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# Sustainable management techniques for trees in the urban areas

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## Introduction

Sustainable arboriculture is broad-based and complex due to the diverse and dynamic character of urban green areas and their environment, owing to the impact that people and their activities have on urban trees - e.g., planting, removal, pruning, land development, plant injury (Nowak 1993, Clark *et al.*. 1997). Wide-ranging activities of people are among the major forces for change in the health and character of the urban forest and ultimately determine its sustainability, more so than with any other forest resource (Nowak 1993).

In this scenario sustainable tree care and maintenance represent the preservation of the long term efficiency of the urban ecosystem in an environmentally conserving and safe manner coupled with economic viability, social justice and equity for the citizens. Although urban green areas have been acknowledged globally to be of outmost importance, the term "sustainable arboriculture" is often used loosely and in a general manner as a label, brand or icon to make it acceptable to all types of stakeholders and under various environments.

In the coming decades, arboriculture and urban forestry will have to face many challenges as population increase and demographic changes, flinching per capita natural resources, environmental degradation, climate change and globalization. At international level urban green areas are more

and more perceived as vital spaces for the development of important functions such as the strictly ecological-environmental and the social and economic ones. Also, in many urban areas, lack of proper tending and maintenance results in much higher tree mortality rates that cannot be sustained over the long term. Therefore, there is a strong need to set up research projects in all the different contexts and on different topics to gather as much information as possible to maximize the benefits brought by trees.

Some of the aspects regarding sustainable planting and management techniques will be considered in this paper with special regard to selection of planting material, mulching techniques and irrigation management in the urban stands.

**Concept of Sustainability**

There are several definitions of sustainability in the urban forestry sector. Sample (1993) stated that sustainable arboriculture comprises management and practices which are simultaneously environmentally sound, economically viable and socially responsible. Actually, in urban areas, we focus on sustaining net benefits of trees and forests at the broadest level. We are therefore sustaining environmental quality, resource conservation, economic development, psychological health, wildlife habitat, and social well-being (Clark *et al.*, 1997).

**The sustainable approach to urban greening**

Sustainable arboriculture implies several steps which are listed below and which start from site design and must follow trees until the senescence phase.

✓ Design: focused on plant needs and on site potentiality

✓ Contract: all details must be specified in order to meet plant requirements

✓ Site preparation: to ensure that site conditions are appropriate for the plants

✓ Tree supply: plant material must be of the highest quality possible (morphological, physiological and phytosanitary) and to have the right fitness (in biology fitness is “The extent to which an organism is adapted to or able to produce offspring in a particular environment”)

✓ Planting: to ensure that all the necessary interventions are provided before, during and after planting

✓ Establishment: to anticipate the typical problems of the urban environment like water scarcity, weed competition and man damages

✓ Maintenance: keep on caring trees for the time need according to plant material type and “don’t think that once planted trees can live on their own”

✓ Monitoring: monitoring trees for an early detection of stress and diseases

All these steps have to be in close relation among them and, in time course,

readjustments can be necessary to reorient them to a newly steady state because without readjustments, no system is infinitely sustainable. This is especially true for urban green areas which are not static but change and evolve through a highly variable set of quasi-stable conditions over time, in tandem with changing demand scenarios such as population growth, demographic transition, evolving tastes, economic strength, technological development, awareness and attitudes.

Whereas aesthetic and beautification assumed top priority until the last part of the past century, the environment and socioeconomic equity have now become greater concerns, and alternative paradigms seeking sustainable and holistic development have become more relevant.

**Selection of planting material**

As stated by Schutzki and Tripp (2008), plant selection is an organized process that examines several factors: function, aesthetics, site adaptability and management. Here follow the main desirable qualities of street trees for a sustainable landscape. These qualities should be kept in mind when selecting trees for urban planting in order to have the highest establishment rate and growth performance and to lowest maintenance costs (From Harris *et al.*. 2004. modified).

