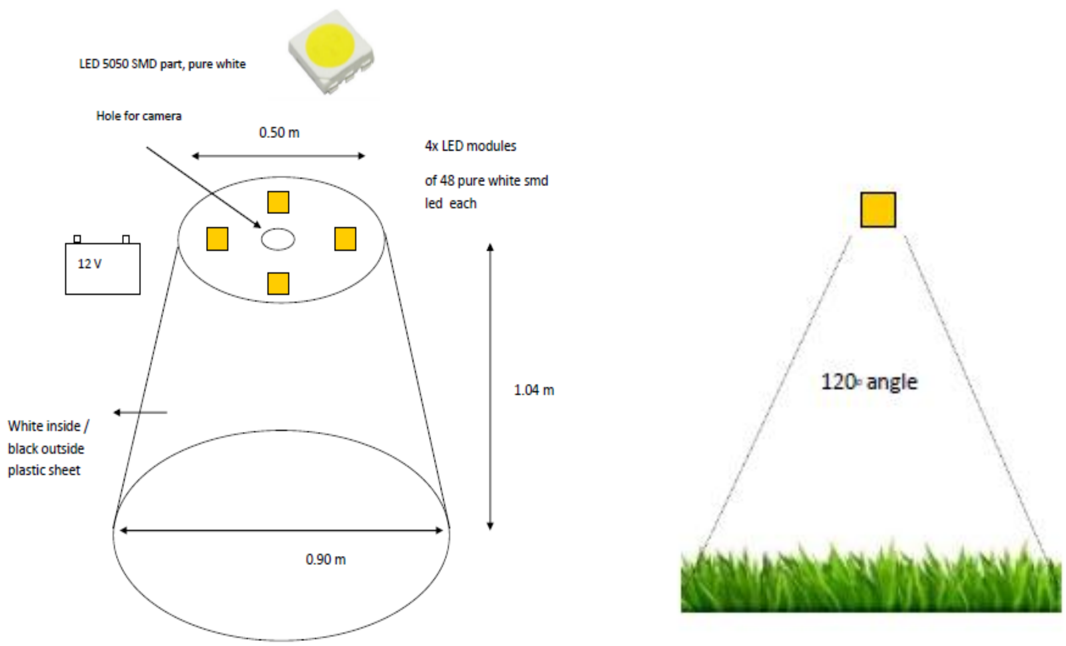

Figure 30 Schematic depiction of the photographic box

Measurement of growth

For shrubs such as *Abelia chinensis*, *Thuja occidentalis*, *Viburnum tinus*, *Pittosporum tobira* and *Hibiscus syriacus* a growth index was estimated based on biweekly measurements of height, width1 (widest width of the plant) and width 2 (the width perpendicular to the widest width) according to the function: G.I.= H x W1x W2 (Shober, 2010; Broschat & Moore; 2010, Scheiber et al., 2008; Wilson et al., 2006). Those plants were initially pruned to a standard formation (shape) with the help of a frame with different dimensions for each species, to provide a baseline size for each plant (Figure 31). Then subsequent measurements were substracted from the initial pruned size (Smiley, Holmes, & Fraedrich, 2009).

For plants such as *Ligustrum japonicum* and *Photinia serrulata* measurements of height (after they have been cut to a uniform size for each species - kind of plant) from the ground level to the apex of the tallest shoot and stem diameter was used for plant growth estimation. (Bell, 2009;Owings & Newman, 1991)

Figure 31 *Abelia chinensis* pruning

Dry weight of roots (at the end of the experiment)

At the end of the experimental period every plant was carefully extracted from soil, root was cut off and rinsed with tap water in order to remove all visible soil particles. Shoots were photographed and weighed. Dry weight was obtained after the roots being dried in an oven (MEMMERT D06061, Modell 500, MEMMERT GmbH+COKG) at 50^{o}C for 120h.

Evaluation of shrub quality

Optical evaluation by experts

Evaluation of plant aesthetic characteristics is usually conducted by in situ rating of the plants by an expert or a group of experts, based on pre specified criteria (Al-Mana & Ahmad , 2013; Broschat & Moore, 2010; Shober, 2010). This approach was modified during the present experiment to a remote evaluation procedure. The external appearance (aesthetic characteristics) of the shrubs was rated on biweekly or monthly basis by a panel of three experienced researchers of different academic institutes of the country. Digital photographs of all plants were uploaded to a Google application and every researcher was invited to the on line evaluation procedure.

Plants such as *Abelia chinensis Viburnum tinus*, *Pittosporum tobira* and *Hibiscus syriacus* were photographed with the help of a box in order to obtain uniform lighting conditions. A white canvas was placed in the base of every plant so that irrigation pipes could be hidden and soil could be covered. Plants such as *Ligustrum japonicum*, *Photinia serrulata* and *Thuja occidentalis* were photographed on vertical axis with the help of a white canvas placed behind and at the basis of the plants.

Photographs were formatted with Adobe Photoshop 7.0 (Adobe Systems) in order to achieve uniform size of the objects so they could be comparable, while rulers were added so experts could estimate the real size of the plants. Evaluation criteria include chlorosis signs (marks), overall health of the plant, leaf color, growth. An example of the evaluation form environment and rating procedure (edited Google Form) is shown in Figure 32.

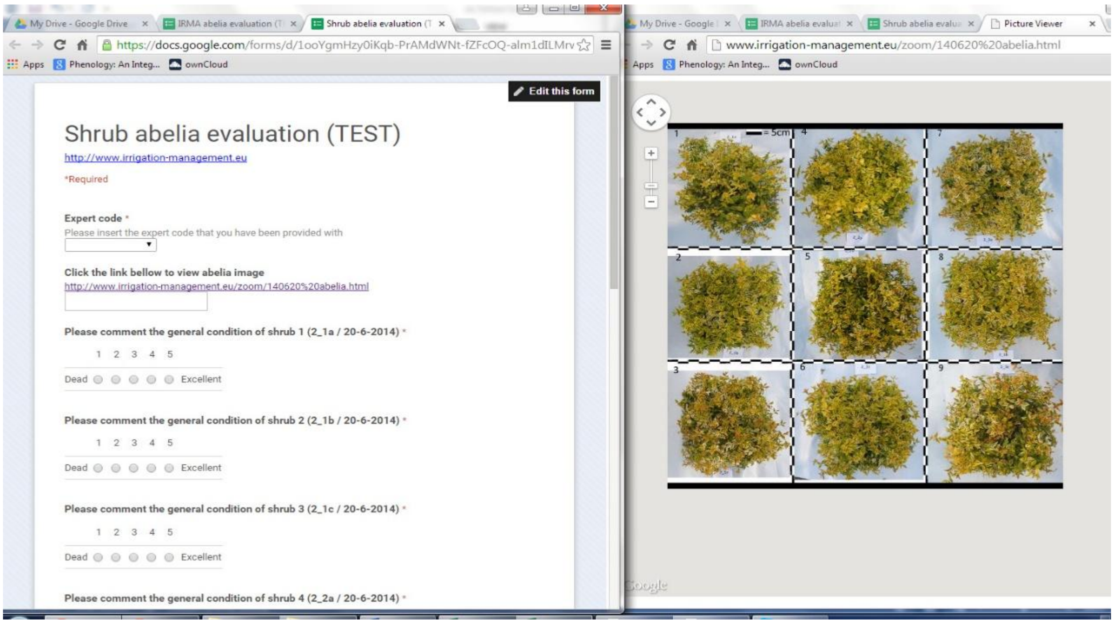

Figure 32 Google Form for shrubs' optical evaluation by experts. Left: questionnaire template, right: photos of evaluated shrubs

Results

Meteorological conditions

Calculated monthly ETo, precipitation rates during the experimental period (2014) and relevant climatic parameters (HNMS,2014) are presented in Table 8. Although the general global climate for the period June-August 2014 was characterized by high temperatures, the conditions for a number of European areas deviated from the general trend (NOAA, 2014). The summer of 2014 had a lower ET demand and less rain during July and August when compared to the typical climatic conditions of the area (Table 8, Figure 33 and Figure 34).

Table 8 Climatic and meteorological information

	mm month^{-1}			
	Climatic (20 y)		During the experimental period (2014)	
Month	ETo[a]	R[b]	ETo[a]	R[b]
April	103.56	81.50	2.06 (±0.17)	129.83
May	145.34	58.50	3.80 (±0.17)	74.43
June	168.67	21.80	5.38 (±0.16)	18.83
July	183.29	12.60	5.22 (±0.10)	7.20
August	163.42	17.20	4.75 (±0.07)	1.80
September	119.23	43.50	3.28 (±0.11)	123.80
October	77.98	115.00	3.46 (±0.10)	157.60

[a] ETo is the daily average reference evapotranspiration as calculated according to FAO paper 56 method and [b] R is the cumulative precipitation height. The standard error of the values -when available or has sense- is provided in the parentheses.

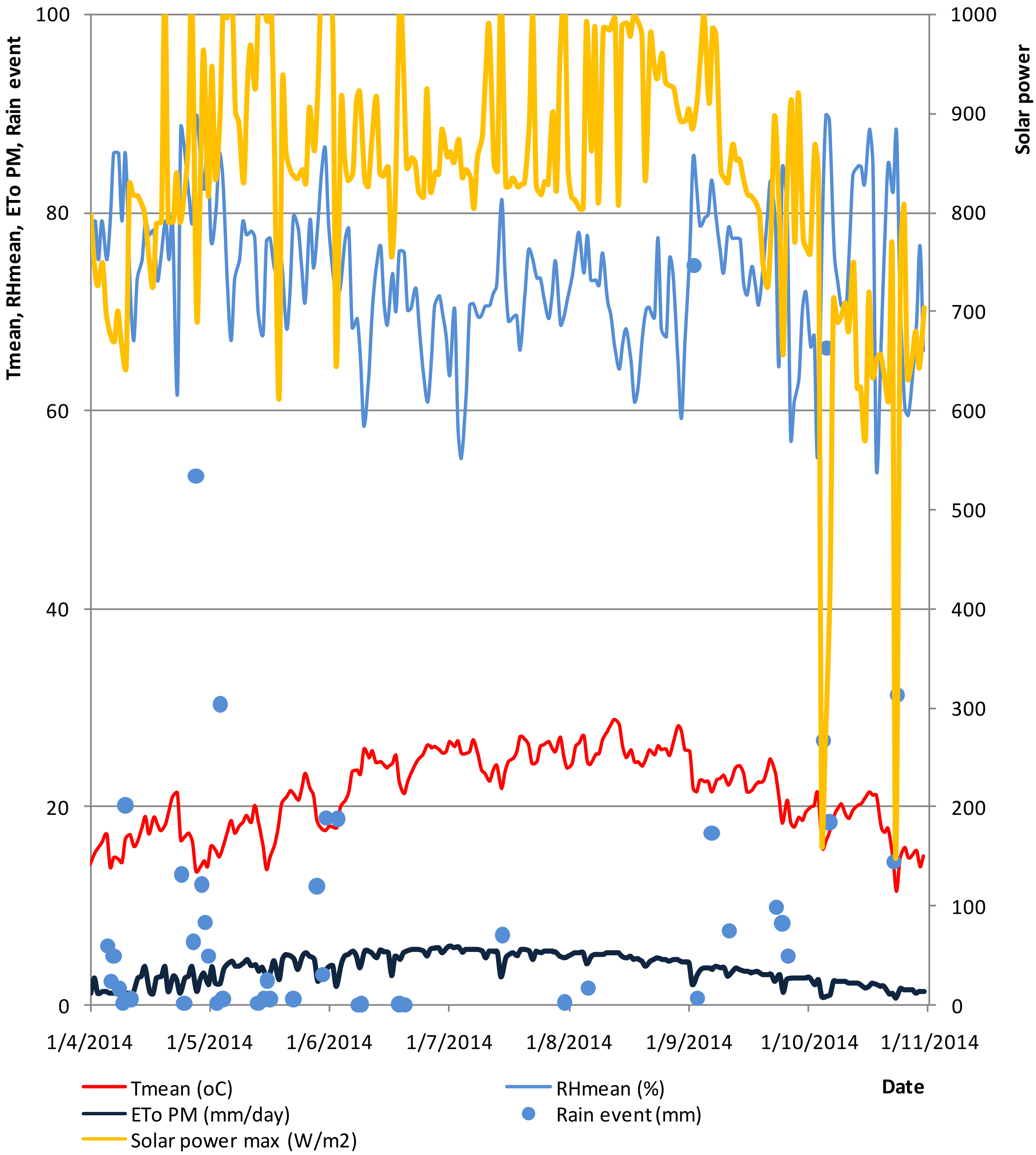

Figure 33 Solar radiation, T, RH, ETo and Rain events during the experimental period

