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NORTH-EAST ROMANIA AS A FUTURE SOURCE OF TREES FOR URBAN PAVED ENVIRONMENTS IN NORTH-WEST EUROPE

SJÖMAN HENRIK [1], RICHNAU GUSTAV[1]

Abstract: Trees are an important feature of the urban environment. The problem today lies not in finding a wide range of well-adapted tree species for park environments, but in finding species suitable for urban paved sites. In terms of north-west Europe, it is unlikely that the limited native dendroflora will provide a large variety of tree species with high tolerance to the environmental stresses characterising urban paved sites in the region. However, other regions with a comparable climate but with a rich dendroflora can potentially provide new tree species and genera well-suited to the growing conditions at urban sites in north-west Europe. This paper examines the potential of a geographical area extending over north-east Romania and the Republic of Moldavia to supply suitable tree species for urban paved sites in Central and Northern Europe (CNE). The study involved comparing the temperature, precipitation, evapotranspiration and water runoff in the woodland area of Iasi, Romania, with those the current inner-city climate of Copenhagen, Denmark and those predicted for Copenhagen 2100. The latter included urban heat island effects and predicted global climate change. The results revealed similar pattern in summer water deficit and temperature between natural woodlands in Iasi and inner-city environment of Copenhagen today. On the other hand, there is a weak match between Iasi and the future Copenhagen. In order to match the future scenario of Copenhagen with the present situation in Iasi, a greater understanding in a early phase that the solution not only depends on suitable tree species, but also on technical solutions being developed in order to have trees in paved environments in the future. On the basis of precipitation and temperature data, natural woodlands in north-east Romania have the potential to be a source of suitable trees for urban paved environments in the CNE region, even for a future climate if other aspects in the planning of trees in paved sites are included.

Keywords: Urban paved environment, city trees, site-adapted species use, urban heat island, climate change.

Introduction

Trees fulfil important aesthetic, social and environmental functions in urban areas. However, trees growing along streets and in paved environments are exposed to numerous hostile factors such as heat, drought, soil compaction, pollution, de-icing salt, high soil lime content and high soil p*H*, which cause reduced vitality and decline and render trees susceptible to pest and diseases [PAULEIT, 2003]. The sealed surface and increased temperatures in cities minimise water infiltration, while simultaneously increasing evaporation rates [FLINT, 1985]. Therefore, many trees in urban paved sites are periodically exposed to critical water stress. In addition to the negative site conditions in urban paved environments, another serious threat to urban tree stocks is lack of diversity, particularly in view of predicted climate change. Traditionally, a limited number of species and genera have dominated urban tree stocks, and recent surveys in European and North American cities show that a few species/genera continue to dominate, especially in urban paved sites [e.g. BÜHLER O. & al. 2007; PAULEIT & al., 2002; RAUPP & al. 2006]. Furthermore, many of the most used tree species show severe symptoms of decline. The recurring outbreaks of

[1] Swedish University of Agricultural Sciences, Faculty of Landscape Planning, Horticulture and Agricultural Science, Department of Landscape Management, Design and Construction, Box 66, 23053 Alnarp, Sweden. E-mail; Henrik.Sjoman@ltj.slu.se , Gustav.Richnau@ltj.slu.se

disease in some of the most commonly used species and the threat of future diseases and pest infestations [e.g. RAUPP & al. 2006; SUN, 1992; TELLO & al. 2005] have led to considerable and persistent arguments on the necessity of using a wider range of species that are better adapted to the harsh conditions in urban paved environments [BARKER, 1975; BASSUK & al. 2003; GREY & DENEKE, 1986; MILLER & MILLER, 1991; MOLL, 1989; SANTAMOUR, 1990; SMILEY E. T., KIELBASO & PROFFER, 1986].

The awareness of habitat factors when bringing trees to city parks, squares and avenues was probably not much developed in the past, partly because the city environment did not differ that much from the local natural habitat at that time. Therefore most of the city trees were origin from local forest areas. Nowadays we tend to use the same species as before, in spite of the fact that the city habitat has changed very much and nowadays have few similarities with the natural grow conditions in the local woodlands and this pattern will change even further in the future.

Therefore, identification of natural environments where trees have evolved in habitats more related to the paved city context may be a successful strategy for selection of new species for urban areas [WARE, 1994]. There are several areas of the world with a climate regime that is similar to the microclimate of streets, squares and courtyards. These areas are mainly found in continental regions, as the continental climate type has obvious similarities to the inner city climate.

