

# Woody Plants in Landscape Planning and Landscape Design

Viera Paganová and Zuzana Jureková  
*Slovak University of Agriculture in Nitra*  
*Slovak Republic*

## 1. Introduction

Vegetation is considered to be a significant element of the landscape. The greenery elements design landscape scenery and have productive and eco-stabilizing functions in the landscape area. Woody plants have a specific position within the greenery elements. They have bigger dimensions in comparison to the other plants, their organs usually have large surfaces and their biomass fills large parts of the overhead space and the soil. Trees and shrubs have great influence on the environment and living conditions of the other organisms. Short-term changes in ecosystems do not significantly impact their lifecycle and survival. Woody plants are long-lived organisms with different adaptability to changes of environmental conditions. The knowledge of the morphological characteristics, as well as biological and ecological qualities of woody plants is very important for their efficient utilization (Paganova, 2006; Paganova et al., 2010; Sjöman, 2012; Valladares et al., 2007).

In urban conditions woody plants have several environmental, economic and social benefits. Trees reduce heat, wind speed and provide shading, increasing the energy efficiency of buildings (Sand, 1994; Simpson, 1998; McPherson & Simpson, 2003). Urban greenery increases the sociological value of the environment, improving the aesthetic and hygienic properties of the particular place. It also increases positive feelings and moods, enjoyment of everyday life and stronger feelings of connection between people and the environment (Dwyer et al., 1992, 2003; Westphal 2003).

However, environmental conditions in urban areas are significantly different to natural habitats. Plants in urban areas are exposed to many negative factors like: water deficit, soil compaction, pollutants, artificial lighting, overheating of the root zone and mechanical injuries. According to Nilsson et al. (2000), street trees are exposed to multiple stresses and their average lifespan is short. Park trees are exposed to moderate stress and compared to street trees their lifespan is relatively high. In urban woodlands the level of stress depends more on climate, soil conditions, recreational patterns and biotic damages rather than on anthropogenic causes (Sæbo et al., 2003).

Proper woody plant selection for specific conditions and establishment of the effective vegetation elements increases the functionality and stability of the landscape area (Paganova, 2004; Paganova, 2006). Like all living organisms, woody plants change in time

and space, and knowledge of the nature and dynamics of these changes is essential for their successful utilization in landscape planning.

## 2. Principles of woody plant selection for landscape planning

The selection of proper plants for specific stand conditions is a very important task that affects success in the landscape planning and landscape design.

In Europe recent studies (Pauleit et al., 2002; Sæbo et al., 2003; Sæbo et al., 2005) documented poor diversity of tree genera and species planted in urban areas. A few genera of woody plants (*Acer*, *Aesculus*, *Platanus* and *Tilia*) are used as street trees. The number of species planted in parks, gardens and residential zones is high, however, an increase in the number of species used for urban forestry is essential. Higher diversity of species used in landscape planning and design would increase ornamental value and longevity of the plantings, and decrease costs of establishment and regular maintenance.

Spellenberg & Given (2008) reviewed the general criteria for selection of trees for urban environments. According to their worldwide knowledge, the most important criteria for selecting trees for urban environments are rather pragmatic: suitability of the taxa for local conditions, low maintenance and avoidance of structural problems. Criteria that contribute to landscape design appear to be next in importance. The authors documented a predominance of artificial mixes of woody plant species in urban areas, which possibly increases the detrimental effects of urbanization on nature and habitats.

However, there are many activities which aim at preservation and utilization of indigenous species in landscape planning and landscape design, including urban areas (Breuste, 2004; Dunnet & Hitchmough, 2004; Florgård, 2004). The new planning and design concept allows using parts of nature with specific beauty and amenity for urban spaces as well as using native species and their communities for urban plantings.

Utilization of indigenous species should support increased biodiversity in urban areas with ecologically better balanced plant communities.

## 3. Scientific tools of woody plant selection for landscape planning

Use of non-traditional woody plant species (species that are not commonly used) in landscape planning and landscape design is quite difficult. In the opinion of many professionals some stereotypes in dealing with urban trees remain with regard to the suitable and unsuitable species for urban environments. Such species are rare on plant markets because their propagation protocols have not yet been elaborated upon and the qualified sources of reproductive material are missing. There are also different opinions about the possibilities of establishment and utilization of tree species on particular stands.

The lack of information and data about growth rate, growth characteristics and maintenance management of non-traditional tree species is another reason why they are not included in landscape and urban plantings. The selection of woody plants established just on their ecological background is not appropriate for specific conditions with cumulative impact of various stresses. Also assessment of growth and physiological parameters directly on trees growing in the field or urban conditions does not give relevant results, because they are influenced by many barely quantified factors.



Fig. 1. Two individuals of *Sorbus domestica* on open stand with significantly different phenotypical traits of the crown architecture (shape, density and angle of branching) (Maceková, 2011).

From the scientific point of view mainly the ecological criteria of selection, the adaptability of trees to local conditions and the functional aspects of trees in the urban environment are studied and evaluated. The ecophysiological characteristics of trees are effective tools for selection. The stress responses of woody plants are considered to be key to the selection criteria and to markers that can be used in tree improvement programmes for specific urban conditions. Although much information can be found on environmental tree physiology (Kozłowski et al., 1991), the stress physiology of urban trees has until now been rather overlooked (Sæbo et al., 2005).

According to Ware (1994), extreme conditions of the original stand can be a good starting point for finding plants adapted to stressful urban environments. Drought is a significant factor influencing the existence and lifecycle of woody plants. However, taxa with similar ecological backgrounds (light-demanding and tolerant to water deficiency) probably use different strategies to overcome water stress impact (Paganová et al., 2010). Explanation of these mechanisms needs more experimental work and larger data files, as well as addition of information on other characteristics of drought impact such as changes of the assimilatory pigments, accumulation of osmoprotectants, water use efficiency (WUE), dynamics of the plant water regime parameters, structural leaf and root adaptations etc.

#### 4. Selection of woody plants for landscape and urban greenery in Slovakia

Service tree (*Sorbus domestica* L.) and wild pear (*Pyrus pyraster* L. Burgsd.) are light-demanding species tolerant to water deficiency during the growing season (Brutsch & Rotach, 1993; Rittershoffer, 1998; Wilhelm, 1998; Paganová, 2003a, 2008; Paganová & Jureková, 2012). According to the ecology background, these woody plants are potentially suitable for extreme conditions of urban and landscape environment.



Fig. 2. Service tree (*Sorbus domestica* L.) with a straight stem, regular crown and thin branching in the late autumn aspect in a vineyard. A “Plus tree” with positive phenotypic characteristics (Maceková, 2011).



Fig. 3. A young wild pear (*Pyrus pyraster* L. Burgsd.) with conical crown and thin branches, growing on abandoned grazing land (Šenšel, 2009).

