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BIODIVERSE GREEN INFRASTRUCTURE FOR THE 21st CENTURY: FROM "GREEN DESERT" OF LAWNS TO BIOPHILIC CITIES

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Abstract. Modern urban green infrastructures are following globalisation trends and contribute to homogenization at all levels of green areas from the master plan to the finest scale. We discuss the place and role of three principal urban living spaces, the "skeleton" of green infrastructures: lawns, green walls and green roofs. This "trio" of modern GI elements provide significant ecosystem services, it contributes to biodiversity and social values; and have environmental and economic impact.
The main goal of our approach to sustainable GI is to introduce a new landscape architecture style – biodiversinesque – as an alternative to the existing global homogenised picturesque-gardenesque. This new approach will combine the best achievements of innovative and alternative landscape design solutions (biodiverse lawns, pictorial meadows, walls and green roofs) and implement them on three major scales: city, intermediate neighborhood and the small biotope level.

Keywords: sustainable urban green infrastructure, biodiversinesque, sustainable lawns, green roofs, green walls, biodiversity, biophilic.

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Introduction

The modern globalized world faces the process of homogenization of cultures and environments. Today urban environments with similar urban planning structure, architecture, public parks and gardens, plants, networks of shops, hotels and restaurants and standardised food form one of the most important parts of a homogenized global culture (Ignatieva 2010).

Modern urban green infrastructures (GI) in many European cities comprise a random combination of green areas: parks, gardens, parkways, cemeteries, abandoned wastelands and connected urban corridors such as street, road, and railway wedges and riversides. GI is characterized by homogenization, loss of identity of place and expensive management and maintenance. Similar urban design and planning approaches are used all over the world. Also, the planning and establishment of urban green areas are predominantly influenced by two landscape architecture styles: global picturesque (or English park style) and gardenesque (Victorian style) including extended lawns and flowerbeds with exotic annual plants (Ignatieva 2010, 2011). Cities are surprisingly similar to each other in terms of flora and fauna independent of geographical and climatic differences (McKinney 2006). For example, among 321 alien plant species found in the city of Braunschweig in Germany, more than 80% were also found in Berlin, Vienna and London (Sukopp 1990). Today, designers even of small street or flowerbed biotopes ought to use "global" plant material from the same nurseries and similar hard material, which have resulted in creating similar urban habitats globally (Ignatieva, Stewart 2009) (Fig. 1).

Fig. 1. Examples of global gardenesque:
a – flowerbeds in Mumbai (India), b – Shanghai (China),
c – Moscow (Russia)

Still, urban areas include heterogeneous environments that provide habitat for many species of, e.g., plants (Müller, Werner 2010), vertebrates (Nilon 2009), bees (e.g., Saure 1996) and other insects (Frankie, Ehler 1978). Thus, they could be of high educational and biodiversity awareness value (Miller 2006), but also provide several ecosystem services to urban areas. Ecosystem services, which are processes in ecosystems that are of value or benefit to human society can be classified as provisioning, regulating, supporting, and cultural services (e.g., MEA 2003; Harrison *et al.* 2010). Urban GI can potentially contribute to a number of these services related to recreation, promotion of human health, pollination of garden fruits and vegetables, water and nutrient management, carbon sequestration, social cohesion and sustainable economic development. This has started to be recognized among scientists and politicians (Müller, Werner 2010).

The main goal of this article is to discuss the place and role of three principal urban living spaces, the "skeleton" of GI: lawns, green walls and green roofs. This "trio" of modern GI elements provides significant ecosystem services, it contributes to biodiversity and social values; environmental and economic effects. Our objective is to find new and more sustainable ways for development and management of urban green areas. As a tool, we will develop ecological and design principles of a new landscape architecture style: *biodiversinesque*, as an alternative to the existing global homogenized picturesque-gardenesque approach.

Global lawns

Today, one of the most prevalent, influential and visible elements within all types of urban GI is the lawn. It is also the most powerful symbol of modern urban global landscapes. The lawn prototype is probably the European floodplain meadow vegetation and secondary meadows after clearing and grazing. In Medieval time lawn was used as a decorative element for the first time. It was mostly cut turf from meadows which was transported to castle gardens. Lawn was an essential element of English landscape parks of the 18th century and an important part in the Gardenesque parks of the 19th century. From this time lawn became the symbol of social status. The decorative grass was used for pleasure and recreation rather than as in a productive landscape for grazing. During the 20th century the desire for lawns created a commercial multibillion industry to produce seeds, pesticides, fertilizers, irrigation technology and lawnmowers.