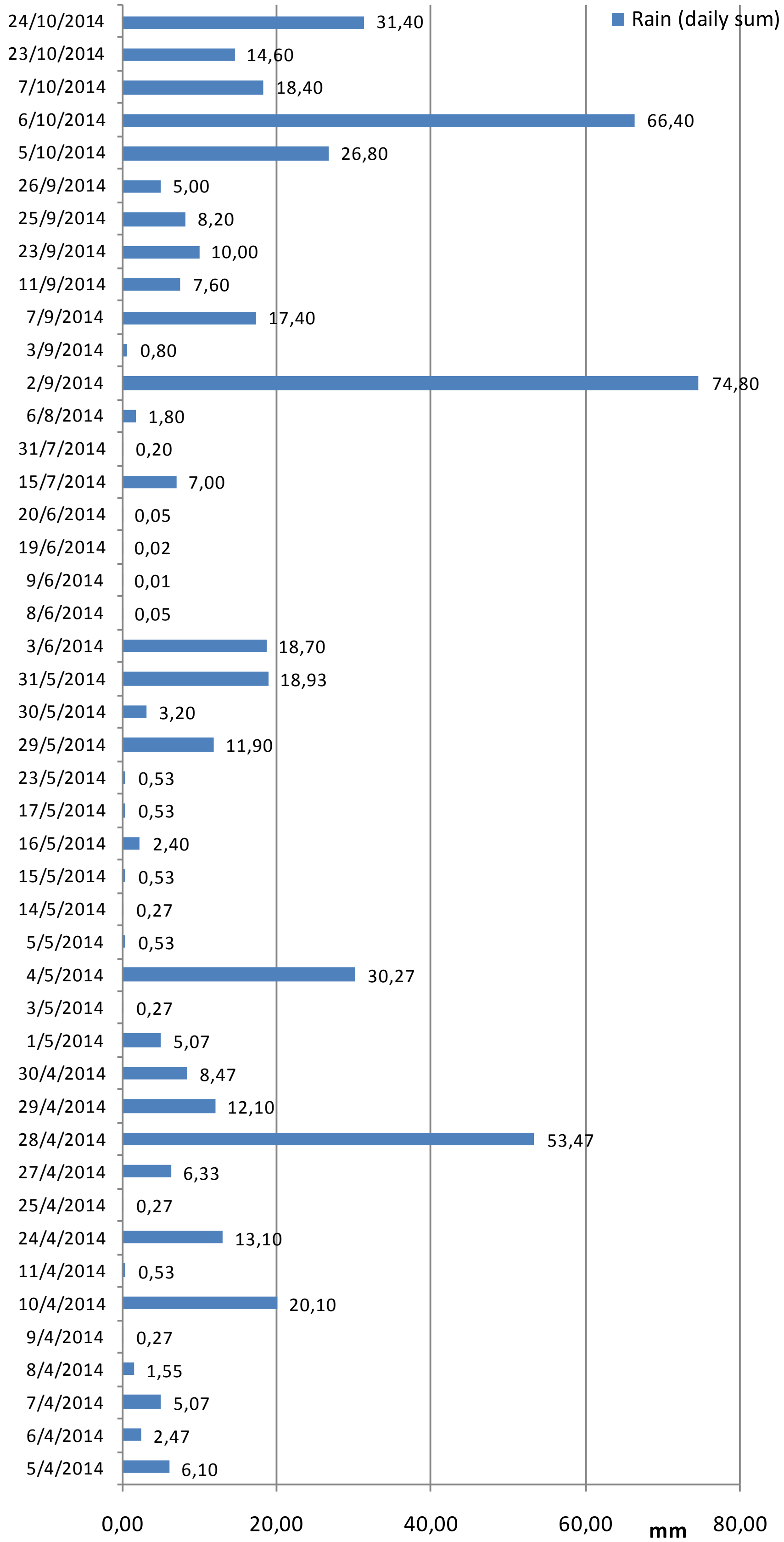

Figure 34 Rain events that occurred during the experimental period

Soil moisture

During the evaluation period soil moisture expressed as volumetric water content (VWC%) ranged between 8% and 18% for turfgrass treatments and between 10% and 24% for experimental plots that contained shrubs, as shown in Figure 35 and Figure 36.

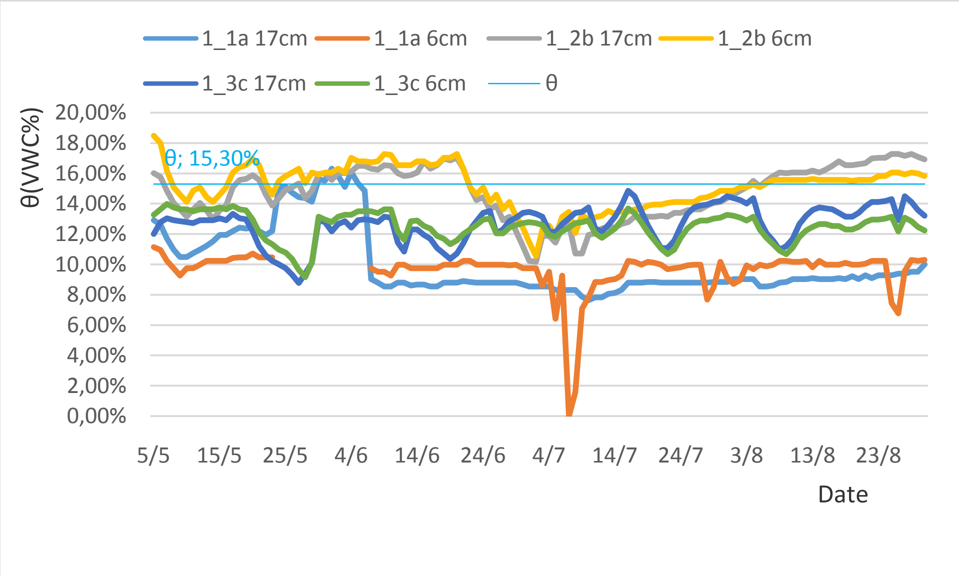

Figure 35 Soil moisture for treatments 1_1, 1_2, 1_3

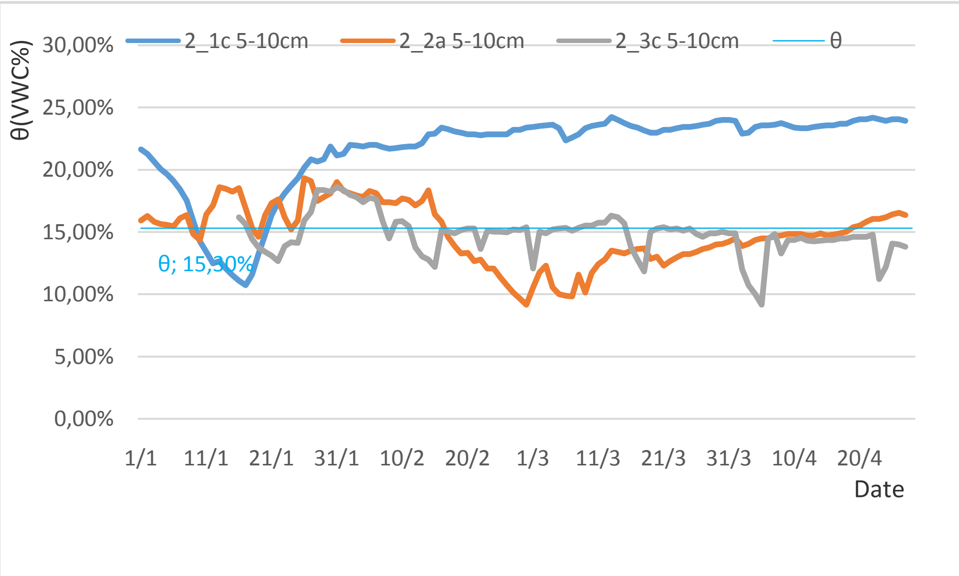

Figure 36 Soil moisture for treatments 2_1, 2_2, 2_3

Irrigation water consumption

Table 9 summarizes water consumption by every treatment during trial period. It has to be mentioned that differences in water consumption should be also attributed to several field trials during the experimental set up and occasional irrigation equipment failures.

Table 9 Water consumption

Treatment	1_1	1_2	1_3	2_1	2_2	2_3
Volume (total, lt)	21050,6	10820,8	24609,8	14027,7	10147,8	8318,9

Soil monitoring

Soil pH and EC values are summarized in the Table 10 and Table 11 and Figure 37, Figure 38 below. Analysis of Variance (ANOVA) revealed statistically significant difference between EC values of soil irrigated with recycled water compared to EC values of soils irrigated with tap(LSD, a=0.024) and grey water treatment(LSD, a=0.003) at the end of the experiment. Such an observation could imply evidence of salt accumulation in the particular treatment's soil. Statistically significant difference was observed also between pH values of soils irrigated with recycled water compared to pH of the other treatments soils on 25/7 (LSD, a=0.05) and on 28/9 (LSD, a=0.01).

Table 10 Soil EC values (mean, ANOVA) in different treatments

	2/7	25/7	28/8	28/9
tap water	0.06	0.15	0.19	0.22
grey water	0.08	0.17	0.11	0.18
recycled water	0.07	0.23	0.24	0.30

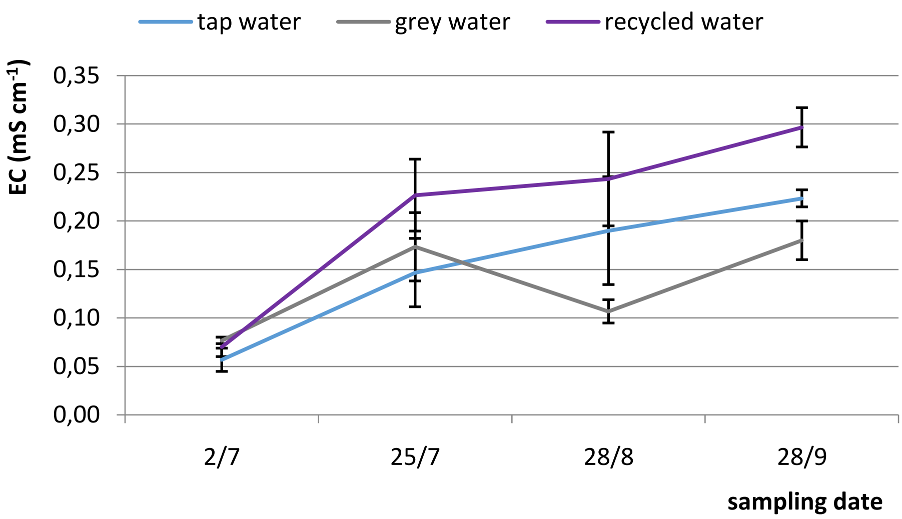

Figure 37 Soil EC values

Table 11 Soil pH values in different treatments

	2/7	25/7	28/8	28/9
tap water	8.23	7.90	8.00	7.70

	2/7	25/7	28/8	28/9
grey water	8.07	7.90	8.07	7.70
recycled water	8.20	7.97	7.93	7.97