- Strong crown structure (branch and stem attachments)
- Predictable size and form
- Rapid growth rate (not always a real desirable quality)
- Limited competition with infrastructures
- Ease of transplanting and establishment
- Minimal litter (leaf, fruit)
- Long-lived
- Resistant to attack by pests and disease
- Non-allergenic
- Solar friendly (or shade-tolerant)
- Tolerant to a wide range of environmental conditions (temperature, precipitation, soil)
- Strong compartmentalization response
- Deep-rooted
- Excellent aesthetic features
- Non-invasive
- High $CO_2$ sequestration ability
- Low BVOCs production

Aesthetics certainly have high relevance in plant selection, but the value of a plant should go far beyond aesthetic appeal. Function guides the selection of a species and we all know that the choice of high quality planting material is the first link to establish a sustainable urban landscape and its importance is obvious. Planting projects can fail because of poor quality plants and when the wrong species or variety is planted.

The first step is to analyze the sensitivity of the different species to the urban conditions and to global change (see Ferrini *et al.*., 2008 for more information). The assessment should identify whether these factors could cause significant negative

impacts on tree growth and physiology. If a species appears to be insensitive to climate change and to the typical urban stress, city planners and arborists should move on the next step-that is site assessment and modification (if needed) and planting. If a species appears to be sensitive to climate change, there will be a need to select potential alternative species.

As reported by Schutzki and Tripp (2008), function, aesthetics, site adaptability and management form the foundation of Right Plant/Right Place/Right management adage and have been used for years to identify appropriate plants for a given landscape. Sustainability can be easily interwoven in this scenario.

Function refers to the purpose that plants serve in the landscape. Plants serve three major functions in our urban landscape: architectural, engineering and environmental. Sustainability adds natural function and the accompanying ecological services to our list of functions which are the product of interactions between plants and elements of the environment: the individual plant's relationship with the soil, within its root zone, the air circulating around its stem and leaves, the water that falls on its leaves and stems and is absorbed by its roots, the insects and animals that eat and disperse its seeds, and, finally, the other plants that exist in association with it (Schutzki and Tripp, 2008).

Finally, landscape management addresses the heart of sustainability. Designing and constructing a landscape is a short-lived process based upon limited human understanding of the complexities of nature. "Sustainability is not a design. It is what happens later". Sustainable plant selection anticipates both the initial and future landscape, and the natural and human functions that these provide.

Based on these assumptions, we should be aware that the presence of trees can make the sharing of space and coexistence difficult, and add to the expenditure of considerable economic resources for their management and maintenance. Often, the individual trees that make up an urban arboreal patrimony belong to different species. As a consequence, there is a great variability in their shape, size, and adaptation to local condition, which leads in turm to various problems and that can render a green space not really sustainable.

The most frequently encountered problems are those linked to the normal cycle of growth and the plant seasonal phenology. For example, there can be negative consequences of flower formation and, thus, pollen production which, in addition to the release of allergens, include attraction of

insects, production of fleshy fruits and, changes in structural stability of the tree.

Recurrent human health disturbances related with seasonal shedding of pollen are common results of improper selection of tree species for urban planting. As underlined by Sogni (2000), pollen responsible for the principal allergic reactions comes mostly from anemophilous species which, in general, produce large quantities of pollen and depend on poorly selective diffusion agents such as wind. Typically, grains of such pollen are very light and small with a smooth, dry surface. Their diameters usually range from 20-30 µm with maximums of 150 µm in some coniferous species. In contrast, entomophilous species produce pollen which is frequently bigger and heavier. As poorly dispersed through the air, it is rarely present in the atmosphere at concentrations sufficient to trigger an allergic reaction. However, there are exceptions such as *Tilia*, an entomophilous genus that can also cause an allergic response. In cases where air-borne spread of pollen is limited, violent allergic reactions are recorded mainly after direct contacts with the pollen producing plant.

The spread of pollen grains in the environment depends also on climatic events during flowering (e.g. wind, rainfall, atmospheric humidity) and the presence of barriers for their diffusion (e.g. vegetation, buildings, etc.). Changes in the intensity of these factors can greatly modify concentration of pollen in the air and frequency of allergy.