These woody plants are part of the original flora in Slovakia. For both taxa large seasonal and phenotypic variability has been documented (Pagan & Paganová, 2000; Paganová, 2003b) that represent a good basis for targeted selection of genotypes with the qualities required for landscape planning and design. Species with high phenotypic plasticity it is assumed survive better on stands with changing environmental conditions. They have higher adaptability to changes by modifications of their functions and structures which increases the probability of their survival and reproduction. However, environmental conditions on stands affected by anthropogenic activities change too fast for manifestation of the evolutionary mechanisms of the plant adaptation (Sultan, 2004), so non-hereditary changes of plants – acclimations – take place. This is why detailed evaluation of the adaptability and phenotypic plasticity of non-traditional or rare woody plants is an essential tool when assessing their wider utilization in the urban landscape.

#### 4.1 Assessment of the potential sources of reproductive material of woody plants

Within programme selection focused on woody plant species for landscape and urban greenery the following steps are essential: qualitative assessment of the potential gene pool of the particular taxon, identification of the appropriate sources of reproductive material in the natural conditions and inclusion of the selected components of the gene pool in the selection and breeding programme of woody plants for targeted utilization in landscape vegetation units, as well as in urban areas.

In Slovakia the sources of reproductive material have not yet been identified for *Sorbus domestica* and *Pyrus pyraeaster*. Therefore, we devote a targeted assessment of phenotypic traits of individuals (growing on the original stands in the landscape), that can be used as a qualified source of the reproductive material (Fig. 2 and 3). The identification of the phenotypes suitable for wider plant production is a significant assumption for systematic planting and use of the mentioned woody plant species.

So far, attention has been paid to a reliable method of phenotypic classification of *Sorbus domestica* on original stands. Options and tools of their interpretation for selection of the sources of reproductive material were also analysed within a field study in the cadastre of the village of Žemberovce (Paganová & Maceková 2011). The scale of quantitative and qualitative parameters was elaborated and confirmed in 2011. For individual trees several parameters were determined which represent tree habit, tree growth and volume production (Fig. 4) (Tab. 1).

Architectural traits, such as patterns of branching or clonal spread and production of terminal versus axial inflorescences, may also vary plastically in certain taxa. These traits provide very important insight into the structural and ultrastructural levels at which phenotypic adjustment takes place in the plant body (WU & Stettler 1998). Therefore, we also apply them within the selection of indigenous woody plant species and their phenotypes suitable for urban landscapes and greenery.

Crown traits, such as branch diameter, branch angle and branch frequency, are also important determinants for the quality of woody plants and timber products (Bowyer et al., 2002). These characteristics also affect the utilization of woody plants in urban areas with limited space for tree growth. According to the literature, variability of the growth habit and

other growth characteristics of woody plants has been the object of extensive research and represent a good basis for selection and tree breeding. In contrast, the crown architecture and structural characteristics of trees are less at the centre of interest and only rarely applied in breeding programmes. It should be noted that structural tree characteristics, such as crown shape, crown diameter, crown density, branch diameter, branch angle and leaf area, influence efficiency and magnitude of radiation interception and competitive interactions with other trees (Emhart et al., 2007). These characteristics have significant influence on the use of individual trees on particular stands and its competitiveness and ecological influence. The crown architecture and the active area covered by an individual woody plant have potential influences on the surrounding environment.

Several tree quantitative parameters are measured: tree height ( $h$ ), stem girth at height 1,3 m ( $O_{1,3}$ ), deployment of living crown ( $a$ ) – vertical distance between the first living branch (that is a part of the living crown) and horizontal plane of the stem base (URL1). Crown diameter ( $b$ ) – average horizontal distance between opposite points of the crown projection. This parameter is usually measured in at least four ways (Šmelko, 2000) using a densiometer. The shape and area of the crown projection is determined with GPS (global positioning system). The branch angle is determined in four categories ( $<30^\circ$ ,  $30 - 60^\circ$ ,  $60 - 90^\circ$ ,  $90^\circ <$ ) according to the deflection of tree branches from the vertical axis (Fig. 4).

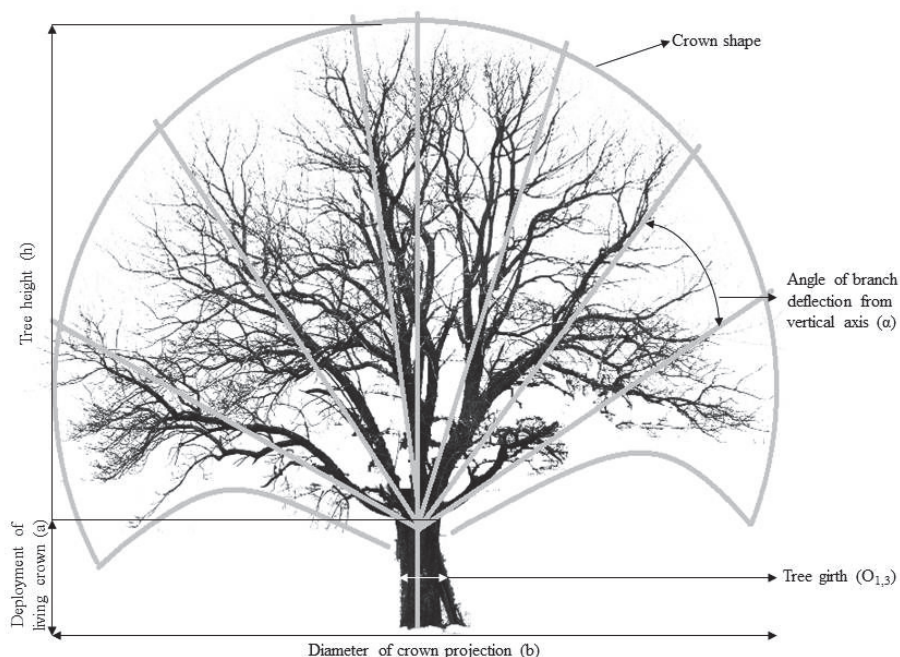


Fig. 4. Selected tree parameters measured and evaluated within the field study of the phenotypic classification of *Sorbus domestica* L (Paganova & Maceková, 2011).

Quantitative parameters		Qualitative parameters
Measured	Calculated	Crown shape Trunk development Tree trunk shape Cross sectional shape of the trunk Thickness of branches Tree branch angle
Tree height	Crown density	
Stem girth	Crown volume	
Deployment of living crown	Crown projection area	
Crown diameter	Crown length	

Table 1. Selected parameters of trees measured and evaluated for *Sorbus domestica* and *Pyrus pyraeaster* within the study of their phenotypic variability and assessment of the gene pool quality.