There are two visions of the lawn and its environmental effects. The most common and positive perception of lawn is its recreational value for example in accessible park's playgrounds, private garden lawns, golf courses and sport fields. On the other hand lawn's intensive management and maintenance at the present status (frequent mowing, application of herbicides and fertilizers, using curtain types of mowers and chemical products) has a significant negative impact on the environment, biodiversity and human health. There is however a common view among the majority of population that non-mown lawn is a sign of neglect and laziness.

At the beginning of the 21st century lawn is the core element in almost all types of urban green areas such as public parks, private gardens, cemeteries, golf courses, boulevards and parkways. Lawns cover up to 70% of open public spaces in cities and are used irrespective of climatic conditions (Stewart *et al.* 2009). For example in the USA lawns cover the 300 000 km^2 which is equal to the combined area of England, Scotland and Ireland (California) green solutions 2008, Tom Ericsson (personal communication, 7th of February 2011). Lawns cover a significant part of open space also in urban areas with arid Mediterranean climate, in desert cities such as Dubai (Ignatieva 2010), as well as in northern European cities. For example, in Sweden public lawns cover 5.8 km^2 in Uppsala and 3.6 km^2 in the Umeå municipality (pers. comm. Per Westerlund and Nina Ingvarsson, Uppsala and Umeå municipalities respectively).

Our previous research on urban biotopes has shown that lawns are strikingly similar in plant species composition, and in their modern articulation they are important contributors to the homogenization of urban landscapes and loss of urban biodiversity (Ignatieva, Stewart 2009, Ignatieva 2011) (Fig. 2). Their original resemblance to floodplain meadows and pasturelands is lost as most grasses used for lawns are hybrids that originate from the same few nurseries or seed mixtures creating monocultures with no equivalents within the native European environment. Allen *et al.* (2010) used the term "green desert" to describe the low environmental value of modern lawns. In addition, lawns can be extremely resource consuming. In the US alone, 60 million kilograms of pesticides are administered to lawns each year and 1.5 trillion liters of municipal water is consumed for their irrigation each summer day (Wood 2006). In cities with very dry and hot summers such as Bucharest lawns have become one of the most important sources of dust pollution as the grass withers and dies within two months (I. Tudora, personal communication, June 2012). It is interesting that there are very few studies on ecological and cultural aspects of lawns worldwide. Analyses of European lawns, their management, environmental impact, provision of ecosystem services, or influence on human health are scarce. For example, in Sweden we know that most grasses used for lawns are hybrids originating from the same few nurseries or seed mixtures creating habitats that have no equivalents within the native Swedish environment. However, there is no comprehensive information about Swedish lawns, their management or environmental impact.

Fig. 2. Global lawn pattern: a – Tel Aviv (Israel), b – Cape Town (South Africa), c – St. Petersburg (Russia)

The environmental impact of lawns largely depends on the intensity of the management (e.g., if fertilizers, pesticides and herbicides are used surrounding areas and ground water could be affected). On the other hand, low intensity managed lawns may have positive effects on the environment. Estimates from the US show that lawns can be net sinks for CO_2 (Zirkle *et al.* 2011) and lawns in general could serve as habitat for grassland species including bees and butterflies that utilise urban environments (e.g., Ahrné *et al.* 2009; Öckinger *et al.* 2009; Matteson, Langellotto 2010). Thus they could be

of high educational and biodiversity awareness value (Miller 2006), but also provide several ecosystem services to urban areas. Lawns can potentially contribute to a number of ecosystem services related to recreation, pollination of garden fruits and vegetables, water and nutrient management and carbon sequestration.

At the moment, most research on lawns has been done in some European countries (Germany and the UK), New Zealand and the US, where lawns are, e.g., causing problems with invasive species (as most lawn grasses originate from Europe). Currently there are two main fields of lawn research: 1) Historical overview including the search for "alternative lawns" (Bormann *et al*. 2001; Ignatieva, Stewart 2009) and 2) Lawns as urban biotopes (e.g., plant species diversity) from UK, Germany and New Zealand (Müller 1990; Thompson *et al*. 2004; Stewart *et al*. 2009).

Green walls and green roofs

Given the constant growth and densification of cities there is a need to consider also other dimensions of green in addition to green areas on the ground such as green roofs and walls (vertical gardens) for the GI of future cities. However, very little research has been done in Europe to study the contribution of these elements to biodiversity and ecosystem services such as noise reduction, pollination, health promotion or food production. The commercialization of green roof technologies and mass production lead to homogenization of these elements as well, e.g., the use of sedum roofs all over Europe and the USA.