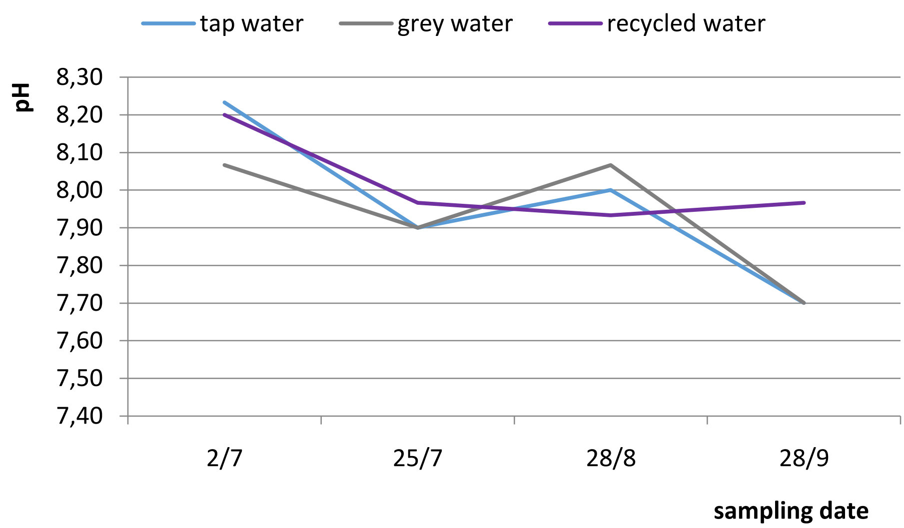

Figure 38 Soil pH values

Water monitoring

National legislation (JMD 145116/8.3.11)defines the terms and sets the standards of water reuse to which application of irrigation with reclaimed water must be conformed. Table 12 summarizes legal requirements and describes results of water monitoring during the experiment. It has to be mentioned that two incidents of microbial enhancement over the acceptable limits have been observed in the beginning of trial period but subsequent corrective actions such as increase of reload frequency effectively suppressed microbial enhancement below acceptable limits. These incidents have been excluded from results presentation.

Table 12 Limits and results of analytical parameters monitored

	BOD_5 mg/lt <10 (80%of samples)	SS (mg/lt) <2 (80% of samples)	N-NO3 (mg/lt) 15	P (mg/lt) 2	turbidity (FTU) 2	TC (cfu/100ml) <20 (80% of samples)
recycled water	9.25	8.275	2.14	0.5725	0	<20
grey water	10	13.5	1.51	1.475	0	0

Evaluation of turfgrass growth

Dry weight of aerial part of turfgrass

During the evaluation period, analysis of variance (ANOVA) revealed statistically significant difference, on several sampling days, between the grey water treatment biomass compared to the tap water treatment biomass, but eventually this difference was converged at the end of the experiment (LSD, a=0.064). Differences are shown analytically in the Table 13 and Figure 39 below. On the other hand, treatment with recycled water showed not statistically significantly difference in turfgrass growth when compared to turfgrass growth of tap water treatments almost during the entire evaluation period till the last sampling (LSD, a=0.850).

Table 13 Cumulative growth of the aerial part of turfgrass (different letters (ie: a, b, c)indicate significant statistical difference, while same letters indicate no statistical significant difference)

	9/5	19/5	29/5	10/6	23/6	4/7	14/7	24/7
tap water	10.00a	40.41a	65.77a	120.67ac	219.44a	252.22a	288.67ac	319.41ac
grey water	4.26b	24.37ab	39.07a	75.22b	162.30a	185.78a	212.97b	241.74b
rec. water	4.15b	23.19b	48.44a	92.59ab	182.19a	205.85a	236.96ab	269.59ab

	4/8	14/8	24/8	4/9	12/9	22/9	2/10
tap water	345.08ac	381.85ac	422.11ac	450.52ac	483.78ac	512.78ac	537.00a
grey water	267.56b	311.89b	345.04b	383.59b	423.78b	460.15b	485.08a
rec. water	298.59ab	335.96ab	375.55ab	424.07ab	461.48ab	505.93ab	532.78a

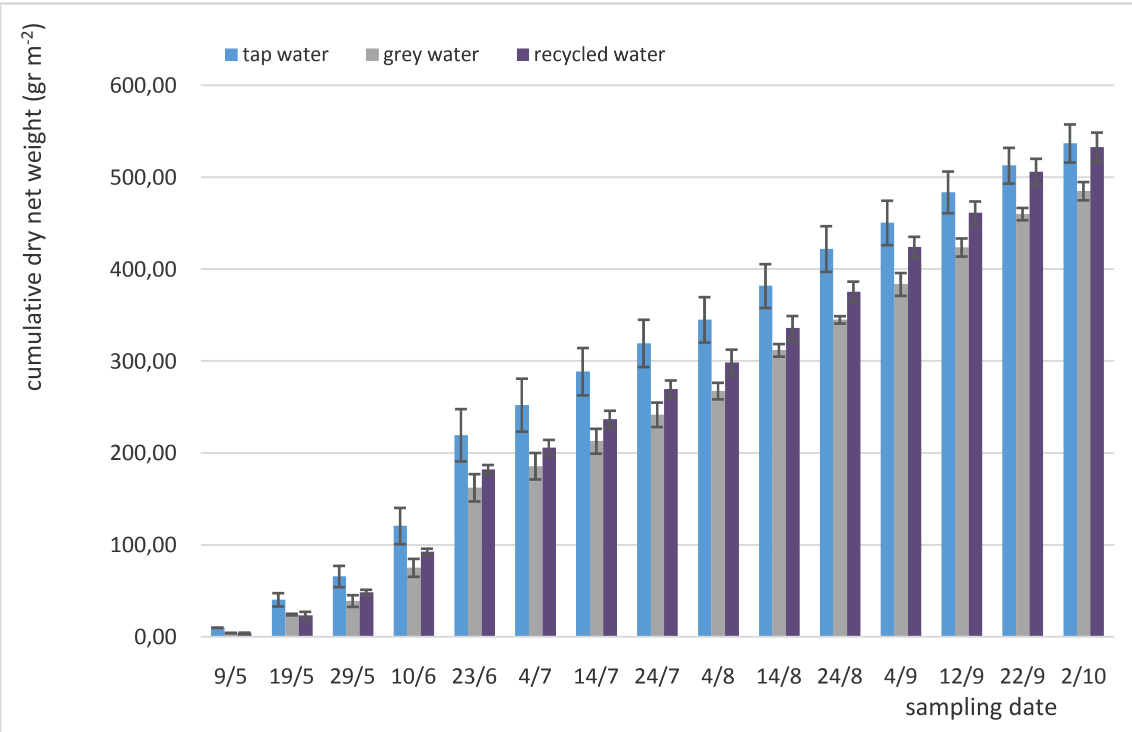

Figure 39 Evolution of aerial part growth of turfgrass

Dry weight of turfgrass roots

During the evaluation period root development did not generally show statistically significant difference between treatments apart from root biomass on 28/8 when root net dry weight of turfgrass irrigated with recycled water was statistically significant less than the root net dry weight of tap water treatment (LSD, a=0.038) (Table 14, Figure 40).

Table 14 Cumulative growth of turfgrass roots (means and differences (Anova, LSD($a_{0.05}$))(different letters (ie: a, b, c) indicate significant statistical difference, while same letters indicate no statistical significant difference)

	24/6	29/7	28/8	3/10
tap water	7.817a	13.187a	18.703a	21.037a
grey water	8.040a	13.037a	18.110ab	22.850a
recycled water	5.520a	8.333a	14.260b	18.967a

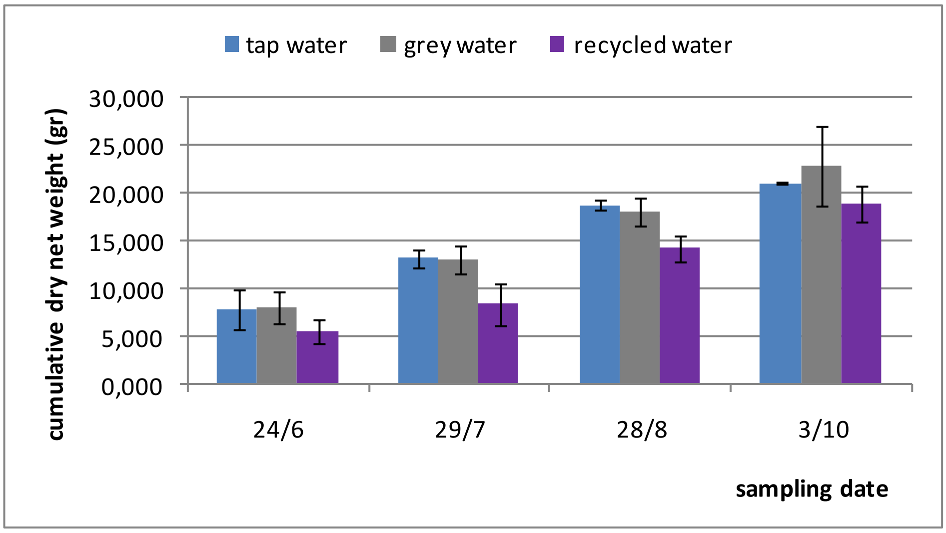

Figure 40 Evolution of root growth of turfgrass

Qualitative Evaluation of Turfgrass

Statistical analysis (ANOVA) revealed no statistically significant difference (LSD, a<0.05) in the PRI values between treatments during the experimental period apart from two cases on 10/7 when PRI computed for treatment with recycled water was statistically significant different with the other two treatments (LSD, a=0.018), and on 30/7 when turfgrass PRI for recycled treatment was statistically significant different from the correspondent PRI value of the tap water treatment (LSD, a=0.037). Table 15 summarizes the PRI values means and Figure 41 depicts different treatments' PRI evolution .

Table 15 PRI values (different letters (ie: a, b, c) indicate significant statistical difference, while same letters indicate no statistical significant difference)

26/5	5/6	13/6	28/6	10/7	18/7

	26/5	5/6	13/6	28/6	10/7	18/7	
tap water	0.224a	0.194a	0.213a	0.203a	0.200a	0.198a	
grey water	0.227a	0.206a	0.214a	0.209a	0.200a	0.199a	
recycled water	0.230a	0.199a	0.216a	0.207a	0.190b	0.199a	
	30/7	8/8	19/8	29/8	8/9	17/9	30/9
tap water	0.208a	0.225a	0.213a	0.218a	0.229a	0.222a	0.207a
grey water	0.200ab	0.218a	0.211a	0.233a	0.238a	0.236a	0.222a
recycled water	0.193b	0.217a	0.208a	0.238a	0.235a	0.231a	0.239a

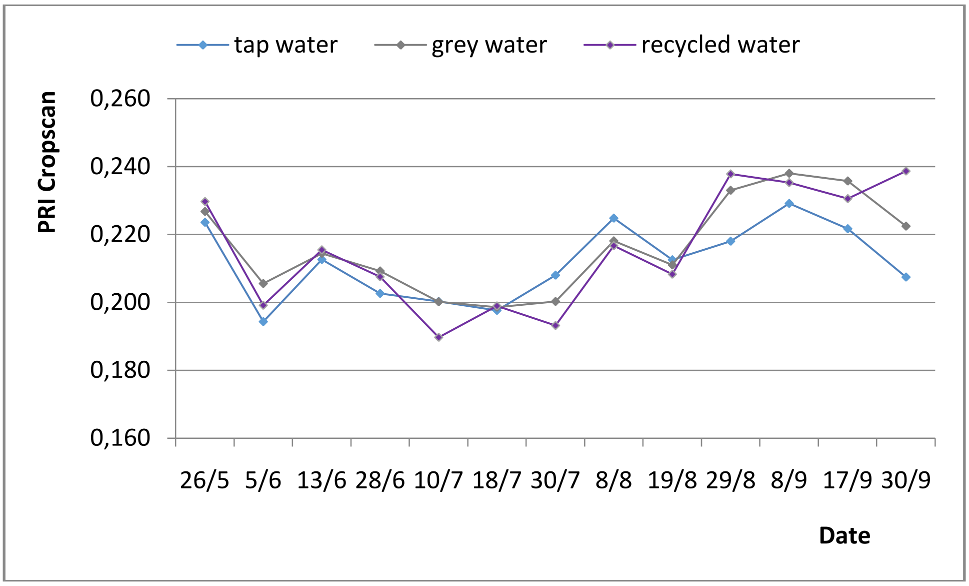

Figure 41 PRI evolution for the three treatments

Analysis of variance (ANOVA) revealed no statistically significant difference in NDVI between treatments during the experimental period (Table 16) apart from several cases such as on day 26/5 when the computed NDVI for turfgrass with grey water treatment was statistically different from the other treatments correspondent index. Additionally on days 13/6 and 30/9 there was observed statistically significant difference (LSD, $a_{0.05}$) between NDVI values computed for turfgrass treated with recycled water and turfgrass irrigated with either tap or grey water. Figure 42 shows NDVI evolution for the three treatments during the experimental period.