In addition to these quantitative parameters, the crown shape, crown density and several other qualitative characteristics (trunk shape, trunk development and cross sectional shape of the trunk) were evaluated within field study. The photo documentation of tree habit was made for each of the evaluated genotypes of *Sorbus domestica* and *Pyrus pyraeaster*. The records will be used for other graphic processing. Within analytical data processing the other quantitative parameters of the tree habit were calculated: crown length, crown area projection and crown volume.

The relationship between parameters of the tree crown and stem were calculated for both woody plant species based on mentioned quantitative data, as well as the relationship between crown architecture and structural characteristics  $\Rightarrow$  regression analysis; we attempted to define a range of structural parameters of the trees, which are characteristic for high-quality phenotypes (plus trees) of *Sorbus domestica* and *Pyrus pyraeaster*. The multivariate statistical methods (discriminant analysis etc.) were used for assessment.

Preliminary data obtained within the field study documented distinctive variability of the phenotypic parameters of *Sorbus domestica* (Paganová & Maceková, 2011). Five basic crown shapes were found: conical, ovate, globular, parabolic and semi-globular (Fig. 5) within the population of trees growing in one location. Good phenotypic characteristics were confirmed for 12 individuals among the whole number of 35 individuals of *Sorbus domestica* which were evaluated according to the phenotypic classifications within the field study. These trees can be later (after additional testing and assessment) included under selected sources of the reproductive material of *Sorbus domestica*.

Location of the evaluated individuals on their original stand was determined using GPS, which will facilitate identification of the trees in the future. GPS was used also for determination of the shape and area of the crown projection within the field data collection.

The aim of the tree assessment is establishment of a database of genotypes for both woody plant species (*Sorbus domestica* and *Pyrus pyraeaster*) from the territory of Slovakia and selection of phenotypes suitable for landscape design and urban greenery. Selection of suitable sources for a reproduction (Drobná & Paganová, 2010) and breeding programme of the mentioned species was identified from the database of genotypes based on the classifications of the phenotypic characteristics (Fig. 6).



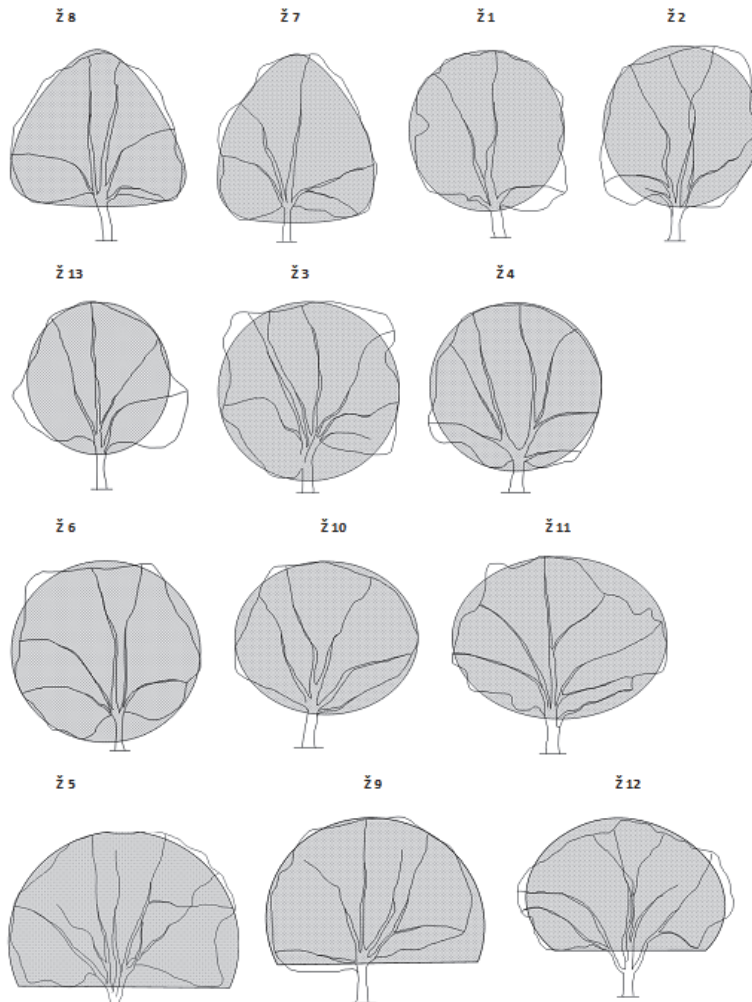


Fig. 5. Models of the crown architecture for *Sorbus domestica* designed according to the data obtained from the field assessment of trees. Quite large phenotypic variability of the specimen growing on one location at Žemberovce is evident. Crown shape - conical (Ž8, Ž7), ovate (Ž1, Ž2, Ž13) globular (Ž 3, Ž4, Ž6), parabolic (Ž10, Ž11) and semi-globular (Ž5, Ž9, Ž12).

#### 4.2 Assessment of the phenotypic plasticity of woody plant species to drought

One-year old seedlings of the wild pear and service tree were analysed. Plant material was produced directly for purposes of the experimental assessment of the physiological parameters of the analysed woody plants. Reproductive material came from the original stands of *Sorbus domestica* (Kosihovce, altitude 250 m) and *Pyrus pyraster* (Tŕnie, altitude 540 m) in Slovakia. The seeds of both species passed winter pre-sowing treatment in the cold



greenhouse with temperatures ranging from +5°C to -5°C and germinated in the boxes with fertilized sowing substrate based on white sphagnum (peat moss). In the phenological stage “expanded cotyledons” (Šenšel & Paganová, 2010) seedlings were placed in the plant boxes (content 1.17 L) filled with fertilized peat substrate (white sphagnum, pH 5.5-6.5; fertilizer 1.0 kg.m<sup>-3</sup>). Construction of the root boxes enabled the analytical assessment of the root growth and root structures (Fig. 3). The boxes were placed under a polypropylene cover with 60% shading. The plants were regularly watered and maintained on 60% and 40% of the full substrate saturation, two variants according to a differentiated water regime. Variant “stress” was supplied with water at 40% of full substrate saturation and “control” at 60% of full substrate saturation. The model of the differentiated water regime was maintained for 170 days (from April to the end of September).

After exposure to water stress the size of the leaf area (A) was calculated from leaf scans using ImageJ software (URL 2). The dry weight of the roots, shoots and leaves (DW) was determined gravimetrically, additionally leaf water content (LWC) was calculated. For metabolic characteristics, the total chlorophyll and carotenoid content were determined in the leaves according to the methods described by Šesták & Čatský (1966).