The potential of pollen for eliciting allergic reactions cannot be directly correlated with its amount and dispersibility. For example, conifers rank first for individual quantity of pollen produced, but, with the exception of *Cupressus sempervirens,* they are toward the bottom of a hypothetical ranking of species responsible for allergic reactions. Conversely, *Graminaceae* are at the top of the list in terms of allergenity, but they are individually modest producers of pollen. However, they are wide-spread in nature, and often highly concentrated in large biophytic associations. It is interesting to note that there are some species able to trigger allergic reaction only at elevated spatial concentrations of individuals. This is the case of *Phoenix dactylifera* and *Trachycarpus fortunei*, primary allergic agents in North African countries, but of little or no interest in countries at higher latitudes, due to their limited presence. Climate change will probably trigger some changes in the species distribution and might enhance pollen production. This could, in turn, increase the risk of allergies. Meteorological factors strongly influence the timing and duration of the pollen season as well as the total pollen count. Thus, the seasonality of pollen-related disorders, such as hay fever, may be affected by the climate.

Litter from urban trees is another widespread problem, although it varies in the magnitude among tree species. Fallen fruits can dirty the environment or produce unpleasant odors (e.g. *Ginkgo biloba*) or, in cases of large (i.e. *Maclura pomifera*) or particularly hard fruits (e.g. cones of the Italian stone pine – *Pinus pinea*), they can cause damage to contacted surfaces. Even normal falling of leaves can cause damage or, at least, troubles when pavements and asphalt become slippery.

A good review on littering from urban trees was provided by Barker (1986). He closely examined the trees that produce the most litter in the urban environment. For example American sweetgum (*Liquidambar styraciflua*) is sometimes extensively planted along urban streets, yet its fruits are a vexing litter problem (Barker, 1986). Lavalle hawthorn (*Crataegus x lavallei)* is frequently recommended for street planting (especially in narrow streets) because of its stress tolerance, but its fruits can increase the risk of slipping. Full-grown purple-leaf plums (*Prunus cerasifera*), are among the most appreciated ornamental trees, but their fruits are an intolerable nuisance, littering roads and sidewalks. In general, fleshy fruits are usually messy, but other types of fruit can also be annoying. Best examples for this group are pods of carob (*Ceratonia siliqua*), honeylocust (*Gleditsia triacanthos*), black locust (*Robinia pseudoacacia*), and Japanese pagoda tree (*Styphnolobium japonicum*), or ball-like fruits of plane trees (*Platanus x acerifolia*).

In terms of sustainable landscape, if little can be done to prevent or diminish the problem of fruit litter from existing trees, possibly the best solution for the future would be to use non fruiting species and cultivars in newly developed areas, where existing trees are replaced (Barker, 1986). In dioecious species (i.e. *Ginkgo biloba, Gymnocladus dioicus*) propagation of only male individuals is the easiest way to obtain non fruiting trees.

Sometimes it is not the plant itself which can cause negative interaction with human health and its environment, but animals, such as insects and ticks which live on the trees. Occasional mass outbreaks of processionary or brown-tail moths, and their caterpillars covered with poisonous hairs, attacks of aphids on street trees and their production of honey dew that covers cars, sidewalks, and pavements with sticky dirt, or accidental dropping of ticks which potentially carry human pathogens are important factors. Without a doubt, whenever possible, careful selection of species and proper placing of trees can help to avoid, or at least minimize, problems described above. The principle of "the right plant in the right place with the right management" is always valid. Yet, frequently, the arboreal patrimony we find

and must manage is a result of plantings that took place in time when attention to space and maintenance, in terms of plant dimensions, did not cause conflicts. It is probable that also the different context in terms of resources presented fewer problems.

**Tree stability assessment**

This subject was already reviewed by Ferrini *et al.*. (2008) who underlined its importance when selecting trees in a global change scenario. The need to rethink tree stability assessment to meet changing objectives lies at the heart of the research into sustainable urban forest management. We know that trees in the urban environment often have to face very harsh conditions. They can easily acquire mechanical defects, which may cause hazard in areas where people and property are present. According to the existing definition: "hazard is a disposition of a thing, condition, or situation to produce injury" (Health and Safety Executive, 1995). In a more specific way a tree is considered to be hazardous, if it is structurally unsound and there is a possible target, like vehicles or people. An unsound tree in an area with no target is not hazardous (Dujesiefken *et al.*., 2005). Although all trees have a potential to fail and become hazardous in particular conditions, senescent trees are most prone to acquire these characteristics. In such trees all functions, including photosynthesis, production of roots, stem growth and branching, resistance to pathogens, and others are gradually reduced or disorganized. The limbs progressively break off and the tree dies. Both the uncontrolled breakage of dead branches and actual fall of the wakened or dead tree can be dramatic in its consequences. Therefore, reliable assessment of the hazard trees and undertaking appropriate actions is a must in publicly accessible alleys, parks and forests.