Today, we face two important challenges in the planning and management of trees in urban streets and other paved sites. Firstly, there is a need for more knowledge and practical experience about site-adapted use of species. Secondly, a greater variety of species and genus with natural adaptations for surviving and developing well at such sites needs to be introduced. The objective of this paper was to examine the potential of a geographical area encompassing north-east Romania and the Republic of Moldavia to supply suitable tree species for urban paved environments in northern parts of Central Europe and in adjacent, mild parts of Northern Europe (in the following abbreviated to ‘the CNE region’). This study forms part of a four-year research programme initiated by the Swedish University of Agricultural Sciences to examine selection of site-adapted species for urban paved sites, with the main focus on identifying geographical areas in the world which have the potential to supply promising tree species for further evaluation.

Global and local climate changes

The modern city creates its own climate, with warmer temperatures compared with the surrounding rural landscape, a phenomenon normally referred to as *Urban Heat Island* (UHI). The city is warmer than the countryside because of differences between the energy gains and losses in each region [KING & DAVIS, 2007]. In a city of 1 million people, this UHI effect can increase the mean annual temperature by 1-3 ^{o}C and in the evening the difference between inner-city environment and surrounding rural landscape can be as high as 12 ^{o}C [LANDSBERG, 1981; US EPA, 2009]. The UHI effect will be much more pronounced in the future as a result of the expected climate change in the CNE region, which is predicted to adversely affect the conditions for tree growth through increased average temperatures of 2-6 ^{o}C combined with more frequent heatwaves and periods of drought during summer [GILL & PAULEIT, 2007; IPCC, 2007; SOU, 2007].

Among the multiple stress factors that characterise urban paved sites, water stress is widely argued to be the main constraint for tree growth and health [e.g. CRAUL, 1999; WHITLOW & BASSUK, 1986]. Water stress is likely to become much more severe in paved city environments in the future, since the UHI effect combined with predicted climate change is likely to cause an increase in mean annual temperature [SIEGHARDT & RANDRUP, 2005; WARE, 1994]. A recent study in Copenhagen, Denmark, indicated that street trees suffer from water stress even in this temperate climate today and this will get worse in the predicted future [BÜHLER & LARSEN, 2007]. This suggests that trees that are able to cope with critical periods of water stress in nature and develop well despite such stress would be of particular interest in future selection of trees for use in urban paved environments.

Areas suitable for supplying trees for urban paved environments in the CNE region

In nature, trees have been stress-tested and selected over evolutionary periods of time. Some species have developed an extensive plasticity and tolerance to a range of environmental conditions, while others have specialised in certain habitat types [GUREVITCH & al. 2002]. In the search for new tree species to be used at urban paved sites, it may be helpful to look at the ecological background of species and concentrate on the selection of species that have specialised in natural habitats with an environment and climate similar to that of urban paved sites [DUCATILLION & DUBOIS, 1997; FLINT, 1985; SÆBØ & SLYCKEN, 2005; WHITLOW & BASSUK, 1986].

From the perspective of the CNE region, it is unlikely that the species-poor native dendroflora can contribute a large variety of tree species with extended tolerance to the environmental stresses characterising urban paved sites of the region [DUHME & PAULEIT, 2000]. However, other regions with a comparable climate yet having a rich dendroflora may potentially contain new tree species and genera well-suited to the growing conditions at such urban paved sites in the CNE region [BRECKLE, 2002; TELLO & al. 2005].

Materials and methods

Study areas: Iasi, north-east Romania, and Copenhagen, Denmark

One of the most interesting areas containing tree species growing in a climate and site conditions similar to those in urban paved environments in the CNE region is south-east Europe. In this area there is a much more continental climate, with cool winters and hot, dry summers. One particular region of interest is north-east Romania (the Moldavian region of Romania) together with the Republic of Moldavia, where various steppe forest types exist. In these steppe forest systems, trees have evolved in a climate with hot, dry summers combined with cold, dry winters. In order to evaluate the potential of this geographical area to supply suitable trees, climate data from a woodland area at Iasi in Romania and from the city of Copenhagen in Denmark were compared. Further, in order to evaluate the climate and site conditions from areas were the majority of the today most used city tree species origin from, also the conditions of woodlands in Copenhagen will be included in the comparison.