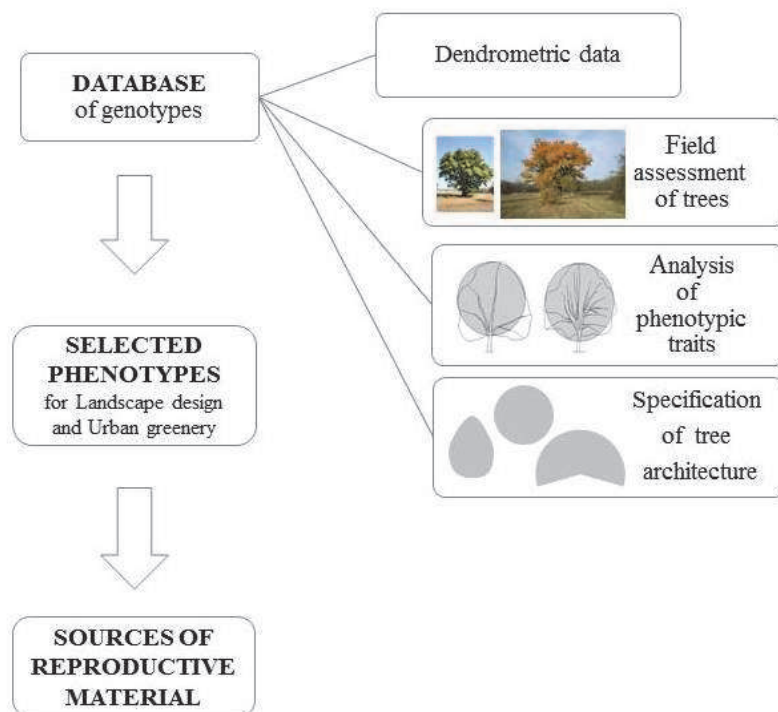


Fig. 6. Assessment and selection of the sources of reproductive material for utilization of indigenous woody plants in landscape planning and urban greenery



Fig. 7. The root box constructed from a metal frame and glass front wall used for the analytical assessment of the root growth and structures (Drobná, 2010).

Data were analysed from two growing seasons in 2010 and 2011 for each taxon under two variations of water regimes (40% and 60% substrate saturation). There was calculated S: R ratio for particular species and both variants of the substrate saturation. The relationship between chlorophyll and carotenoid content of the plants under stress and control conditions, as well as impact of water stress on complex of assimilatory pigments were analysed. A statistical assessment of these parameters was conducted by regression analysis and multivariate analysis of variance of using the statistical software Statgraphics Centurion XV (StatPoint Technologies, USA). A  $P < 0.05$  was considered statistically significant.

The reactions of two woody plant species *Pyrus pyrastrer* and *Sorbus domestica* on water stress in the juvenile phase of their growth (one-year old seedlings) were analysed in the model experiments with controlled water regime. In the first step of analysis, the size of the leaf area, dry weight of roots, shoots and leaves (DW) were determined, leaf water content calculated and the content of assimilatory pigments was quantified. In the last analysis, the significant interspecific differences in the size of leaf area were documented (Table 2), when *Sorbus domestica* had nearly twice higher leaf area than *Pyrus pyrastrer*. The difference in the size of the leaf area has not been accompanied by significant differences in accumulation of dry mass of leaves. However, there were differences in the investment of assimilates, *Sorbus domestica* used them for growth of the leaf area and *Pyrus pyrastrer* for construction of the mesophyll structures. The interspecific differences are documented also by values of the specific leaf area (SLA) for *Sorbus domestica* (SLA =  $0.0219 \text{ m}^2 \cdot \text{g}^{-1}$ ) and for *Pyrus pyrastrer* (SLA =  $0.0157 \text{ m}^2 \cdot \text{g}^{-1}$ ).

Assessment of the dry mass distribution into particular organs of woody plants confirmed different strategies for analysed species. Comparison of the values of shoot : root ratio (S : R) for analysed taxa is also interesting. There were found statistically significant differences, between wild pear and service tree. According to the obtained data, *Sorbus domestica* preferentially distributes higher amount of dry mass to roots (S : R = 0.70), while

distribution of dry mass is rather balanced between underground and upper organs of *Pyrus pyraister* (S : R = 1.11) (Table 2). The impact of water stress on distribution of dry mass to organs has not been documented. According to the obtained results seedlings under stress and in control conditions had very similar values of the shoot : root ratio (S : R = 0.87 and 0.93). The impact of water stress is manifested in production of dry mass of roots, that represents average value of the parameter for one plant ( $DW_R=0.59g$ ). While in control conditions the average value of this parameter is nearly twice higher ( $DW_R=1.22g$ ). Dry mass distribution patterns typical for particular species are determining also under conditions of differentiated water regime. Service tree (*Sorbus domestica*) preferably accumulates dry mass in root system, wild pear (*Pyrus pyraister*) distributes evenly dry mass to upper and underground organs. Distribution of dry mass in organs of analysed woody plants has not been significantly influenced by drought. Species differentiation in shoot-root ratio (S:R) in favour of the distribution of dry mass in the root was confirmed for young cuttings of poplar Ibrahim et al.(1997).

The content of assimilatory pigments was also evaluated for both species. Significant differences were found in the total chlorophyll content (CC) and the content of carotenoids (CAR) (Table 2). Seedlings of *Sorbus domestica* cumulated a significantly lower content of total chlorophyll and carotenoids in the leaves than did the *Pyrus pyraister* seedlings. The interspecific differences are documented by average values of the total chlorophyll content *Sorbus domestica* ( $311.67 \text{ mg.mm}^{-2} * 10^{-6}$ ) and *Pyrus pyraister* ( $490.90 \text{ mg.mm}^{-2} * 10^{-6}$ ) and also by average values of the carotenoid content for *Sorbus domestica* ( $72.72 \text{ mg.mm}^{-2} * 10^{-6}$ ) and for *Pyrus pyraister* ( $117.07 \text{ mg.mm}^{-2} * 10^{-6}$ ). The ratio of carotenoid to total chlorophyll content (CAR : CC) had the same value (0.24) for both species. In this context, significant differences in the content of the assimilatory pigments indicate differences in the performance of the assimilatory apparatus of the wild pear and service tree in the juvenile phase of growth.