The management of trees and evaluation of potential problems connected to their presence in the urban environment involves a series of actions linked not only to the knowledge of plant placement, but also to the analysis of health and stability of trees in such a way that would allow the planning of necessary interventions for their care, and to limit the risk of their unexpected fall.

**Tree selection and maintenance in the urban environment with the aim to reduce $CO_2$ concentration**

$CO_2$ is one of the main externalities of human activities. $CO_2$ emissions, jointly with deforestation, have lead to an 25% increase of atmospheric $CO_2$ concentration over the last 150 years, and this trend is still going on (Giordano, 1989; Akbari, 2002). It's proved that $CO_2$ is one of the main greenhouse gases and changes in its atmospheric concentration are leading to an average increase in Earth temperature and, in Europe, to a significant decrease in the frequency of rainy events and to a significant increase in their intensity. Kyoto protocol set the targets to fight climate

change. Reforestation and shift to renewable sources of energy are the main ways proposed by Kyoto protocol to stop the increase in $CO_2$ atmospheric concentration. Urban environment is particularly sensitive to these changes. Most of the pollution is directly produced in the urban environment because of high traffic and house-heating. Urban trees are good allies to prevent or reduce the increase of $CO_2$ atmospheric concentration (McPherson, 2007). Tree planting in the urban environment is particularly effective because: 1) they have a direct effect of CO2 by fixing it through photosynthesis; 2) through shading and wind-screening they can effectively reduce the need of fossil fuels for house-warming and summer cooling. The net save in carbon emissions that can be achieved by urban planting can be up to 18 kg $CO_2$/year per tree Rosenfeld *et al.*., 1998), and this benefit corresponds to that provided by 3 to 5 forest trees of similar size and health (Akbari, 2002). Despite of the great potential power of urban trees to counteract climate change, still some methodological and environmental problems remain:

1) urban environment significantly differs from the natural one. Temperature is generally higher ("Urban heat island") and soil compaction, waterlogging, water stress, pollution, altered light conditions and restricted rooting space set the need to look for species which can survive and sequester efficiently $CO_2$. Selected species should be able to tolerate the predicted increase in temperature by 1,5-3 degrees over the next 70 years, to tolerate medium to long periods of drought which may arise from reduced frequency of rainy events and to tolerate pollution and salt stress. Native species growing in the natural environment in the surroundings of the city may not be the best choice for urban planting because of altered environmental condition within the town. Anyway care must be taken when selecting non-native species and potentially invasive species should be rejected.

2) Poor health of most urban trees down-regulate photosynthesis and growth, thus the effective storage of atmospheric carbon in woody biomass. Since large trees generally store far more carbon than young plantings, arborists and municipalities should try to maintain healthy and preserve mature trees and keep them as healthy as possible.

3) Most of the existing models for estimating $CO_2$ sequestration by trees are generally based on above-ground biomass production as stem diameter, plant height, crown size and age (Nowak, 1994; Nowak e Crane, 2002; Banks *et al.*., 1999; Brack *et al.*., 1999; Brack, 2002). Errors of such estimates can be substantial: Nowak (2002) calculated an average yearly $CO_2$ uptake of 30 kg by a healthy 23-30 cm caliper tree. The uptake rate of a similar tree was quantified in 4-10

kg/year by Akbari (2002). Moreover many models don't take account of carbon store in roots, which may be up to 23% of total carbon storage, depending also on the growing condition (i.e. a tree grown in full sun or in water-limiting conditions will allocate more carbon to below-ground parts than an identical tree grown in optimal conditions). Models don't even consider carbon stored in leaf, which may not be totally released in the atmosphere if shedded leaves are properly managed (i.e. compost production).

Therefore more research is needed on this topic. Some ambitious projects are mushrooming to offer a positive answer to the request for research funds. Banca del Verde ("Green Bank www.bancadelverde.org) is a recent initiative started in Italy. Banca del Verde collects money from public and private actors and invest it in urban forestry programs both at local and national scale. Some programs have already begun and more will be undertaken in the close future.