Data collection

In predicting the survival of trees transplanted from one region to another, precipitation, temperature, water runoff and evapotranspiration are considered to be the most important parameters [NEILSON & MARKS, 1994]. For our comparison, we obtained climate data for Iasi from Sirbu (2003) [SÎRBU, 2003] and for Copenhagen from the Danish Meteorological Institute [DMI, 2009]. Due to the predicted scenario of global climate changes the comparison with Iasi also included the predicted inner-city climate of Copenhagen 2100. In order to compare Iasi with the future scenario in Copenhagen, we obtained worst case scenario data due to global climate change in the region from the Swedish Meteorological and Hydrological Institute [SMHI, 2009].

As mentioned earlier, drought is the main stress factor for trees in urban paved environments. It is therefore important to predict the future potential water stress in the actual city or region of interest in order to match the tree supply area to requirements. This can be done by combining data on the climate parameters listed above with potential evaporation and water runoff and then comparing these data to assess the match between the areas. To calculate potential evapotranspiration, we used the regression model by Thornthwaite [THORNTHWAITE, 1948], where the potential evapotranspiration is a function of monthly values of temperature, number of sunshine hours per day and cloudiness. The numbers of sunshine days was then based on the amount of sunshine hours divided by day length [MEEUS, 1991]. The water runoff data were based on Pauleit and Duhme [PAULEIT & DUHME, 2000], were woodlands assumed to have less than 10% water runoff, and pavements in Copenhagen approximately 70% water runoff.

Results

The climate data presented in Table 1a and 1b show the current situation in the two areas, while Table 1c shows the climate situation in woodland areas of Copenhagen today. When comparing the climate data between urban paved sites and natural woodlands of Copenhagen today a significant difference is noticeably in the cumulative water net difference where the negative trend starts much earlier and is in greater quantity in paved sites due to a much more effective water runoff (Fig. 1). When comparing the climate of Iasi with Copenhagen today, annual precipitation is rather similar with 532mm in Iasi and 525mm in Copenhagen. Further, when comparing the summer precipitation (May-September) between the two areas the sum is again rather similar with 298mm in Iasi and 250mm in Copenhagen, yet the average temperature during same period much higher temperatures occur in Iasi with med. 19,2 ^{o}C compare to Copenhagen 14,5 ^{o}C. This difference in temperatures clearly affects the evapotranspiration which is much more effective in the warmer climate of Iasi (Tab. 1a and 1b). The cumulative water net difference between Iasi and Copenhagen today, differ somewhat with a partial water stress in April in the Copenhagen case while Iasi experiences a partial water stress in May (Fig. 1). Further, in both areas the water netto differences have a similar trend and quantity during the remaining season, yet with a slightly more negative trend in paved sites of Copenhagen today. This variation in water net difference between the areas disappear in July and August were same levels of water stress occur and thereafter it is Iasi which have a slightly higher water stress (Fig. 1). When comparing the water netto difference between woodlands areas in Iasi with woodlands areas in Copenhagen today, similar conclusion can be made as the comparison with paved sites of Copenhagen today – with a poor matching with each other (Fig. 1).

In the future climate scenario of Copenhagen 2100, the mean temperature during December, January and February increased by 9 ^{o}C whiles the temperature in the remaining months increased by 8 ^{o}C. In addition, precipitation during summer decreased by 50%, while precipitation during spring and autumn increased by with 15% and that in winter by 70% (Tab. 1d). Comparing the climate in Iasi and the future scenario in Copenhagen 2100, the annual precipitation still does not differ greatly. However, in summer (May-September) there is up to 111 mm less precipitation in the future Copenhagen and in terms of day temperatures in May-September, it is predicted to be 3,3 ^{o}C warmer in the future Copenhagen compare to the present situation in Iasi (Tab. 1d). When comparing the cumulative water net difference between Iasi and the future Copenhagen, a clear difference is visibly with a negative water netto already in March, which thereafter has a dramatically negative trend (Fig. 1).