Content of assimilatory pigments of the seedlings was negatively affected by water stress. Under conditions of water scarcity seedlings produced significantly less chlorophyll ( $346.02 \text{ mg.mm}^{-2} * 10^{-6}$ ), as well as carotenoids ( $84.42 \text{ mg.mm}^{-2} * 10^{-6}$ ) than in control conditions ( $CC=456.55 \text{ mg.mm}^{-2} * 10^{-6}$ ,  $CAR = 105.37 \text{ mg.mm}^{-2} * 10^{-6}$ ). The ratio of the carotenoid content to total chlorophyll content CAR : CC differs significantly according to level of the substrate

Parameter Source of variance	A (mm <sup>2</sup> )	DW <sub>R</sub> (g)	DW <sub>L</sub> (g)	DW <sub>S</sub> (g)	S/R	LWC (%)	CC (mg.mm <sup>-2</sup> )* 10 <sup>-6</sup>	CAR (mg.mm <sup>-2</sup> )* 10 <sup>-6</sup>	CAR/CC
<i>Sorbus domestica</i>	12016,5b	1,19b	0,55a	0,20a	0,70a	52,44a	311,67a	72,72a	0,24a
<i>Pyrus pyraister</i>	6286,99a	0,62a	0,40a	0,26a	1,11b	50,09a	490,90b	117,07b	0,24a
Control	12292,3b	1,22b	0,64b	0,34b	0,87a	48,78a	456,55b	105,37b	0,23b
Stress	6011,13a	0,59a	0,31a	0,13a	0,93a	53,75a	346,02a	84,42a	0,25a

Table 2. Average values of the selected physiological parameters of one-year seedlings of *Sorbus domestica* L. and *Pyrus pyraister* L. Burgsd. Seedlings were planted in the root boxes under conditions of differentiated water regime. Statistically significant differences (according to 95% LSD test) between average values of the analysed parameters are documented by different letters.

saturation in variant stress (0.25) and under control conditions (0.23). The content of carotenoids in the leaves increased in conditions of water scarcity. That is evidence of the negative impact of drought on the complex of assimilatory pigments. The results (Table 2) document species differentiation in production of the assimilatory pigments for individuals in the juvenile phase of growth, as well as significant impact of drought on the total content and particular components of the assimilatory pigments.

An interesting view on responses of the analysed woody plants is supplied within comparison of the relationship between parameters leaf dry weight ( $DW_L$ ) and size of leaf area (A). The relationship between these parameters is highly significant in both variants of the substrate saturation (stress and control) for *Sorbus domestica* (Fig. 8 and 9). The course of values is described by an exponential function in control variant:  $Y = (a + b \cdot X)^2$

$$A = (-1.68046E^8 + 6.45785E^8 \cdot DW_L)^2,$$

by contrast, in stress variant is documented with an exponential function:  $Y = a + b \cdot X^2$

$$A = 3723.8 + 23848.7 \cdot DW_L^2.$$

Under conditions of water scarcity, *Sorbus domestica* accumulated less dry mass in the leaves and significantly reduced the growth of leaf area, that is evident in the course of the functional relationship of these parameters. In the control variant (Fig. 8) the value of leaf dry weight ( $DW_L = 0.63\text{g}$ ) corresponds to leaf area size ( $A = 14800\text{ mm}^2$ ), whilst in the stress variant (Fig. 9) the same value of leaf dry weight ( $DW_L = 0.63\text{ g}$ ) corresponds to higher size of the leaf area ( $A = 11800\text{ mm}^2$ ). *Sorbus domestica* significantly reduced growth of the leaf area under conditions of water scarcity and formed thicker leaves, probably for better water management.

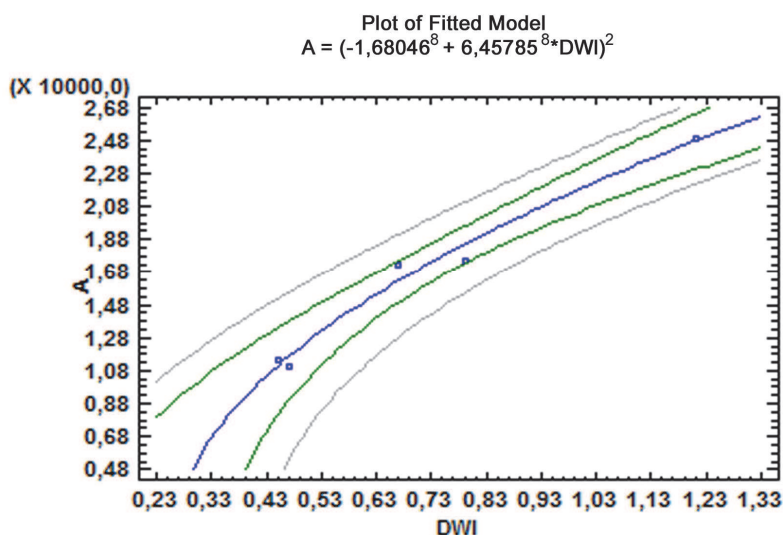


Fig. 8. Simple regression between leaf dry weight ( $DW_L$ ) and size of the leaf area (A) for seedlings of *Sorbus domestica* growing under control conditions. Correlation coefficient ( $r$ ) = 0.992349 p value = 0.0008

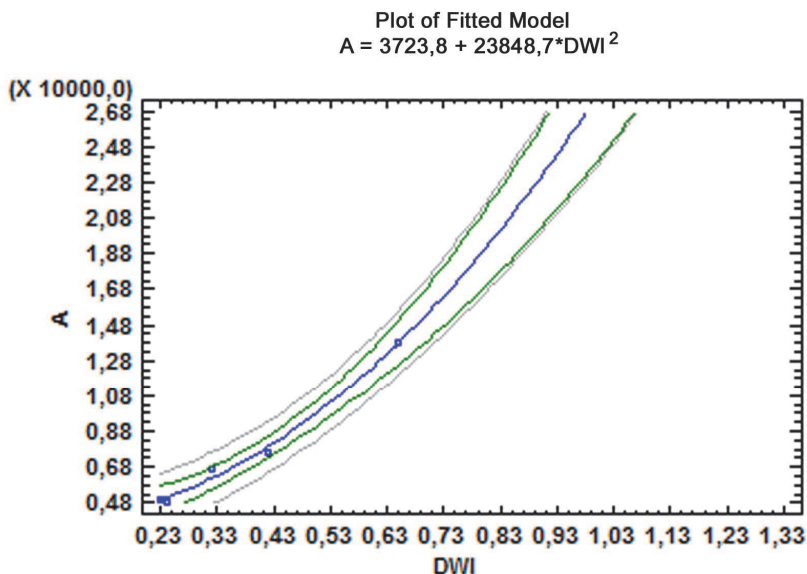


Fig. 9. Simple regression between leaf dry weight ( $DW_L$ ) and size of the leaf area ( $A$ ) for seedlings of *Sorbus domestica* growing under conditions of water stress. Correlation coefficient ( $r$ ) = 0.995305 p value = 0.0004