**Sustainable planting and maintenance**

**Using compost for amending and mulching**

A key to success for new tree planting in the urban environment is the protection of young plants from non-crop plant species (including some hardwoods, shrubs, grasses, and forbs). These fast-growing plants often kill or greatly suppress desired trees by competing with them for light, water, and nutrients needed to grow. As a result arborists and urban forest managers generally use herbicides to suppress non-crop vegetation.

However the EU's Fifth Environmental Action Programme (5EAP) set out a series of targets for the year 2000 including 'the significant reduction in pesticide use per unit of land under production, and the conversion to methods of integrated pest control and in some countries the use of chemicals is strictly limited or even forbidden.

As a consequence, to protect young trees, environmentally sound, effective, cost-efficient, and socially acceptable techniques for managing non-crop vegetation are needed.

In this scenario, we need to focus on the need for environmentally friendly establishment and low cost management methods of the urban green areas. Mulching and its skilled use can contribute to such a development by improving organic matter content in the soils and by affecting other soil characteristics (Harris *et al.*. 2004).

Even if mulching is a world-wide practise in urban green areas and different materials can be used for this purpose (mainly shredded wood, chipped woods, pine bark and, above all, composted materials)(Rakow 1989), little research has been done to determine the effects of this practice on tree physiology and on soil chemical, physical and biological characteristics in the actual urban stand.

Positive effects following organic mulch application have been obtained by previous research which has shown beneficial effects on soil physical and chemical properties (Fraedrich and Ham 1982; Litzow and Pellett 1983; Watson 1988; Appleton et. al. 1990; Himelick and Watson 1990; Smith and Rakow 1992; Iles and Dosmann 1999, Tiquina et. al 2002, Dahiya *et al.*. 2007) and on plant growth and physiology (Watson, 1988; Green and Watson 1989; Appleton et. al. 1990; Himelick and Watson 1990). Also the invertebrate diversity can be positively affected by mulching (Jordan and Jones 2007). However, sometimes the results from mulching are variable being affected by the different environmental conditions and by the different tree species (Whitcomb 1979; Iles and Dosmann 1999). Moreover, if the quality of the mulching materials supplied by the producers is not satisfactory, tree performances can be affected in a negative way. This can be related either to its quality or to its misuses, i.e adding too much material which can negatively affect soil oxygen content (Gilman and Grabosky 2004; Hanslin *et al.*. 2005), though Watson and Kupkowski (1991) found no detrimental effect from the application of 0.45 m (18 in) of wood chip mulch over the soil in which the roots of trees were growing. The application of bark mulch can sometimes decrease growth in the first year, but the effects on plant growth are positive when examined in the long term (Samyn and de Vos 2002). This can be caused by a temporary nitrogen depression until the microorganisms are able to decompose a sufficient amount of organic material to provide the needed nitrogen (Craul 1992).

In a study carried out on two common landscape species Fini *et al.*. (2008) found that mulching with compost is a useful practice to improve plant growth, leaf gas exchange and leaf chlorophyll content. In this study, the use of compost on the row also mitigated the effect of competition with turf and reduced soil temperature. Plots mulched with compost were 13°C, 10,8°C and 7,2°C colder than bare soil, tilled and turf plots respectively. This significant reduction in soil temperature contributed to create a more favourable environment for root growth: soil temperature in mulched plots didn't exceed 35°C, which is considered the threshold temperature above which root growth is hampered and root mortality increased (Coder, 1996; Fini and Ferrini, 2007). Soil oxygen content was slightly reduced by mulch application. The oxygen content didn't fall below critical levels for root growth, which was found around 10% but this data confirm the importance of a correct mulch application, as described in Saebo and Ferrini (2006). On the basis of results obtained in this study, mulching can be considered an environmentally-friendly and sustainable

alternative to tillage and chemical weeding for managing plants in the urban environment.