Table 16 NDVI values (different letters (ie: a, b, c) indicate significant statistical difference, while same letters indicate no statistical significant difference)

	26/5	5/6	13/6	28/6	10/7	18/7
tap water	0.906a	0.903a	0.878a	0.865a	0.877a	0.870a
grey water	0.879b	0.888a	0.875ab	0.874a	0.878a	0.871a

	26/5	5/6	13/6	28/6	10/7	18/7
recycled water	0.895ab	0.901a	0.889b	0.876a	0.880a	0.882a

	30/7	8/8	19/8	29/8	8/9	17/9	30/9
tap water	0.888a	0.892a	0.880a	0.867a	0.868a	0.875a	0.916a
grey water	0.882a	0.888a	0.890a	0.864a	0.889a	0.892a	0.921a
recycled water	0.882a	0.887a	0.880a	0.866a	0.895a	0.884a	0.897b

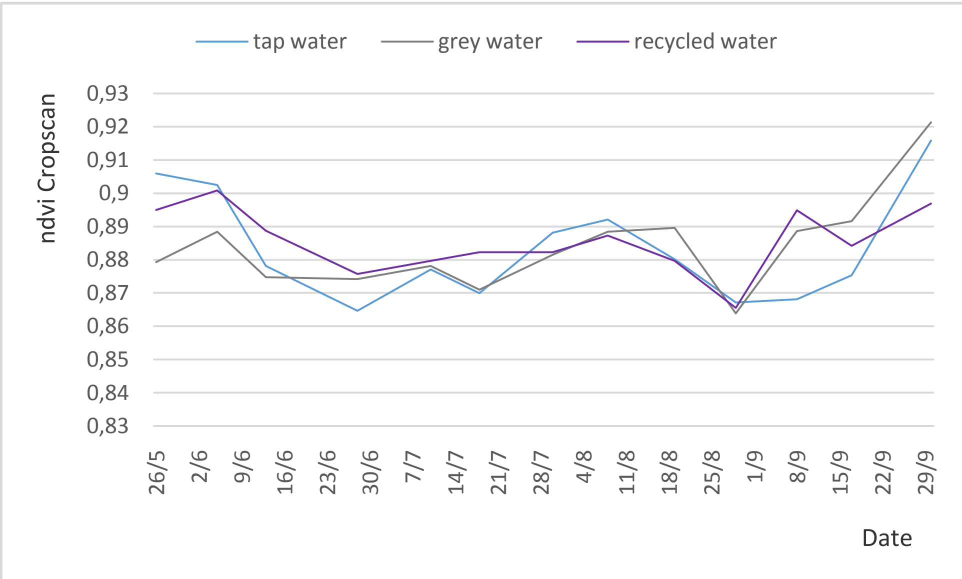

Figure 42 NDVI evolution for the three treatments

Evaluation of shrubs growth

Abelia chinensis Growth Index:

Analysis of variance (ANOVA) showed no statistically significant difference between treatments during the entire experimental period as shown as the Table 17 and Figure 43 below.

Table 17 *Abelia chinensis* growth index (G.I.) values (different letters (ie: a, b, c) indicate significant statistical difference, while same letters indicate no statistical significant difference)

	20/6	10/7	25/7	11/8	25/8	11/9	4/10
tap water	0.088457a	0.144137a	0.188987a	0.31422a	0.385673a	0.504553a	0.653687a
grey water	0.110137a	0.14008a	0.163367a	0.20147a	0.26205a	0.398003a	0.602813a
recycled water	0.099313a	0.14151a	0.18073a	0.229657a	0.329183a	0.509243a	0.80466a

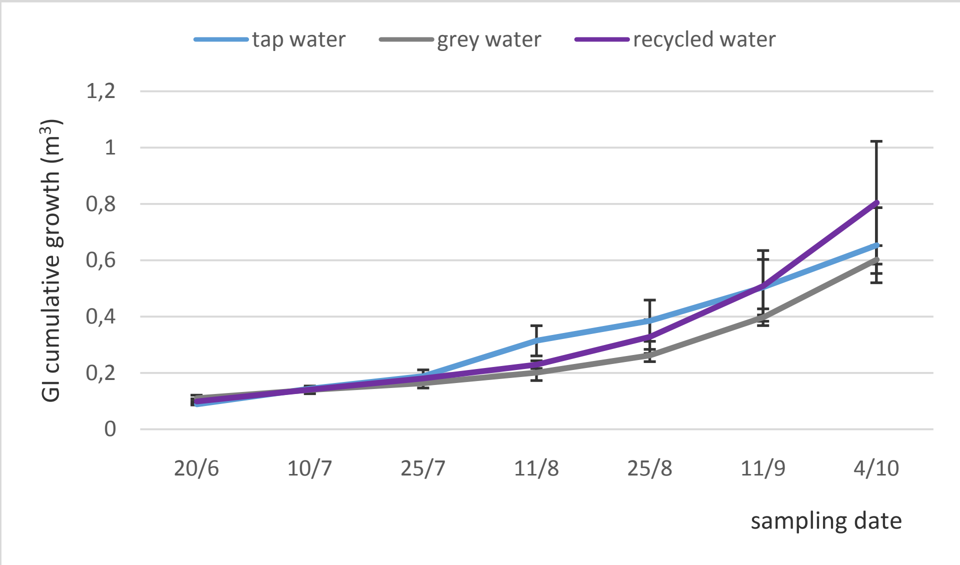

Figure 43 *Abelia chinensis* GI development

Ligustrum japonicum Height:

Analysis of Variance (ANOVA) revealed no statistically significant differences in the height of ligustrum shrubs between the different treatments during the entire experimental period (Table 18, Figure 44).

Table 18 *Ligustrum japonicum* height means (ANOVA) (different letters (ie: a, b, c) indicate significant statistical difference, while same letters indicate no statistical significant difference)

	5/6	20/6	10/7	25/7	11/8	25/8	11/9	4/10
tap water	0.760a	0.840a	1.013a	1.120a	1.277a	1.397a	1.467a	1.620a
grey water	0.760a	0.857a	1.000a	1.053a	1.177a	1.320a	1.467a	1.607a
recycled water	0.760a	0.777a	0.973a	1.090a	1.190a	1.253a	1.343a	1.400a

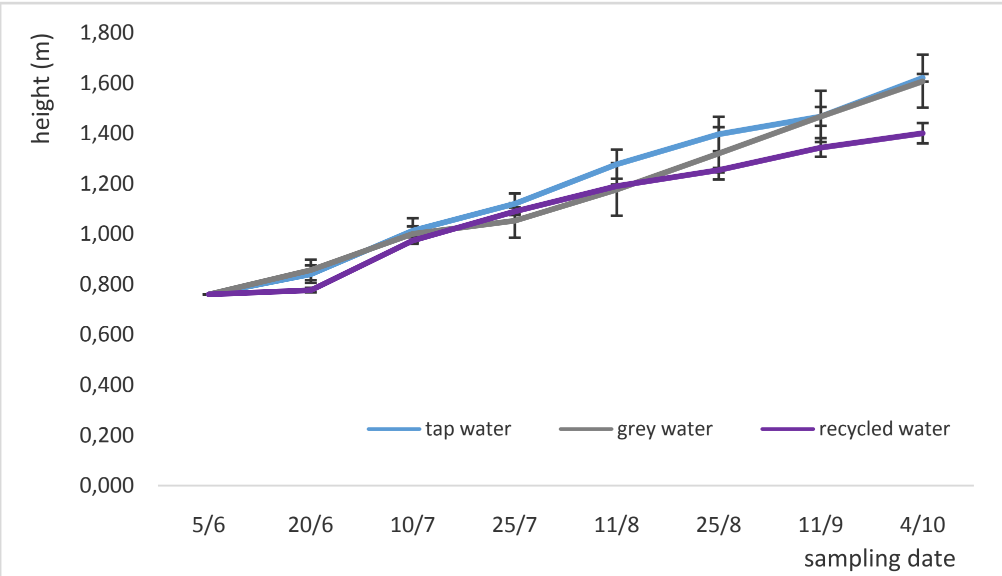

Figure 44 *Ligustrum japonicum* height development

Ligustrum japonicum Stem Diameter:

According to analysis of variance (ANOVA) there has been observed statistically significant difference in the stem diameter of *Ligustrum* shrubs between tap water treatment and recycled water treatment only during the last two months of the experimental period, whereas no significant difference was observed in the stem diameter of the same plants during the entire experimental period between tap water and grey water treatments. The above are summarized in Table 19 and depicted in Figure 45 below.

Table 19 ***Ligustrum japonicum* stem diameter means (ANOVA) (different letters (ie: a, b, c) indicate significant statistical difference, while same letters indicate no statistical significant difference)**

	20/6	10/7	25/7	11/8	25/8	11/9	4/10
tap water	1.767a	2.133a	2.400a	2.667a	2.767a	3.433a	3.667a
grey water	1.800a	2.067a	2.133a	2.233a	2.417a	2.667ac	3.267ac
recycled water	1.700a	1.833a	2.133a	2.233a	2.433a	2.567bc	2.683bc

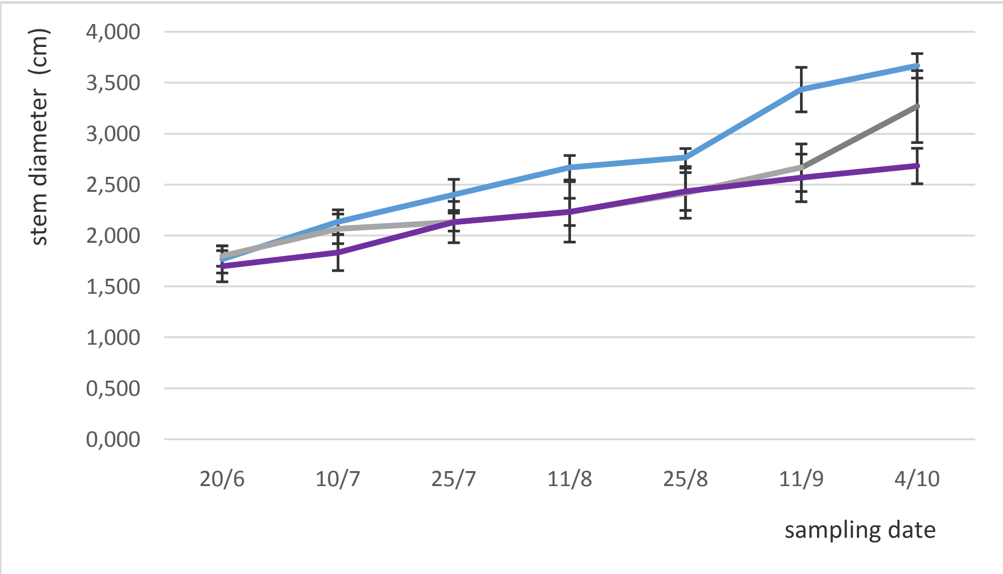

Figure 45 *Ligustrum japonicum* stem diameter evolution

Photinia serrulata Height:

Statistical analysis (ANOVA) showed no significant differences in the height of *Photinia serrulata* shrubs among the three treatments during the evaluation period. Table 20 below summarizes the results of comparisons between treatments (LSD, $a_{0.05}$). Plants treated with recycled water exhibited better performance when compared to treatments with tap or grey water (Figure 46).