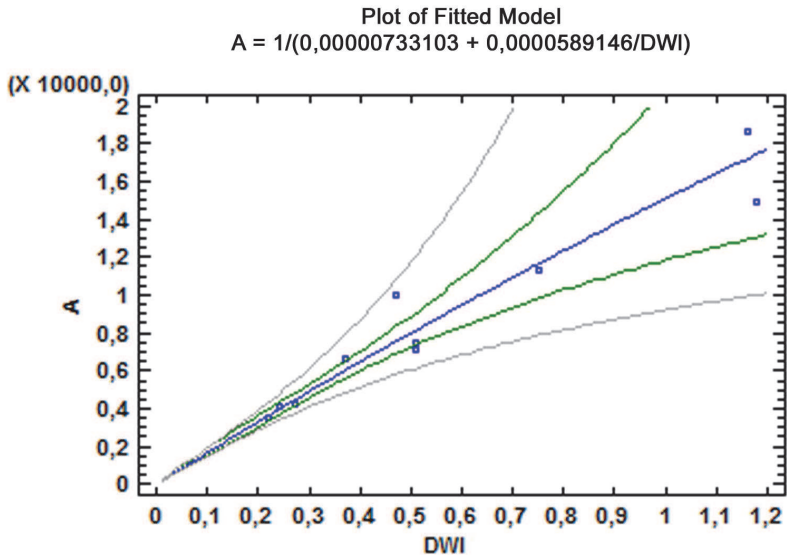


Fig. 10. Simple regression between leaf dry weight ( $DW_L$ ) and size of the leaf area ( $A$ ) for seedlings of *Pyrus pyraster* growing under control conditions. Correlation coefficient ( $r$ ) = 0.980787, p value = 0.0000

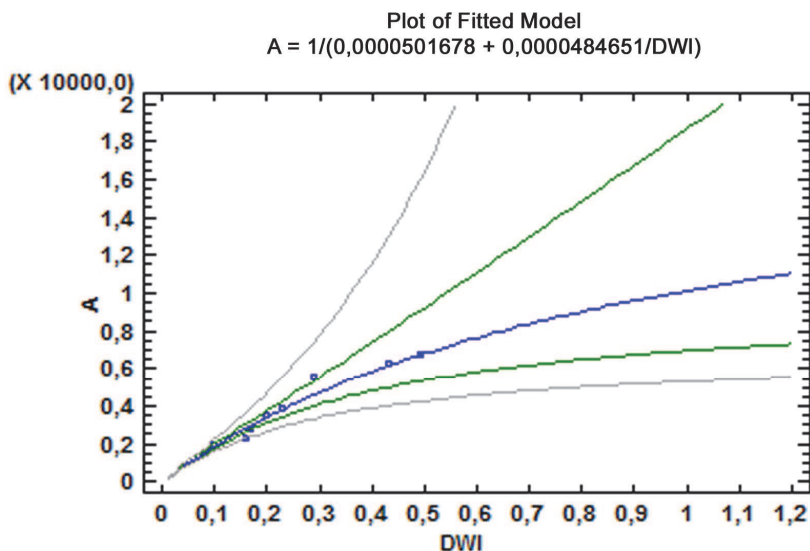


Fig. 11. Simple regression between leaf dry weight ( $DW_L$ ) and size of the leaf area ( $A$ ) for seedlings of *Pyrus pyrastrer* growing under conditions of water stress. Correlation coefficient ( $r$ ) = 0.984167,  $p$  value = 0.0000

The relationship between size of the leaf area ( $A$ ) and leaf dry weight ( $DW_L$ ) is highly significant and closely correlated ( $r = 0.98$ ) for the wild pear (*Pyrus pyrastrer*). It is described by double reciprocal function:  $Y = 1/(a + b/X)$  in both variants of the substrate saturation (stress and control).

The reduction of growth of the leaf area under water stress conditions has been documented also for *Pyrus pyrastrer* according the course of the functional relationship between the analysed parameters. In the control variant the leaf area 9000 mm<sup>2</sup> corresponds to leaf dry weight  $DW_L = 0.60g$ , whilst in the stress variant (Fig. 11) the same value of leaf dry weight corresponds to lower leaf area to about 7000 mm<sup>2</sup>. Wild pear also demonstrated a reduction of the leaf area in conditions of water scarcity. However, wild pear forms a lower leaf area in comparison to the service tree generally.

In this context it is interesting to note that between the wild pear and the service tree seedlings analysed in the juvenile phase of growth, significant differences in leaf water content (LWC) were not confirmed (Table 2). The average value of the leaf water content for the wild pear (*Pyrus pyrastrer*) was 50.2% and for the service tree (*Sorbus domestica*) the average value of the same parameter was 52.4%. Non-significant differences of LWC were found also for seedlings growing in conditions of the different level of substrate saturation: control (48.8%), stress (53.7%).

Both species are able to maintain balanced water content in leaves, even in conditions of water scarcity. However, they probably use different mechanisms of adaptability to water stress.



## 5. Conclusions

This study describes criteria and tools for woody plant selection for landscape planning, where there is potential to use a wider range of species. A limiting factor for selection of other woody plant species is the lack of information about their eco-physiological characteristics. These are key characteristics of the adaptability of woody plants to changed environmental conditions in the cultural landscape and urban areas.

The new planning and design concept allows for taking parts of nature with its specific beauty and amenity for urban spaces, as well as using native species and their communities for urban plantings. Utilization of indigenous species should support an increase of the biodiversity in urban areas with ecologically better balanced plant communities.

The advantage of using native woody plant species in landscape planning and design is the broad base of their genetic resources in the landscape and this represents a sufficient basis for the selection of the most suitable phenotypes and individuals.

Efficient use of indigenous species of plants and trees in landscape planning requires well-defined selective criteria within natural populations of plants, thus enabling distinguishing from within the native populations genotypes with the appropriate traits for specific environmental conditions.

The evaluation of woody plants and their responses to specific conditions and stress factors in the urban environment and cultural landscape requires exact assessment methods and techniques.

The results presented synthesize information about woody plants obtained from field research on original stands in the landscape, as well as findings obtained from experimental research held under controlled conditions (study aimed at assessing the impact of drought on some physiological parameters).

*Sorbus domestica* and *Pyrus pyraeaster* are considered to be light-demanding woody plants with similar ecological requirements on environmental conditions. However, their adaptability and response to water scarcity are different.

Data about the phenotypic structure and properties of the natural genetic resources were collected within a programme of selection of woody plant species for landscapes and urban environments. According to the ensemble of the quantitative and qualitative phenotypic traits the most valuable architectural individuals can be selected. The selected genotypes are recommended for further testing under controlled and regulated conditions in order to determine their adaptability to negative (stress) factors. These selection principles were used within assessment of the indigenous woody plant species *Sorbus domestica* and *Pyrus pyraeaster* in Slovakia.

Reactions of woody plants on water stress were evaluated in the juvenile phase of their growth. Significant interspecific differences in the size of leaf area were documented, with *Sorbus domestica* having nearly double the leaf area of *Pyrus pyraeaster*. The difference in the size of the leaf area has not been accompanied by significant differences in accumulation of dry mass of leaves. However, there were differences in the investment of assimilates, *Sorbus domestica* used them for growth of the leaf area and *Pyrus pyraeaster* for construction of the mesophyll structures.