As far the composted material as concerned, it has to be remarked that it needs to be well characterised for nutrient values, stability and other properties for the support of tree growth and effect against weeds. In a review of the use of composts for mulching and soil amendments, Sæbø & Ferrini (2006) suggest designing the composts as to fit the specific effects that are wanted. For example composts for mulching should consist of layers of compost of different particle sizes, so that both nutrients can be supplied and weeds are not given good germination conditions. Organic compost materials generally have long term beneficial effects on soil physical properties, though in the short term these benefits are less evident (Watson 2002; Ferrini *et al.*. 2005; Ferrini *et al.*., 2008). Some research projects have shown that organic amendments have a potential role in ensuring quality restoration works (Hornick and Parr 1987) and their application is beneficial and relatively inexpensive (Vetterlein and Huttl 1999). This works well with the European Union countries which target is to decrease the quantity of organic waste going to landfill sites by 20% by 2010 and by 50% by 2050 (Council Directive 1999/31/EC). The follow-up of this directive could result in a large increase in composted organic wastes (Crowe *et al.*. 2002).

Besides soil quality, other important components of planting sites are the open soil surface and the surface treatment over the rooting zone (Coder 1996; Trowbridge and Bassuk 2004).

In many urban sites, the soil surface is covered after planting; typical coverings of paving stones, asphalt and concrete are impermeable to the water and oxygen required by both the tree roots and the soil for proper functioning (Bradshaw *et al.*. 1995). Metal grids or grates used in conjunction with concrete, allow water and oxygen exchange only if the soil is not compacted and are also expensive.

Planting the area around the trees with small shrubby cover seems to have a very beneficial effect on soil humus and microrganisms (Bernatzky 1978). Benefits are probably due to the fact that with ground cover the risk of being walked on is much reduced. A research carried out on Norway maple showed that after three years, trees with larger and mulched planting areas had higher leaf gas exchanges, leaf chlorophyll and mineral content, than those grown under pavement (Ferrini and Baietto, 2007).

Anyway To be effective, sustainable management techniques as mulching and use of turf should not penalize plant growth and health.

**Irrigation management**

Global environmental conditions have changed during the last century and, based on

current trends, temperature will rise by about 1-3.5 °C over the next 70 years; rainfall will also be affected by a decrease in the frequency and an increase in intensity of rainy events (UNEP/IUC 1999). Water limitation may prove to be a critical constraint to primary productivity of plants under future scenarios of more arid climates due to climate change (Fisher *et al.*. 2001).

The primary reason for irrigation is to provide water to a crop when the frequency and amount of rainfall is not sufficient to replenish water used by a crop system. Water requirements of the crop system depend on growth and development needs as well as environmental demands. The levels of water used by the plant in growth and development are usually small compared to the atmospheric demands.

One question needed to be answered in order to schedule irrigation in a sustainable way: how can I reduce the amount of water to apply without limiting growth of the new planting? Efficient water use in the new landscape will contribute substantially to the conservation of this resource. Water use efficiency can be achieved by supplying only the amount of water sufficient to meet plant needs. The potential for plant injury caused by water deficits or excess can be minimized by identifying and meeting plant needs. Also control of water application uniformity and amount in relation to evapotranspiration is the key to efficient, effective water management.

In order to take full advantage of an irrigation system the following technical points need to be known or/and are recommended:

- ✓ The plants that are watered by a single controller valve should have similar water requirements (a hydrozone). In particular plants with very different water requirement should be controlled by different valve in order to adjust to the right water amount and increase irrigation efficiency.
- ✓ The irrigation system should be well designed and maintained in order to apply water uniformly and efficiently.
- ✓ The approximate rooting depth and water holding capacity of the soil should be known so that the soil water reservoir can be estimated
- ✓ The application efficiency of the irrigation system should be used to figure the amount of water to apply to replace that evapotranspired or the amount desired.

When we specifically refer to shade trees planted in the urban environment and peri-urban forests and recreational areas, plant productivity may correspond with the ability of single plants or plant communities to provide benefits to the inhabitants. Healthy, long-lived trees provide environmental, ecological, economic, social, cultural and aesthetic benefits to the community (Akbari