Table 20 *Photinia serrulata* height means (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)

	5/6	20/6	10/7	25/7	11/8	25/8	11/9	4/10
tap water	0.570a	0.630a	0.720a	0.827a	1.003a	1.197a	1.433a	1.723a

	5/6	20/6	10/7	25/7	11/8	25/8	11/9	4/10
grey water	0.570a	0.680a	0.780a	0.887a	1.080a	1.230a	1.433a	1.557a
recycled water	0.570a	0.663a	0.773a	0.913a	1.147a	1.283a	1.567a	1.807a

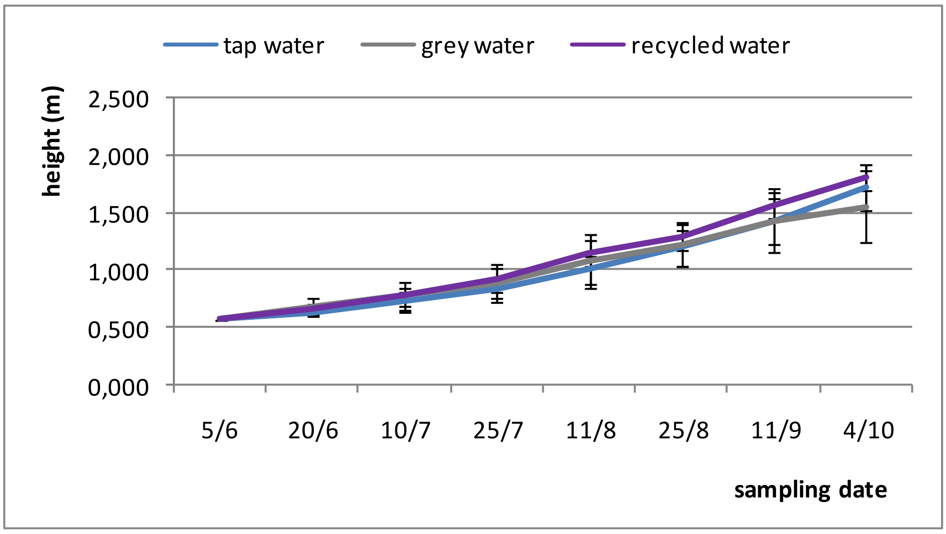

Figure 46 ***Photinia serrulata*** **height development**

Photinia serrulata Stem diameter:

Stem diameter of *Photinia serrulata* plants showed no statistical significant differences (LSD, $a_{0.05}$) among treatments. Plants treated with recycled water though developed the greatest stem diameter (Figure 47, Table 21).

Table 21 ***Photinia serrulata*** **stem diameter means (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)**

	20/6	10/7	25/7	11/8	25/8	11/9	4/10
tap water	2.333a	2.433a	2.467a	2.500a	2.600a	2.633a	2.800a
grey water	2.267a	2.333a	2.333a	2.367a	2.400a	2.500a	2.733a
recycled water	2.533a	2.600a	2.633a	2.700a	2.900a	2.967a	2.967a

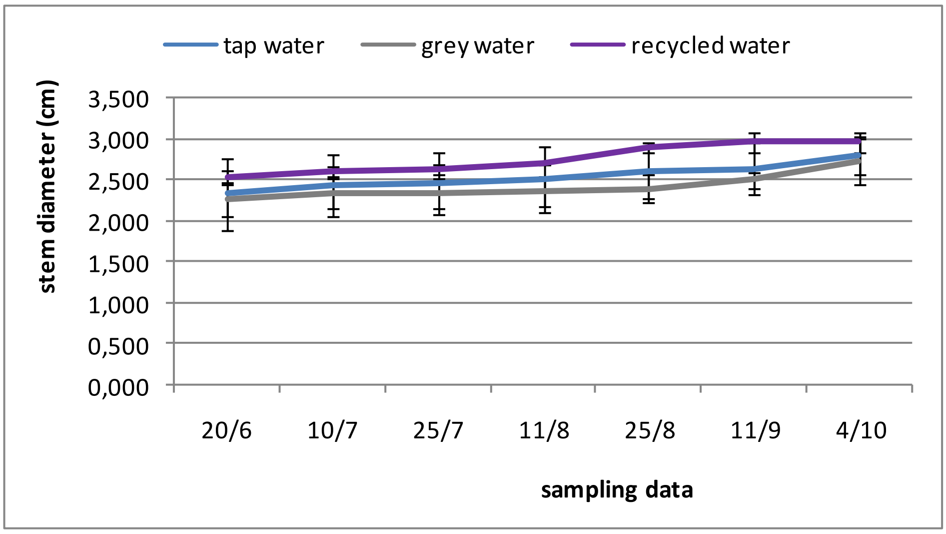

Figure 47 *Photinia serrulata* stem diameter evolution

Viburnum tinus Growth Index:

Growth Index computed for *Viburnum tinus* plants generally indicated no significant difference between treatments, according to statistical analysis (LSD, $a_{0.05}$)(Table 22, Figure 48).

Table 22 *Viburnum tinus* Growth Index means (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)

	5/6	20/6	10/7	25/7	11/8	26/8	11/9	4/10
tap water	0.040a	0.053a	0.077a	0.087a	0.117a	0.147a	0.203a	0.277a
grey water	0.040ac	0.057ab	0.063ab	0.070a	0.077a	0.097a	0.160a	0.217a
recycled water	0.040bc	0.083ac	0.107ac	0.123a	0.137a	0.147a	0.170a	0.197a

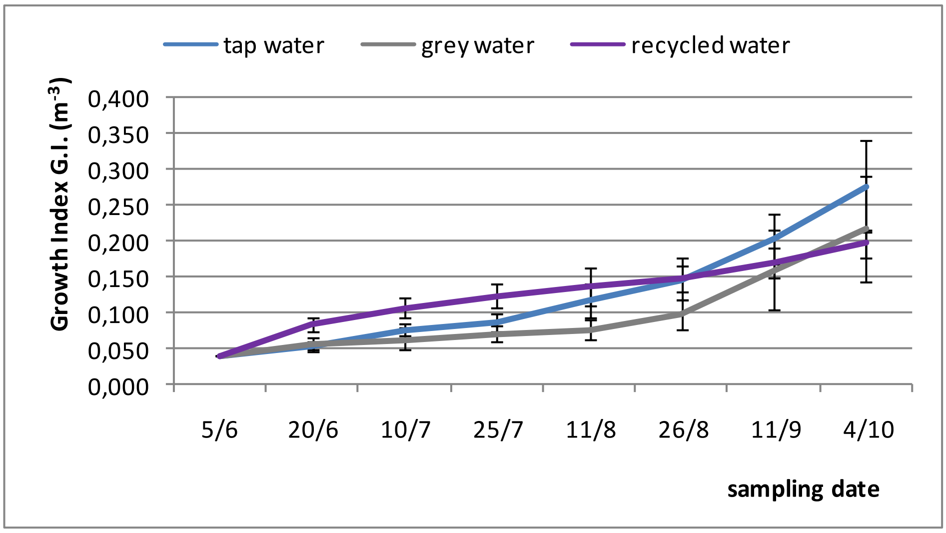

Figure 48 *Viburnum tinus* growth index

Pittosporum tobira Growth Index:

Table 23 and Figure 49 present *Pittosporum Tobira* Growth Index evolution during the experimental period.

Table 23 *Pittosporum tobira* Growth Index means (ANOVA)

	5/6	20/6	10/7	25/7	11/8	26/8	11/9	4/10
tap water	0.022	0.039	0.063	0.071	0.088	0.118	0.164	0.278
grey water	0.027	0.042	0.064	0.070	0.089	0.134	0.193	0.303
recycled water	0.023	0.030	0.045	0.050	0.065	0.069	0.078	0.090

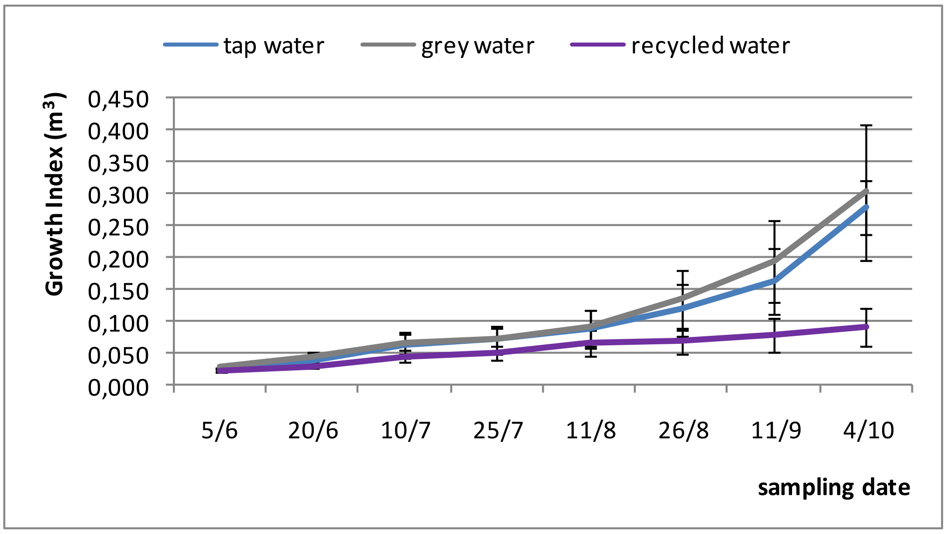

Figure 49 *Pittosporum* Growth Index evolution

Thuja occidentalis Growth Index:

Thuja occidentalis Growth Index showed no statistically significant difference (ANOVA, a=0.05) between treatments during the entire study period. Plants treated with grey water exhibited better performance in comparison with plants treated with tap or recycled water (Table 24 Figure 50).