Dry mass distribution patterns characteristic for particular species were also determined under conditions of differentiated water regimes. The service tree (*Sorbus domestica*) preferably accumulates dry mass in the root system, while the wild pear (*Pyrus pyraeaster*) distributes dry mass evenly to upper and underground organs. Distribution of dry mass in the organs of the analysed woody plants was not significantly influenced by drought.

Content of assimilatory pigments of the seedlings was negatively affected by water stress. Under conditions of water scarcity, seedlings produced significantly less chlorophyll and carotenoids than in control conditions. The carotenoids content to total chlorophyll content ratio (CAR : CC) values differed significantly according to level of the substrate saturation. The content of carotenoids in the leaves increased in conditions of water scarcity. That is evidence of the negative impact of drought on the complex of assimilatory pigments. The results document species differentiation in production of the assimilatory pigments for individuals in the juvenile phase of growth, as well as the significant impact of drought on the total content and particular components of the assimilatory pigments.

Between the evaluated species significant differences of the leaf water content (LWC) were not confirmed in the juvenile phase of growth. Both species are able to maintain balanced water content in the leaves, even in conditions of water scarcity. However, they probably use different adaptability mechanisms to water stress.

## 6. Acknowledgment

This research was supported by research grant projects VEGA 1/0426/09 "Plant adaptability and vitality as criteria of their utilization in urban environment and VEGA 1/1170/11 „Anthropogenic impacts on production and quality of surface runoff from small basins in conditions as climate change“ from Slovak Grant Agency for Science.

## 7. References

- Bowyer, J.L., Shmulsky, R. & Haygreen, J.G. (2002). Forest products and wood science: An introduction. Iowa State Press, Ames, Iowa, 554 p.
- Breuste, J. H. (2004). Decision making, planning and design for the conservation of indigenous vegetation within urban development. *Landscape and Urban Planning*, 68 (2004) 439-452.
- Brütsch, U. & Rotach, P. (1993). Der Speierling (*Sorbus domestica* L.) in der Schweiz: verbreitung, Ökologie, Standortsansprüche, Konkurrenzkraft und waldbauliche Eignung. *Schweiz. Z.Forstwes.*, vol. 144, No. 12 :967-991.
- Drobná, L. & Paganová, V. (2010). Germination rate and qualitative characteristics of true service tree (*Sorbus domestica* L.) seeds from different stands. *Acta Horticulturae et Regio Tecturae. Acta horticulturae et regioteecturae*. 2010. Vol. 13, spec. issue, p. 17--20. ISSN 1335-2563.
- Dunnett, N. & Hitchmough, J. (2004). The dynamic landscape: Design, Ecology and Management of Naturalistic Urban Planting. 2004, Spon press, Taxylor & Francis group: London and New York. 484 pp ISBN 0-415-25620-8
- Dwyer, J.F., McPherson, E.G., Schroeder, H.W. & Rowntree, R.A. (1992) Assessing the benefits and costs of the urban forest. *Journal of Arboriculture* 18(5)227-234.

- Dwyer, J.F., Nowad, D.J. & Noble, M.H. (2003). Sustaining urban forests, *Journal of Arboriculture* 29:49-55.
- Emhart, V. I., Martin T. A., White, T.L. & Huber, D.A. (2007). Clonal variation in crown structure, absorbed photosynthetically active radiation and growth of loblolly pine and slash pine. *Tree Physiology* 27, 421-430
- Florgård, C. (2004). Preservation of indigenous vegetation in Urban areas – an introduction. *Landscape and Urban Planning* 68(2004) 343-345.
- Ibrahim, L., Proe, M.F. , Cameron, A.D. (1998). Interactive effects of nitrogen and water availabilities on gas exchange and whole-plant carbon allocation in poplar. *Tree physiol.*,18(7):481-487 2002 Heron Publishing-Victoria, Canada
- Kozłowski, T. Kramer , P.J. & Pallardy, S.G. (1991) *The Physiological Ecology of Woody Plants*. New York, Academic Press, 1991, ISBN 978-0124241602, 657p.
- McPherson, E.G. & Simpson, J.R. (2003). Potential energy savings in buildings by an urban tree planting programme in California, *Urban Forestry & Urban Greening* 2:73-86.
- Nilsson, K. Randrup T.B & Wandall B.M. (2000). Trees in the urban environment. In: *The Forest Handbook* (Ed. Evans J), Volume 1:347-361. Blackwell Science, Oxford.
- Pagan, J. & Paganová, V. (2000). Variability of service tree in Slovakia (Premenlivosť jarabiny oskorušovej (*Sorbus domestica* L.) na Slovensku). *Acta Facultatis Forestalis*, vol. 42., 2000, p. 51-67. ISBN 80-228-0982-9
- Pauleit, S., Jones, N., Garcia-Martín G., Garcia-Valdecantos J.L., Riviere L.M., Vidal-Beaudet L., Bodson, M. & Randrup T.B. (2002). Tree establishment practice in towns and cities – results from a European survey. *Urban Forestry & Urban Greening* 1(2):83-96.
- Paganová, V. (2003a). Wild pear *Pyrus pyraeaster* (L) Burgsd. requirements on environmental conditions. In: *Ekológia*, Bratislava, vol. 23, 2003, No.3, p. 255-241.
- Paganová, V. (2003b). Habit and dimensions of wild pear (*Pyrus pyraeaster* /L./ Burgsd.) in Slovakia. *Folia Oecologica*, vol. 30., 2003, no. 1, p. 7-19. ISBN 80-967238-2-0
- Paganova, V. (2004). Planning arrangement of vegetation in the agricultural landscape. In: Demo, M. & Látečka, M. (eds). *Designing of the sustainable farming system in the landscape. (Projektovanie trvalo udržateľných poľnohospodárskych systémov v krajine)*. Nitra : Slovenská poľnohospodárska univerzita, 2004. 603 - 629. ISBN 80-8069-391
- Paganová, V. (2006). Biodiversity research of the rare woody plants in Slovakia as a condition of their conservation and utilization in the landscape / In *Biotechnology 2006 [elektronický zdroj] : sborník Zemědělské fakulty JU, 15.- 16.2.2006 České Budějovice. - České Budějovice : Jihočeská univerzita, 2006. - ISBN 8085645-53-X. - S. 1121-1124.*
- Paganová, V. (2008). Ecology and distribution of service tree *Sorbus domestica* (L.) in Slovakia. In: *Ekológia*, Bratislava, 2008, 27(2):152-168.
- Paganová, V., Jureková,Z., Dragúňová, M. & Lichtnerová, H. (2010). Monitoring of physiological characteristics for assortment selection of woody plants in urban areas. *Acta horticulturae et regioteurrae*. 2010. Roč. 13, spec. issue, s. 7--11. ISSN 1335-2563.
- Paganová, V. (2011). Design of the vegetation modifications in agricultural landscape. In: Demo, M. (ed.) *Sustainable farming system's designing. Projektovanie udržateľných poľnohospodárskych systémov v krajinnom priestore*. Vyd. Nitra : Slovenská poľnohospodárska univerzita, 2011. 487- 524 . ISBN 978-80-552-0547-2
- Paganová, V. & Jureková, Z. (2012). Adaptability of woody plants in aridic conditions. In: *Evapotranspiration - Remote Sensing and Modeling. -- 1st. ed.. -- 514 p.. -- 978-953-307-808-3 Rjeka : InTech, 2011. -- p. 493-514.*