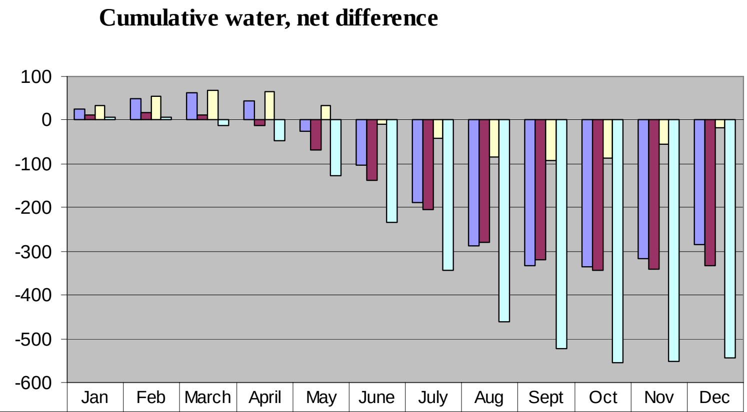
Tab. 1a-d. Heat and water stress conditions in natural woodland at Iasi compared with those in the inner-city environment and natural woodlands of Copenhagen at present and inner-city environment of a future Copenhagen, 2010.

Iasi	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean monthly temp. (ºC)	0	0,4	3,6	11,2	16,6	20,8	22	20,9	15,7	9,9	4	0
Sunshine daily (h)	9	9	12	13	16	16	17	19	16	14	8	7
Precipitation (mm)	27	28	29	36	34	64	74	70	56	48	31	35
Left after water runoff	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Potential evapotranspiration (mm)	0,0	0,1	1,2	5,2	9,2	12,2	13,3	11,7	7,4	3,9	1,2	0,0
Cumulative water net difference (mm)	24,3	48,9	63,2	44,4	-26,9	-103,5	-189,6	-287,0	-331,8	-336,0	-317,0	-285,5

Copenhagen, present	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean monthly temp. (ºC)	0	0	4	6	11	15	16.5	16.5	13.5	9.5	5	2
Sunshine daily (h)	6	8	10	13	14.5	13	12	13	10	9	7	6
Precipitation (mm)	36	24	34	35	40	45	57	55	53	47	52	47
Left after water runoff	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Potential evapotranspiration (mm)	0.0	0.0	2.1	3.3	6.8	9.3	10.4	9.8	7.1	4.7	2.2	0.9
Cumulative water, net difference (mm)	10.8	18.0	11.1	-11.7	-67.6	-137.0	-204.1	-278.8	-320.3	-342.7	-342.0	-333.0

Copenhagen, present, Woodland	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean monthly temp. (ºC)	0	0	4	6	11	15	16.5	16.5	13.5	9.5	5	2
Sunshine daily (h)	6	8	10	13	14.5	13	12	13	10	9	7	6
Precipitation (mm)	36	24	34	35	40	45	57	55	53	47	52	47
Left after water runoff	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Potential evapotranspiration (mm)	0.0	0.0	2.1	3.3	6.8	9.3	10.4	9.8	7.1	4.7	2.2	0.9
Cumulative water, net difference (mm)	32,4	54,0	67,5	65,7	33,8	-8,6	-41,5	-83,2	-92,9	-87,1	-55,2	-18,0

Copenhagen, 2100	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean monthly temp. (ºC)	9	9	12	14	19	23	24.5	24.5	21.5	17.5	13	11
Sunshine daily (h)	6	8	10	13	14.5	13	12	13	10	9	7	6
Precipitation (mm)	61	41	39	40	46	23	29	28	61	54	88	80
Left after water runoff	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Potential evapotranspiration (mm)	1.8	1.8	3.6	4.9	9.2	12.8	14.5	13.7	9.7	6.4	3.4	2.5
Cumulative water, net difference (mm)	7.7	5.9	-11.2	-48.0	-126.2	-233.7	-342.7	-461.7	-521.8	-555.2	-552.0	-542.9



	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Iasi	24,3	48,9	63,2	44,4	-26,9	-103,5	-189,6	-287	-331,8	-336	-317	-285,5
Copenhagen present	10,8	18	11,1	-11,7	-67,6	-137	-204,1	-278,8	-320,3	-342,7	-342	-333
Copenhagen present, Woodland	32,4	54	67,5	65,7	33,8	-8,6	-41,5	-83,2	-92,9	-87,1	-55,2	-18
Copenhagen, 2100	7,7	5,9	-11,2	-48	-126,2	-233,7	-342,7	-461,7	-521,8	-555,2	-552	-542,9

Fig. 1. The cumulative water net difference in natural woodland at Iasi compared with those in the inner-city environment and natural woodlands of Copenhagen at present and inner-city environment of a future Copenhagen, 2100.