2002; Brack 2002; Fini and Ferrini 2007; Nowak *et al.*. 2007; Elmendorf 2008; Escobedo *et al.*. 2008). Mortality rate in the urban environment is usually very high and ranges from 10 to 50% with water stress playing a major role, especially where pavements, soil compaction and small planting pits prevent infiltration into the root zone (Kaushal and Aussenac 1989; Miller and Miller 1991; Whitlow *et al.*. 1992; Pauleit *et al.*. 2002). This threat is very dangerous in the first years after planting, when mortality peaks up to 50% in the first year and up to 34% in the second (Gilbertson and Bradshaw 1985; Nowak *et al.*. 1990). Irrigation is an important factor to increase plant survival and quality during the establishment phase, but landscape water consumption is highly visible and provides a prime target for water restrictions and subsequent regulations (Scheiber *et al.*. 2007). Despite the need to save water, water restrictions during landscape establishment can be detrimental to plants which have not had enough time to develop a sufficient root system to compensate for evapotranspirational losses (Montague *et al.*. 2000). One way to increase water efficiency is to irrigate trees until they are fully established and then terminate irrigation unless there are periods of extreme drought. Establishment time can be estimated by comparing leaf gas exchange and growth rates of newly planted stressed (non irrigated) and unstressed (irrigated) trees (Scheiber *et al.*. 2007).

As regards possible change in the climate, the whole strategy of coping with its impacts on the landscape, and especially in its effects on water supplies and water bodies, will need to rely on learning lessons from nature rather than trying to overrule it. Response to these alternating deficits and surfeits of water will require careful management of water flow and water quality. Techniques might include impounding run-off, recycling irrigation water and using grey water where possible, combined with land contouring, improving soil structure and better drain maintenance.

The impacts of climate change on water supply to the landscape will be significant, but can be reduced by sound water management using methods different method. Shortage of water in the summer can be made good by irrigation, preferably using stored water, and concentrating on the most important plants in the event of a prolonged hosepipe ban. Irrigation after dusk, using an ET controlled station to schedule irrigation will reduce evaporative losses.

In well managed gardens, surplus water in winter should infiltrate into good garden soil and runoff drives, paths and patios onto lawns or borders or into drains if levels are suitably designed.

Growing concerns for the future water supply and more stringent wastewater

discharge standards to surface water bodies have contributed to increasing interest in using recycled wastewater for urban landscape irrigation. Increasing numbers of landscape facilities and development areas have been switched to or plan to use recycled wastewater for irrigation though there are still some limitations. While the environmental and conservational benefits of wastewater reuse in landscape and turfgrass irrigation are obvious, the major concerns associated with wastewater reuse include: 1) additional costs in installing irrigation pipelines and irrigation equipment maintenance (such as, prevention of nozzle plugging); 2) health risk due to the possibility of the presence of pathogens; 3) salt damage to landscape plants and salt accumulation in soil surface and soil profile; and 4) leaching of excess nutrients to ground water (Harris *et al.*, 2004; .

A preventive strategy to reduce drought-related transplant losses is to plant species/cultivars which show a certain degree of drought tolerance during the establishment phase. Even within a genus or species, great differences in water needs for establishment can be found among species/cultivars. A previous work ranked drought tolerance of *Fraxinus* genotypes on the basis of drought-induced changes in chlorophyll fluorescence, chlorophyll content and carbon assimilation (Percival *et al.*., 2006). Other Authors found different responses to water shortage among different species of *Tilia* and cultivars of *Acer platanoides* which also adopt different strategies of coping with water stress. Since few studies have assessed drought tolerance among ornamental trees during the establishment phase, so more information is needed on this topic.

## Conclusion

The recently introduced concept of sustainable arboriculture represents the maintenance of the long term efficiency of the urban ecosystem in an environmentally conserving and safe manner coupled with economic viability, social justice and equity for the citizens. Although the importance of urban green areas has been acknowledged globally to be of outmost importance, the term “sustainable arboriculture” is often used loosely and in a general manner as a label, brand or icon to make it acceptable to all types of stakeholders and under various environments.

The experiences described before show the high potential of urban arboriculture to be part of a sustainable development for the future city environment. However, arboriculture and the promotion of its contribution to sustainable development at large require a comprehensive approach, since it needs to be linked to a broad range of issues and agendas.

Three directions for immediate action deserve to be underlined. First some new

planting policies can be encouraged and funded since they have immediate environmental and economic benefits. It is well-known, even under present-day market forces, that great strides can be made towards energy conservation and improved energy efficiency by planting trees in the urban areas to reduce the heat island effect and to improve air quality.

Second, the process of identifying the full range of sustainable techniques for responding to the environmental, social and economic questions, should move forward without delay.

Third, there should be continuing, strong support for research on this topic, because as the scientific uncertainties narrow, the choices become easier to make.

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