Table 24 *Thuja occidentalis* Growth Index means (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)

	6/6	20/6	10/7	25/7	11/8	26/8	11/9	4/10
tap water	0.040a	0.063a	0.070a	0.073a	0.083a	0.103a	0.143a	0.183a
grey water	0.047a	0.063a	0.067a	0.070a	0.093a	0.113a	0.153a	0.180a
recycled water	0.050a	0.060a	0.070a	0.080a	0.087a	0.103a	0.117a	0.157a

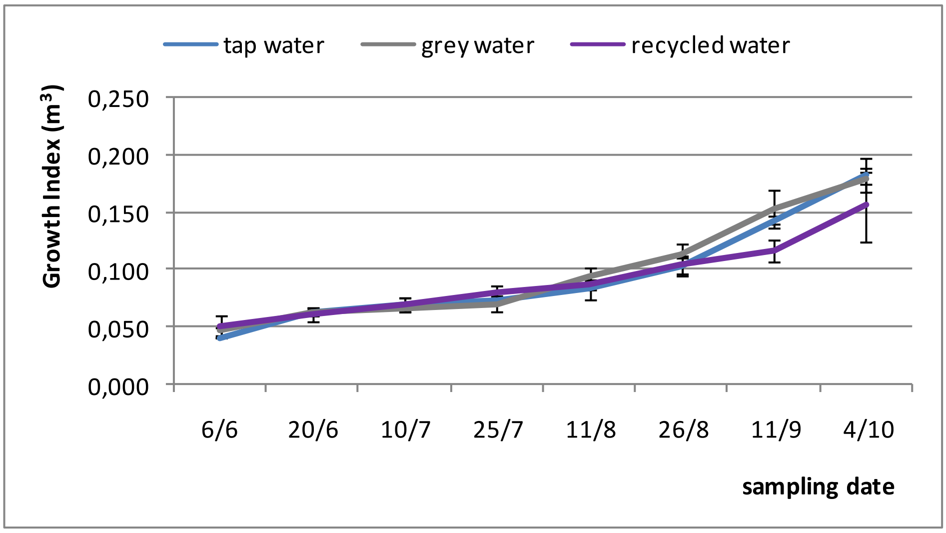

Figure 50 *Thuja occidentalis* Growth Index evolution

Qualitative evaluation of shrubs

Rates resulted from optical evaluation of each shrub species by experts' panel have been statistically processed (ANOVA) in order to define differences between treatments. Since difference between expert's rating was not of significant importance for statistical analysis a cumulative rate was computed by adding each expert's rate, which scaled between 1 to 5, on every evaluation event. So 1 represented the lowest quality while 15 represented the highest quality.

An additional approach to rating evaluation was to correlate the duration (in days) of a certain status of a plant with the correspondent rate that characterized that status. For this reason an index was invented by computing the area covered between two rating events in the evaluation graphic output as it is described in figure below. Technically the index is estimated according to the equation: Index= (rate $_{(day1)}$+rate$_{(day2)}$)*(days2-days1) / 2 (Figure 51).

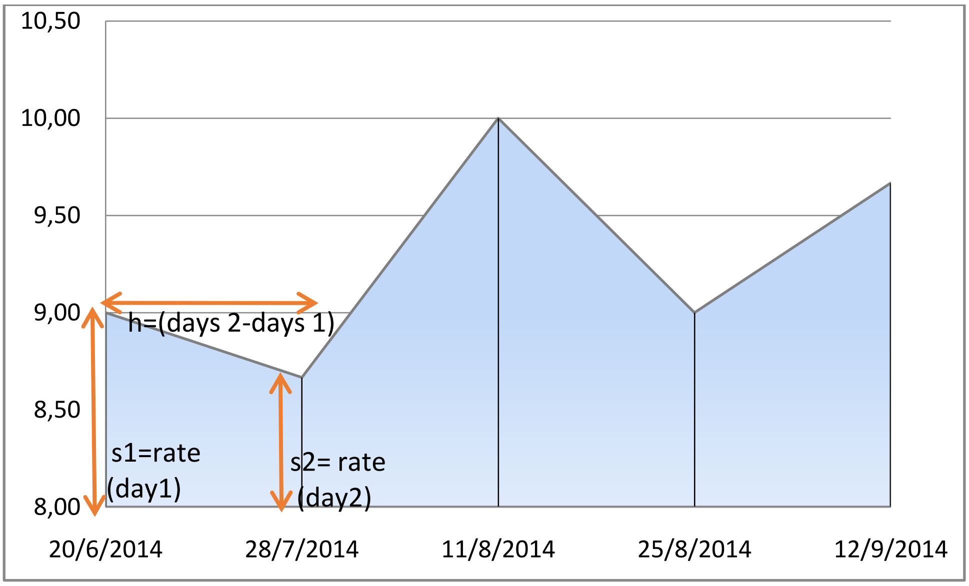

Figure 51 Calculation of Shrub Quality Index

Abelia chinensis

Abelia chinensis plants did not show any statistically significant difference between treatments as described in Table 25 and shown in Figure 52 below.

Table 25 *Abelia chinensis* mean rates (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)

	20/6/2014	28/7/2014	11/8/2014	25/8/2014	12/9/2014
tap water	9.00a	8.67a	10.00a	9.00a	9.67a
grey water	10.33a	8.33a	8.00a	9.33a	8.67a
recycled water	9.00a	8.00a	11.33a	9.00a	8.33a

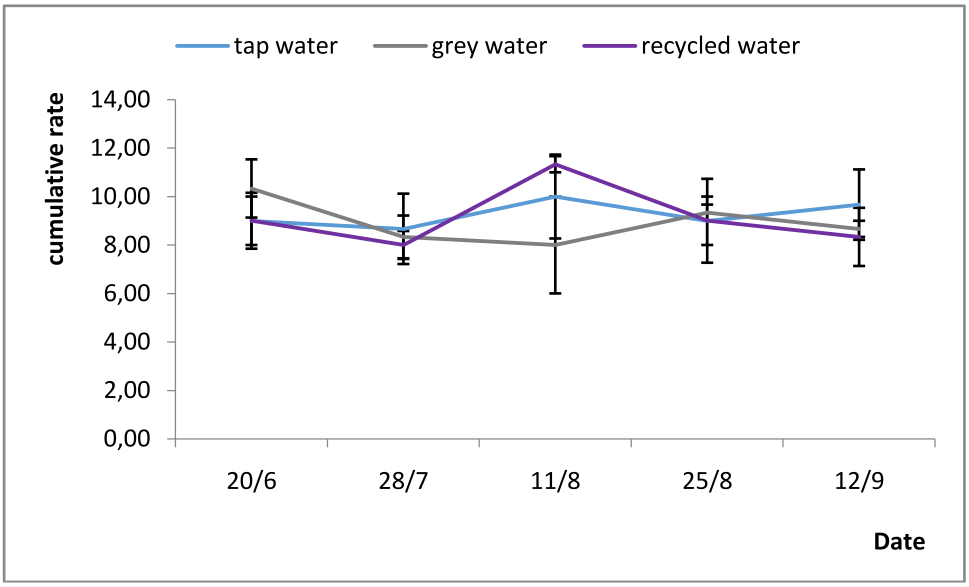

Figure 52 Cumulative rate of *Abelia cinensis* quality performance

Quality Performance Index (Table 26, Figure 53) shows that quality performance for all three treatments declined from an initial high status to be almost stabilized in a mediocre level until the end of the experiment.

Table 26 *Abelia chinensis* index

	28/7/2014	11/8/2014	25/8/2014	12/9/2014
tap water	335.67	130.67	133.00	168.00
grey water	354.67	114.33	121.33	162.00
recycled water	323.00	135.33	142.33	156.00

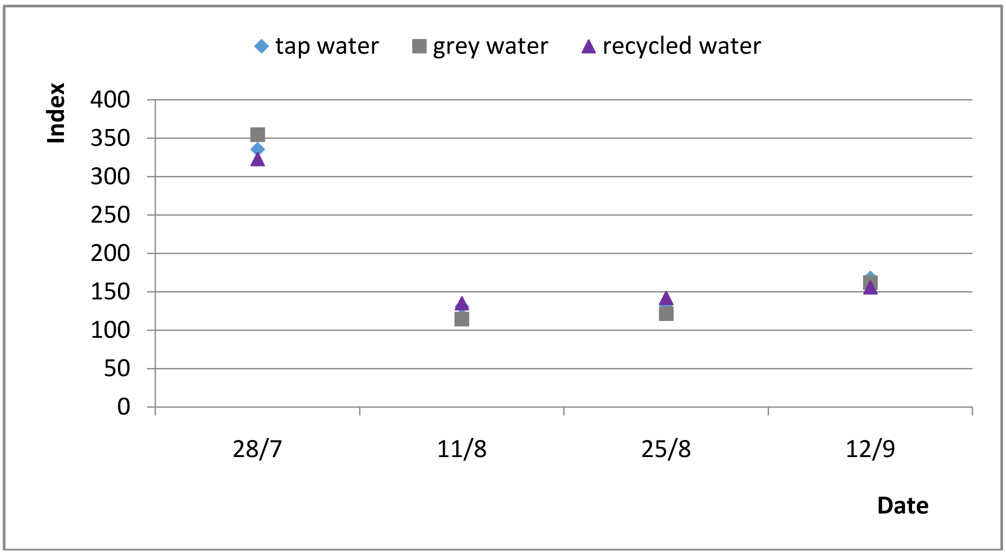

Figure 53 ***Abelia chinensis*** **Index**

Ligustrum japonicum

Ligustrum japonicum shrubs treated with recycled water showed statistically significant lower qualitywhen compared to other treatments plant at the end of the experiment (LSD, a=0,042). Table 27 summarizes mean values of plants' rates.

Table 27 ***Ligustrum japonicum*** **mean rates (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)**

	27/6/2014	17/7/2014	28/7/2014	24/8/2014	15/9/2014
tap water	9.33a	10.67a	12.33a	13.00a	13.00a
grey water	8.33a	8.00a	8.00a	9.33a	9.33a
recycled water	9.00a	8.33a	9.00a	9.00a	7.33b

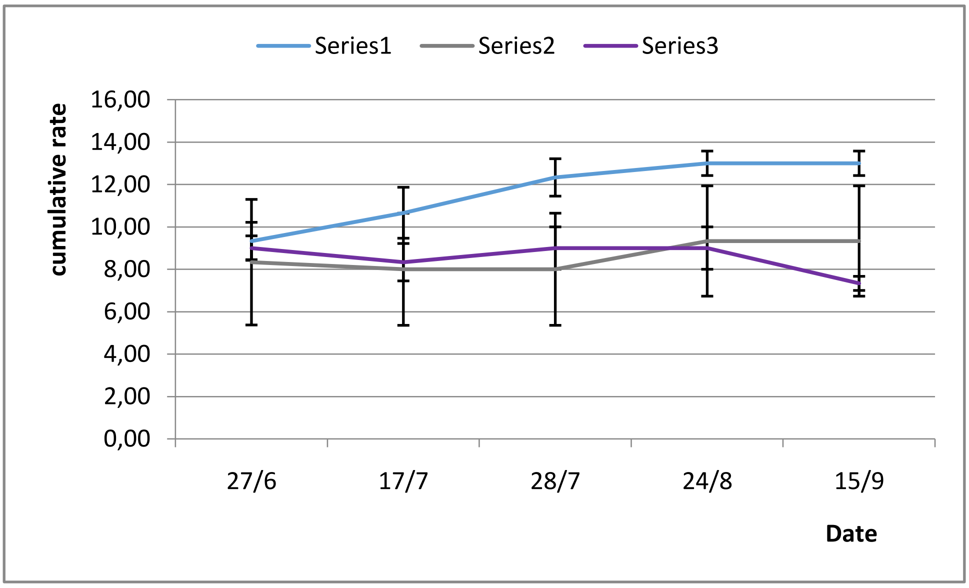

Figure 54 Cumulative rate of ***Ligustrum japonicum*** **quality performance**

Quality Performance Index varied between treatments during the experiment(Table 28, Figure 55 *Ligustrum japonicum* Index. Better quality performance exhibited plants irrigated with tap water (286.00) and lowest performance plants irrigated with recycled water (179.67). It has to be mentioned that performances were above medium level.