The most common function of modern green roofs is regulation of runoff. In some innovative practices, such as Low Impact Design, green roofs are seen as the steps in water management practice together with swales and rain gardens. Historically, in Scandinavia, green roofs were used in countryside (picture) to cover some utilitarian buildings such as storages and stables and cowsheds. The main function of such green roofs in old days was to protect roof material (birch bark) and increase the roof longevity and as a side effect – roof insulation. In Sweden the turf was simply cut from the meadows or forest margins and placed on roofs. This authentic Scandinavian method is studied by Anna Bubnova, the PhD student from St. Petersburg State Forest Universityand used as an inspiration for sustainable biologically diverse green roofs (Fig. 3).

Even the most famous and successful examples of existing green walls (i.e., MFO-Park in Zurich and Musee du Quai Branly in Paris) are not sustainable since they require a lot of resources and maintenance and cannot be used as prototypes for sustainable GI.

Fig. 3. Traditional Scandinavian biodiverse green roofs, Stockholm, Skansen Museum

However recently in Sweden the new innovative ecological thinking was demonstrated by the green wall enterprise, Butong which created pre-cultivated living wall panels and instant ground covers for different urban environments. Butong implemented vertical park projects in Stockholm and Belgrade. Recently (October 2012) this firm has been commissioned by one of the Swedish largest building contractors to implement green wall test stations for the evaluation. This generation of test station project is an important step of implementing Swedish first large scale maintenance free (or low maintenance) green facades. Furthermore, the Butong's panels can neutralize nitrogen oxides from car pollution in a catalytic process under influence of sunlight. Plant panels have a positive effect on sound levels. This green wall project is currently carried out in co-operation with the acoustic section of the Royal Institute of Technology. Butong is also seen green walls as an important habitat for birds and insects.

Urban biodiversity and design as a foundation for Green Infrastructure research

To be able to promote biodiversity and enhance the provision of ecosystem services by urban GI in European cities it is crucial to: 1) identify the main elements of urban GI of different cities today; 2) assess the biodiversity of different elements of the GI; 3) find out in which ways different elements of urban GI contribute to ecosystem services; 4) understand the social, cultural and regulatory motives behind decisions about establishment and management of urban GI at present; 5) identify innovative and sustainable solutions for future urban GI; 6) estimate their economic and environmental benefits when compared to conventional practices.

The development of urban biodiversity research started in Europe after WWII and was initiated by Central European scientists (German and Polish schools). The most advanced was the study of urban flora and vegetation (Sukopp 1990). By the beginning of the 21st century there were books and several publications on urban ecology summarizing different aspects of urban ecosystems such as 1) climate, 2) soils, 3) hydrology, 4) biodiversity, 5) structural analysis of urban landscapes for management and planning, 6) homogeneity of biotopes and similarity of landscape design language and how to use ecological knowledge in urban planning and 7) the role of ecosystem services in contemporary urban planning (e.g., Grimm *et al.* 2008; McDonnell *et al.* 2009; McIntyre 2000; Niemela 2011).

The establishment of URBIO (Urban Biodiversity and Design) – an International Network for Education and Research in Urban Biodiversity and Design in 2008 – and publish of the book "*Urban Biodiversity and Design*" manifested the beginning of a new era of "fostering research and education into urban biodiversity and design" (Müller, Werner 2010). The URBIO conferences of 2008 and 2010 speeded the process of integrating urban biodiversity research, landscape architecture and urban planning.

Joint Russian-Danish projects on the green areas, greenbelt and green infrastructure of St. Petersburg provided a new framework for researching, demonstrating and analyzing green and blue components for sustainable GI. The results of the research on creating and maintaining green wedges in Stockholm and Uppsala and its successful implementation provided an innovative model for several current European cities for preserving and developing an integrated green infrastructure in a whole city-region. The program "Ecopolis" (the ecological city of the future) developed by Moscow State University as early as 1979 tested a truly interdisciplinary approach for searching sustainable cities and GI demonstration sites (Ignatieva 2002).

Architectural and planning aspects of urban GI were traditionally studied by architects, urban planners, landscape architects and landscape ecologists. They worked mostly at the large master plan scale and suggested integration of landscape ecology principles in planning (Ignatieva 2011; Ignatieva *et al.* 2012). However, there is no comprehensive integral research in Europe aiming at bringing together empirical research, methods to promote urban biodiversity (on different scales and concerning all aspects of urban biodiversity), combining them with social studies and making them useful in practical landscape architecture and urban planning.

Needs for new interdisciplinary practically oriented research of Green Infrastructure

Urban ecological research on the "trio" of modern GI: lawns, green roofs and green walls, however is very sporadic and studies these elements in physical and temporal isolation from one another (e.g., their floristic compositions, green roof design and management or storm water management). There are some purely practical publications concerning horticultural practices of design and establishment of commercial lawns, green roofs and green walls (van Uffelen 2011), but there is a lack of projects and studies combining ecological, design, social, economic and regulatory aspects in research on these three GI elements. There is a real need in modern landscape architecture research to fill this gap and to carry out interdisciplinary research to practitioners, citizens and project stakeholders. The growing trend of companies marketing themselves as "green alternatives" could create demand for further research on the positive influence of vegetation on, e.g., property value.