Discussion

The grand old man in the sphere of modern arboriculture, Alex Shigo [SHIGO, 1991] said about the use and maintenance of city trees that: *"…we must understand the tree as it grows in its natural site first. To try to treat a city tree without understanding the tree as it grows in its natural site is like drawing a data curve with only an y axis; and no base line!"* To find trees suitable for urban paved sites, it has been suggested that the ecological background of species be examined and species specialised in natural habitats with environment and climate similar to that of urban paved sites be selected [DUCATILLION & DUBOIS, 1997; FLINT, 1985; SÆBØ & al. 2005; WARE, 1994].

This paper had the aim to compare natural growing conditions in south-east Europe with inner-city environment of Copenhagen. When comparing the site situations between paved sites and natural woodlands of Copenhagen today, a clear difference is noticeable with a much more stressful environment in paved sites due a more severe water stress based on an effective water runoff (Tab. 1b and 1c). This demonstrate the mismatch between these areas, yet this is still the background for the majority of the tree species in paved sites today which undoubtedly explain the poor health status of the tree stock in urban paved sites today. In the comparison between the climate and site conditions of natural woodlands in Iasi and inner-city environment of Copenhagen today, a much closer matching is noticeable (Tab. 1a and 1b). In the calculation of potential water stress, negative numbers occur in April of Copenhagen today while negative numbers occur in May in the Iasi case (Fig. 1). This difference continues until July and August when the water netto difference is similar in the two study areas. This spring and early summer differences is probably smaller then this calculation show. In the field of climate calculation, the main parameters are temperatures, precipitation, evapotranspiration and water runoff [NEILSON & MARKS, 1994]. However, to get even more accurate results, local climate data on humidity, wind speed and solar radiation would also be included. Humidity has in this case almost certainly an important effect in the calculation depending on the northern location of Copenhagen which diminishes the water stress due to a much lesser transpiration. Therefore it is possible to conclude that the matching between natural woodlands in Iasi have a good corresponding with urban paved sites of Copenhagen today. The comparison with natural woodlands in Iasi with the future Copenhagen 2100, show a poor matching with a much earlier and dramatically water stress status in the future Copenhagen (Fig. 1). Even if parameters such as humidity were included in the calculation the poor matching between the areas will still remains.

If this worst case scenario of climate change materialises, the question is whether it will be possible to have healthy and long-living trees in urban paved environments in Copenhagen. It is important to understand at an early phase that the solution not only depends on suitable tree species being found, but also on technical solutions being developed in order to have trees in paved environments in the future [e.g. GRABOSKY & BASSUK, 1996; KRISTOFFERSSEN, 1999; ROBERTS & al. 2006; TROWBRIDGE & BASSUK, 2004]. In a future climate there will need to be an attitude change in the overall planning of urban green structures in order to create suitable living conditions for trees in urban paved environments. Therefore it can be interesting to know the differences in cumulative net water index based on changes in water runoff, as shown for the Copenhagen 2100 in Table 2. These data clearly indicate the potential of technical solutions that decrease runoff and thus increase water infiltration into the planting pits. This potentially gives significantly later and much less extreme water stress status for the trees, with a much closer matching with the woodlands of Iasi today (Tab. 2).

Tab. 2. Effect of reducing runoff rate from 70% to 50% or 25% on cumulative net water difference in Copenhagen 2100

Copenhagen, (2100)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Cumulative water, net difference (mm) – water runoff 70%	7.7	5.9	-11.2	-48.0	-126.2	-233.7	-342.7	-461.7	-521.8	-555.2	-552.0	-542.9
Cumulative water, net difference (mm) – water runoff 50%	19.9	26.3	17.0	-11.8	-80.8	-183.7	-286.9	-400.3	-448.2	-470.8	-450.0	-424.9
Cumulative water, net difference (mm) – water runoff 25%	35.2	51.8	52.2	33.4	-24.1	-121.2	-217.1	-323.6	-356.2	-365.3	-322.5	-277.4

Conclusions

On the basis of precipitation and temperature data, natural woodlands in north-east Romania have the potential to be a source of suitable trees for urban paved environments in the CNE region, even for a future climate if other aspects in the planning of trees in paved sites are included. However this conclusion is based on only temperatures, precipitation, evapotranspiration and water runoff while data on a number of other climate and site factors are necessary for the definitive identification of potential climate matches. Furthermore, field investigations in the actual areas are essential to provide more detailed evidence. With these additional data, it will be possible to determine the potential of the area to provide suitable species and candidate trees can be selected for further evaluation in test plantations in urban paved sites in the CNE region. Overall, this type of theoretical approach is necessary in identifying promising and matching areas in the world that can supply new tree species for urban paved environments.

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