Table 28 *Ligustrum japonicum* index

	17/7/2014	28/7/2014	24/8/2014	15/9/2014
tap water	200.00	126.50	342.00	286.00
grey water	163.33	88.00	234.00	205.33
recycled water	173.33	95.33	243.00	179.67

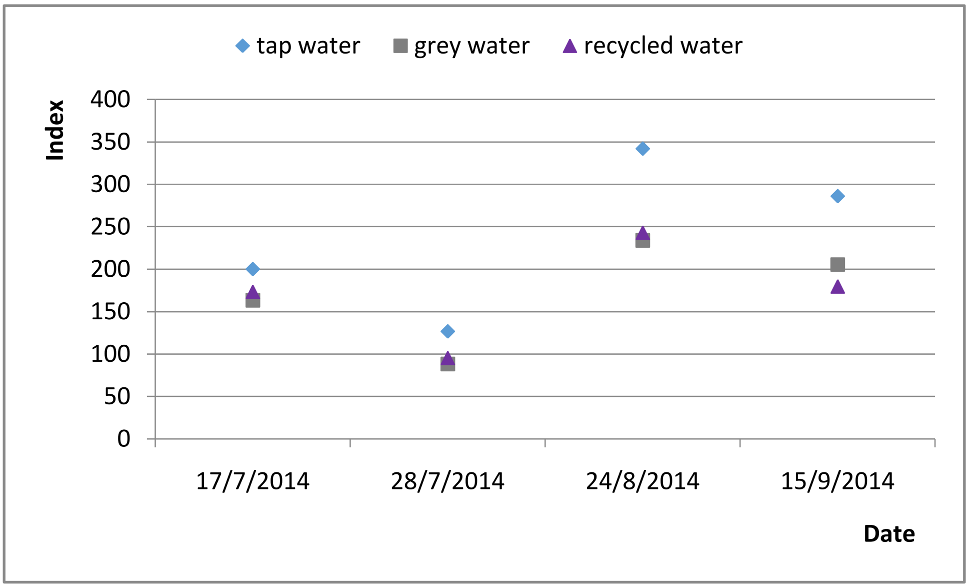

Figure 55 *Ligustrum japonicum* Index

Photinia serrulata

Photinia serrulata plants' quality performance did not differ statistically between treatments as shownin Table 29 and Figure 56.

Table 29 *Photinia serrulata* mean rates (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)

	27/6/2014	28/7/2014	24/8/2014	15/9/2014
tap water	7.00a	9.67a	8.00a	8.00a
grey water	9.67a	9.67a	10.67a	10.67a
recycled water	10.00a	8.00a	7.67a	8.00a

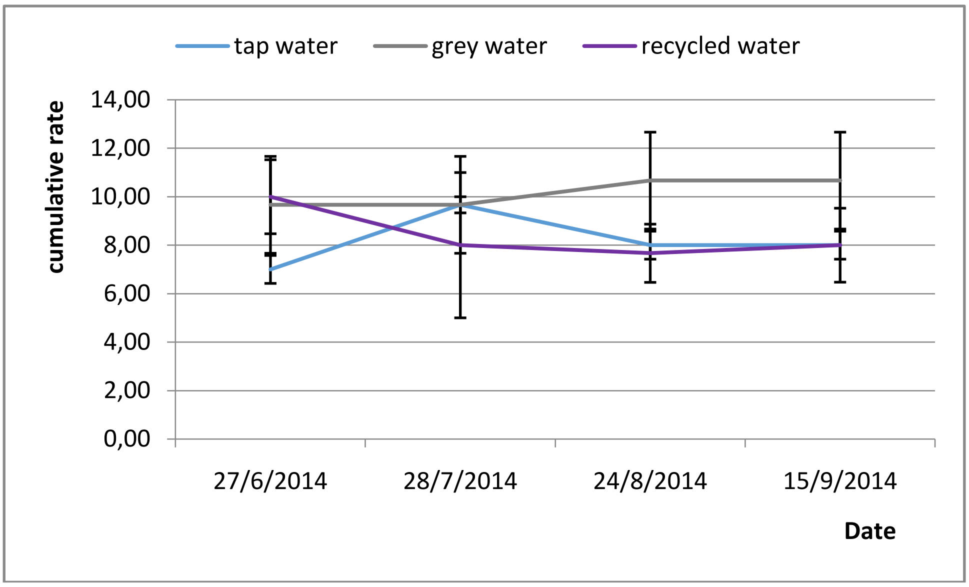

Figure 56 Cumulative rate of *Photinia serrulata* quality performance

Quality Index revealed that better quality performance exhibited *Photinia* shrubs irrigated with tap water, while the lowest performance was observed at recycled water treatments. (Table 30, Figure 57)

Table 30 *Photinia serrulata* index

	28/7/2014	24/8/2014	15/9/2014
tap water	258.33	238.50	176.00
grey water	299.67	274.50	234.67
recycled water	279.00	211.50	172.33

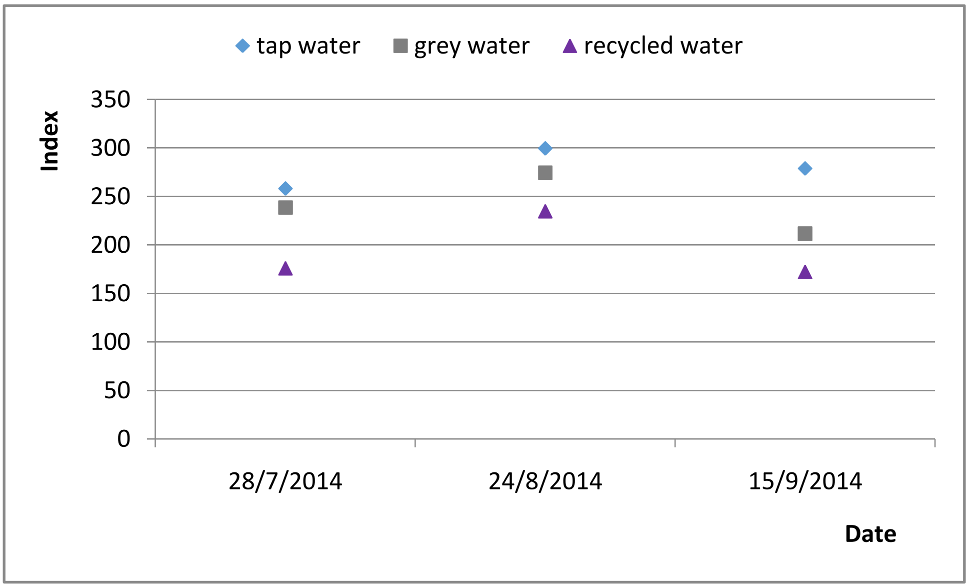

Figure 57 *Photinia serrulata* Index

Pittosporum tobirum

During the entire experimental period there has been observed a single case when treatments differ statistically significantly, that is on 28/7/14 when recycled water treatment plants exhibited statistically significant lower quality performance compared to other treatments' plants (LSD, a=0.013)

Table 31 *Pittosporum tobirum* mean rates (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)

	20/6/2014	28/7/2014	11/8/2014	27/8/2014
tap water	8.33a	11.33a	10.00a	9.67a
grey water	9.00a	8.67a	10.00a	9.67a
recycled water	7.33a	5.67b	8.00a	7.33a

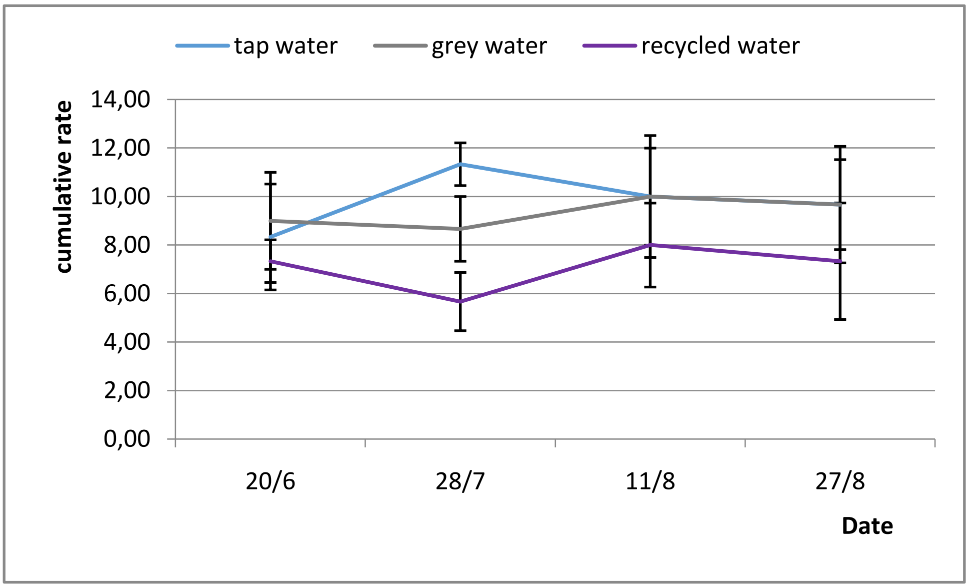

Figure 58 Cumulative rate of *Pittosporum tobira*quality performance

On the other hand quality Index exhibited a declining trend during the experimental period and varied among treatments. Plants irrigated with tap water demonstrated better quality performance whereas plants irrigated with alternative water demonstrated a below medium level quality performance (Figure 59, Table 32)

Table 32 *Pittosporum tobirum* index

	28/7/2014	11/8/2014	27/8/2014
tap water	373.67	149.33	157.33
grey water	335.67	130.67	157.33
recycled water	247.00	95.67	122.67

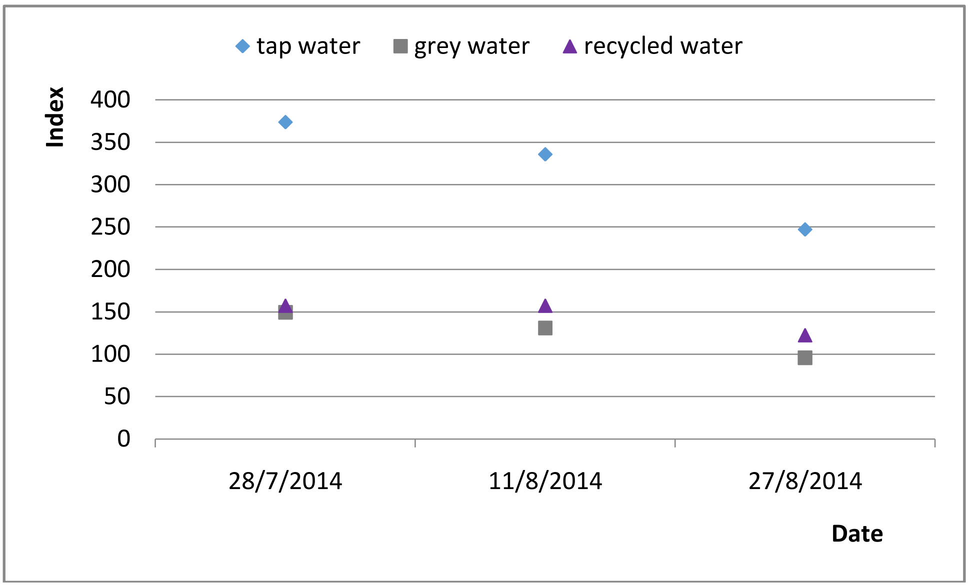

Figure 59 *Pittosporum tobira* index

Thuja occidentalis

Analysis of Variance (Table 33) showed that *Thuja occidentalis* plants demonstrated no statistically difference between treatments during the entire trial period. This is contradicting to graphic depiction of evaluation (Figure 60) (probably because of great mean deviation) according which plants treated with tap water and grey water exhibited higher quality performance compared to plants irrigated with recycled water.