- Paganová, V. & Maceková M. (2011). Significance of the phenotypic classification of the Service tree (*Sorbus domestica* L.) in Slovakia. Význam fenotypovej klasifikácie jarabiny oskorušovej (*Sorbus domestica* L.) v podmienkach SR. In: Aktuálne otázky štúdia introdukovaných drevín : Proceedings of the scientific conference. Arborétum Mlyňany SAV. p. 136-142. ISBN 978-80-970849-8-1.
- Rittershoffer, B. (1998). Förderung seltener Baumarten im Wald. Auf den Spuren der Wildbirne. In: Allgemeine Forstzeitschrift / Der Wald, 16, p. 860-862.
- Sæbo, A., Benedikz, T. & Randrup, T. (2003). Selection of trees for urban forestry in the Nordic countries. Urban Forestry and Urban Greening 2 (2003): 101-114
- Sæbo, A., Borzan Ž., Ducatillon, C., Hatizstathis A., Lagerström, T., Supuka J., García-Valdecantos, L., Rego, F. & Van Slycken, J. (2005). The Selection of Plant Materials for Street Trees, Park Trees and Urban Woodland. In: Konindejik, C., Nilsson, K., Randrup, T., Schpperijn, J. (eds.) Urban Forests and Trees: A Reference Book. 2005. Springer Verlag. Berlin Heidelberg. 257-280 ISBN 354025126X
- Sand, M. (1994). Design and species selection to reduce urban heat island and conserve energy. In: Proceedings from the Sixth National Urban Forest Conference: Growing Green Communities. Minneapolis, Minn. (pp. 148-151). Washington D.C.: American forests.
- Simpson, J.R. (1998). Urban forest impacts on regional space conditioning energy use: Sacramento and county case study. Journal of Arboriculture. 24(4):201-214.
- Sjöman, H. (2012). Trees for Tough Urban Sites. Doctoral thesis, Swedish University of Agricultural Sciences, Alnarp 2012
- Spellenberg, I. & Given, D. (2008). Trees in urban and city environments: a review of the selection criteria with particular reference to nature conservation in New Zealand cities. In : Landscape Review, 2008, 12 (2) 19-31.
- Sultan, S.E. (2004). Promising directions in plant phenotypic plasticity. In: Perspectives in Plant Ecology, Evolution and Systematics. Elsevier GmbH, 2004, Vol. 6/4, pp. 227-233
- Šenšel, R. & Paganová, V. (2010) Identification key of the wild pear (*Pyrus pyraster* L. Burgsd.) - phenological stages and potential for application in research and practice. Acta horticulturae et regiotecturae. 2010. Vol. 13, spec. issue, s. 21--23. ISSN 1335-2563.
- Šesták, J. & Čatský J. (1966). Metody studia fotosyntetické produkce rostlin, Akademia, ČSAV Praha, 393 p.
- Šmelko, Š. (2000). Dendrometria. Vysokoškolská učebnica. Vydavateľstvo TU vo Zvolene. ISBN 80-228-0962-4, 399s.
- URL1: *Inventarizace lesů, Metodika venkovního sběru dat* [cit. 2011-09-09]. Dostupné na internete: [http://www.uhul.cz/il/metodika/metodika6/kap\\_3\\_6\\_0.pdf](http://www.uhul.cz/il/metodika/metodika6/kap_3_6_0.pdf)
- URL2: ImageJ. Image Processing and Analysis in Java. <http://rsbweb.nih.gov/ij/>
- Valladares, F., Gianoli, E. & Gómez, J., M. (2007). Ecological limits to plant phenotypic plasticity. New Phytologist 176: 749-763
- Westphal, L.M. (2003). Urban greening and social benefits: A study of empowerment outcomes. Journal of Arboriculture 29(3): 137-147.
- Wilhelm, G., J. (1998). Im Vergleich mit Elsbeere und Speierling Beobachtungen zur Wildbirne. AFZ. Der Wald, 16: 856-859.
- Wu R. & Stettler, R.F. (1998). Quantitative genetics of growth and development in *Populus*. III. Phenotypic plasticity of crown structure and function. *Heredity* 81: 299-310.



## **Landscape Planning**

Edited by Dr. Murat Ozyavuz

ISBN 978-953-51-0654-8

Hard cover, 360 pages

**Publisher** InTech

**Published online** 13, June, 2012

**Published in print edition** June, 2012

Landscape architecture is the design of outdoor and public spaces to achieve environmental, socio-behavioral, and/or aesthetic outcomes. It involves the systematic investigation of existing social, ecological, and geological conditions and processes in the landscape, and the design of interventions that will produce the desired outcome. The scope of the profession includes: urban design; site planning; town or urban planning; environmental restoration; parks and recreation planning; visual resource management; green infrastructure planning and provision; and private estate and residence landscape master planning and design - all at varying scales of design, planning and management. This book contains chapters on recent developments in studies of landscape architecture. For this reason I believe the book would be useful to the relevant professional disciplines.

### **How to reference**

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Viera Paganová and Zuzana Jureková (2012). Woody Plants in Landscape Planning and Landscape Design, Landscape Planning, Dr. Murat Ozyavuz (Ed.), ISBN: 978-953-51-0654-8, InTech, Available from: <http://www.intechopen.com/books/landscape-planning/woody-plants-in-landscape-planning-and-landscape-design>

**INTECH**  
open science | open minds

### **InTech Europe**

University Campus STeP Ri  
Slavka Krautzeka 83/A  
51000 Rijeka, Croatia  
Phone: +385 (51) 770 447  
Fax: +385 (51) 686 166  
[www.intechopen.com](http://www.intechopen.com)

### **InTech China**

Unit 405, Office Block, Hotel Equatorial Shanghai  
No.65, Yan An Road (West), Shanghai, 200040, China  
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元  
Phone: +86-21-62489820  
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.