Table 33 *Thuja occidentalis* mean rates (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)

	20/6/2014	28/7/2014	11/8/2014	27/8/2014
tap water	10.67a	9.67a	10.33a	10.67a
grey water	9.33a	10.00a	10.00a	11.00a
recycled water	7.33a	7.00a	7.33a	8.00a

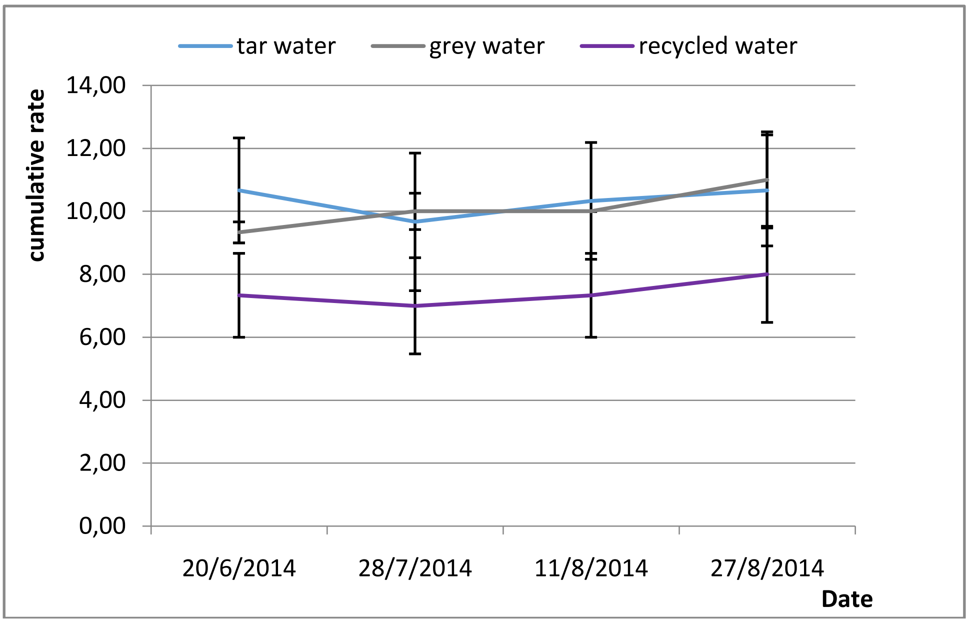

Figure 60 Cumulative rate of *Thuja occidentalis* quality performance

Quality Index computed for plants irrigated with alternative water sources was steadily lower compared to the correspondent for reference plants and had values below moderate level (Table 34, Figure 61).

Table 34 *Thuja occidentalis* Index

	28/7/2014	11/8/2014	27/8/2014
tap water	386.33	140.00	168.00
grey water	367.33	140.00	168.00
recycled water	272.33	100.33	122.67

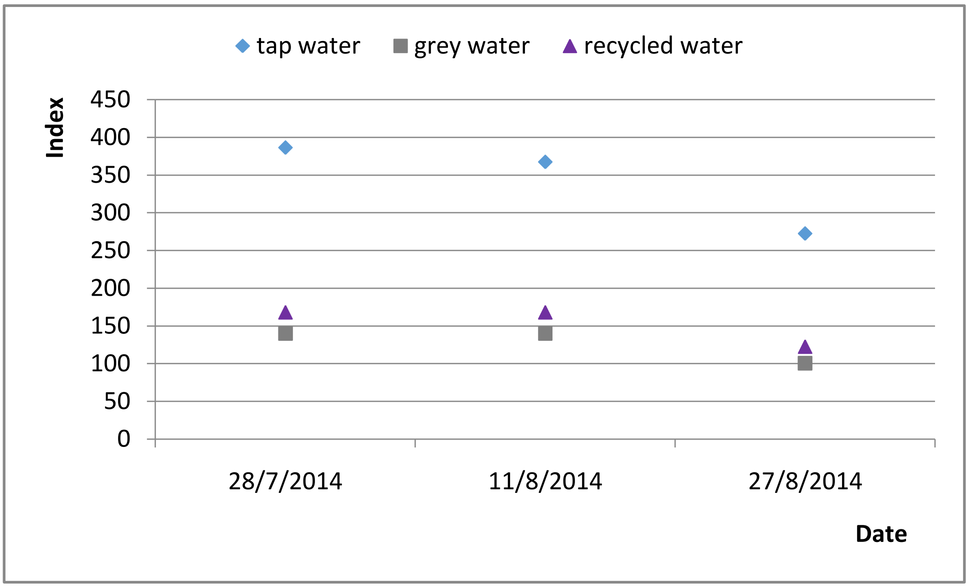

Figure 61 *Thuja occidentalis* Index

Viburnum tinus

Analysis of variance (ANOVA) indicated no staistically significant difference between treatments as seen in Table 35 and Figure 62)

Table 35 *Viburnum tinus* mean rates (ANOVA) (different letters (ie: a, b, c) indicate statistically significant difference, while same letters indicate no statistically significant difference)

	20/6/2014	28/7/2014	11/8/2014	25/8/2014	16/9/2014
tap water	8.00a	7.67a	9.33a	9.33a	10.33a
grey water	7.67a	7.67a	7.33a	8.33a	8.33a
recycled water	10.00a	8.67a	9.33a	8.67a	8.00a

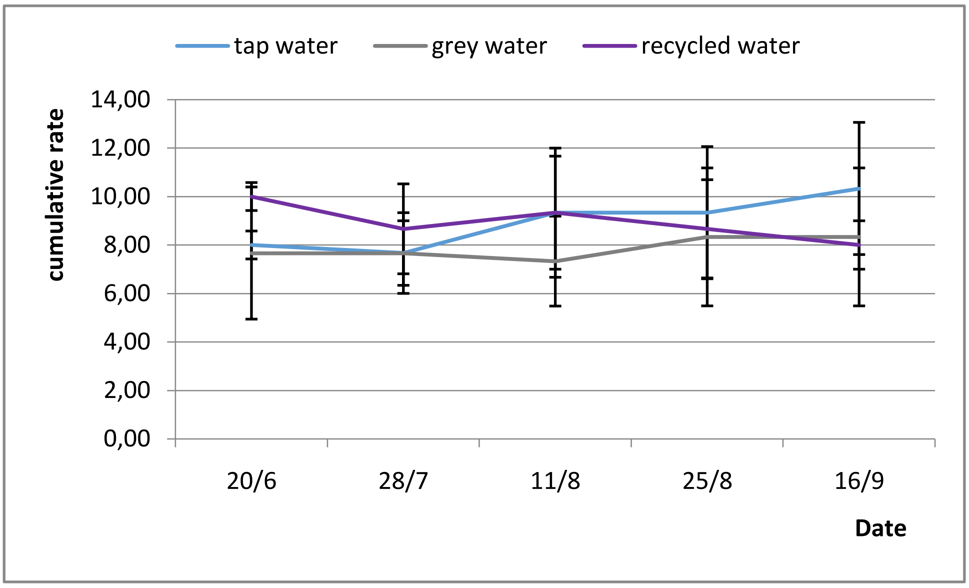

Figure 62 Cumulative rate of *Viburnum tinus* quality performance

Quality Index varied along the experimental period (Table 36 Figure 63), but not among treatments, having a declining trend and taking a slightly moderate value at the end of the experimental period.

Table 36 *Viburnum tinus* Index

	28/7/2014	11/8/2014	27/8/2014	16/9/2014
tap water	297.67	119.00	130.67	216.33
grey water	291.33	105.00	109.67	183.33
recycled water	354.67	126.00	126.00	183.33

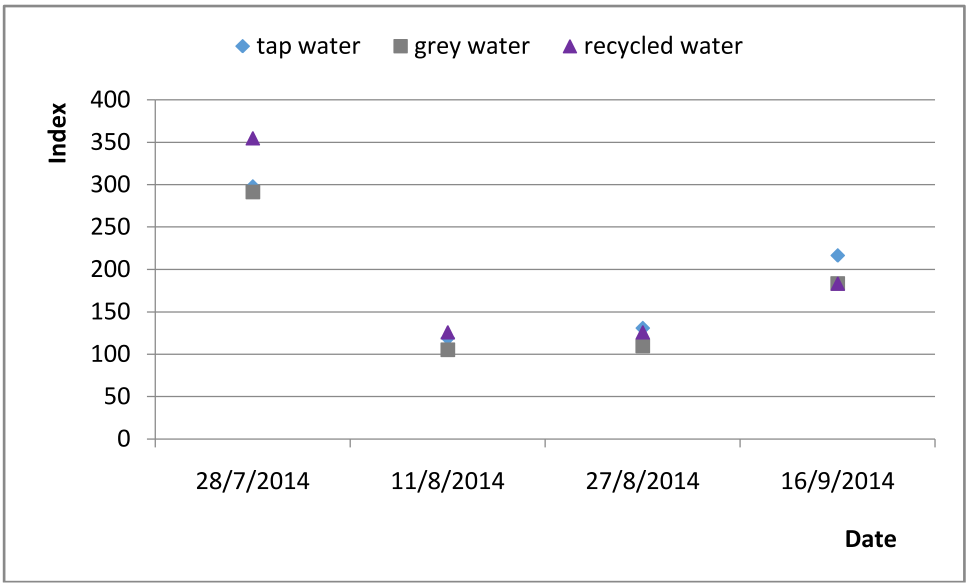

Figure 63 *Viburnum tinus* Index

Discussion, Conclusions and Recommendations

Historically alternative water resources have been applied in several regions that are generally characterized or periodically suffered from water scarcity. Evaluation of the effects of alternative water sources on several plants has been already carried out before but it is needed to be studied on regional level and additionally in combination with the investigation and proposal of practical methods for the implementation of such alternative water sources for landscape irrigation in residential or even municipal level.

In overall recycled and grey water did not have any reverse effect on all species although there have been pointed out some variations in quantitative or qualitative characteristics of those plants when compared to irrigation with tap water. Turfgrass irrigated with recycled water demonstrated no difference in growth development compared to the reference turfgrass. On the other hand treatment with grey water although exhibited the lowest growth development among three treatments did not demonstrate any difference in qualitative means as determined by PRI and NDVI and that could be an important outcome in cost effectiveness terms.

Growth development of shrub species that were treated with reused water did not show to be significantly affected by the application of those alternative water sources apart from *Pittosporum tobiris.* Quality evaluation on the other hand differentiated some of the species (*Thuja, Pittosporum*) indicating in those cases that shrubs irrigated with either recycled or grey water had lower quality when compared to reference shrubs. Generally though, also quality evaluation for the rest of the species did not reveal any deficiency. It has to be mentioned at this point that optical evaluation of shrubs could not avoid subjectivity which is an important factor. Possibly a greater number of evaluations could smooth these differences and ensure more objective and safe conclusions.

Another finding that should be mentioned is the observance of rise of EC and pH values in soil irrigated with recycled water. Although those values did not exceed the acceptable limits and didn't seem to correlate with any effect in growth or other qualitative characteristic of most of the plants, this observance should be taken into consideration for cases of applying this kind of irrigation to susceptible plants.

An important issue that should be taken into consideration is health hazards that implementation of reuse of waste water could pose to human health. There are several treatment practices that can be applied to a treated water irrigation system in order to ensure safety which include disinfection, filtration with either sand or activated carbon filters, aerobic biological treatment or membrane bioreactor treatment (Allen , Christian-Smith, & Palaniappan, 2010). Recycled water used in the experiment was of tertiary treatment which means that it had passed through a last stage of chlorination at the WWTP. According to our findings if treated reclaimed water remained in the storage tank less than seven (or ten) days, microbial enhancement could be prevented. Grey water disinfection included the use of a filter (AQUA2USE) as it has been described in the relevant paragraph and additionally a chlorinating device that was (adjusted to) incorporated in the exit of that filter previous to its storage to the tank. Everyday check of free chlorine concentration with a portable device and another arrangement at grey water irrigation system (pipes loop) helped calibration of chloride concentration in the storage tank and the management of chloride accumulation in the field. This applied mechanism along with periodical controls according to legislation, is a feasible and applicable method for safe use of domestic grey water. Generally periodic monitoring of potential chemical or biological hazardous agents according to national’s legislation is crucial for safe and sound alternative water irrigation.

In conclusion this report’s findings can support the effort of supplementation or even when possible substitution of natural water sources with alternative since no quantitative or qualitative adverse effect has been observed. In residential or municipal level (municipal buildings or establishments) grey water capture and management as described in this report is feasible both practically and economically. Application of irrigation urban landscape with recycled water needs a more central administration but it is a viable approach to urban water sources management.

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