This kind of research could also contribute to fill the gap of practical knowledge for sustainable green building rating systems such as BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (US Green Building Council) and make them attractive to potential clients. The innovative concept of biophilic urban landscapes and "design with nature" are powerful visual tools for reinforcing urban biodiversity and make it more visible and recognizable for the general public as well. The new landscape design approach should include not only plants, but also insect and animal populations.

Let's go biodiversinesque!

Our new *biodiversinesque* approach will be influenced by the 19th and 20th century public park movement and new approaches such as: xerophyte gardens, plant signatures, wildlife gardens, pictorial meadows and naturalistic plantings. The *biodiversinesque* style should respect, mimic and make visible ecological processes in urban landscapes. Instead of combining trees, shrubs and flowers at random only based on their appearance and design qualities, the *biodiversinesque* style will be flexible, based on ecological knowledge and adjusted to local climatic and biotic conditions. Promoting biodiversity will be the driving force for creating sustainable GI. Biodiverse lawns, green roofs and green walls are essential stepping stones for creating biophilic urban landscapes. Our understanding of biophilic cities is the same as that Professor Tim Beatley where a biophilic city is a biodiverse city which contains abundant nature and which helps to make human life happier, healthier and more meaningful (Beatley 2010).

Biodiversinesque GI represents a wide range of alternative, location-specific design solutions appropriate at different scales – from large interconnected urban forests, green wedges and green corridors along rivers, re-constructed wetlands and district-level green spaces to townscape adapted courtyard greens in smaller local communities, and building/site-level living green elements. Manifestations of these practices are, for example, already found in: 1) the large-scale GI urban planning of Nordic and German cities; 2) Low Impact Design programs in the US and New Zealand aimed at enhancing storm water management and biodiversity (Ignatieva *et al.* 2008) (Fig. 4); 3) movements towards small-scale, biodiverse, alternative sustainable, native species lawns (UK, USA, New Zealand, Denmark); and 4) global proliferation of spontaneously vegetated systems (Germany, Sweden).

The practice when landscape design schemes have just used plants as an instrument for "filling" spatial structure of architectural project has passed. New vision is based on the perception that each landscape architecture composition can be also seen as a dynamic ecosystem. New design approaches such as Bush Garden (Australia), Plant Signatures (New Zealand), xeroscaping (US), wild lawns and wildlife habitats (USA) are using the models from nature (different ecosystems or their fragments) as an inspiration for planting design (Ignatieva 2010). These innovative concept "design with nature" are powerful visual tools for reinforcing urban biodiversity and make it more visible and recognizable for the general public as well. The most recent trends in landscape design are going even broader and include not only plants but insect and animal population, for example bird's garden or lizard's garden (Barnett 2008) (Fig. 5). In a time of economic crisis and climate change, alternative lawns, green roofs and green walls can enhance urban food production and solve the problem of nutritional deficiency. For example, the creation of rooftop farms, front yard edible gardens, grazing roofs and productive green walls are alternative ways of using urban GI for food production in Europe, the US and Asia (China and Japan).

Direction for studying and implementing alternative lawns and green roofs

Based on previous studies (Ignatieva *et al.* 2008); we would suggest at least two alternative sustainable solutions for creating lawns and green roofs for European cities. We should first of all study how perennial communities can be composed (in terms of species richness and density, functional groups and growth forms) and how they should be managed to maintain their species richness over time and remain attractive from design point of view. These general recommendations and findings could be the starting point then we could expand the experimental trials in the direction of how to manage naturalistic perennial plantings, make their maintenance economical, investigate various combinations of exotic and native species, and ensure sustainability in relation to urban fauna and wildlife and the value of attractiveness and public perception. We should also take into account local social structures and cultural practices as well as climatic and environmental conditions of the particular city. Plantings could consist of perennial meadows and edible plants.

The idea of using a multi-scale approach and looking for alternative solutions to conventional lawns and creating new innovative green infrastructure elements such as green walls and green roofs from an interdisciplinary perspective (using biological, social as well as economic expertise) can be leading towards large international comparative systems analysis project. The breadth and depth of knowledge invested in this approach – covering all aspects of sustainable GI, – lead

Fig. 4. Low Impact Design practice example (rain garden) in Seattle (USA)

Fig. 5. Lizard Garden in Zurich (Switzerland)

us to believe that we can have a great impact by providing materials on three levels: 1) supporting researchers with primary data and theory building; 2) supporting policy makers and practitioners, including small and medium-sized enterprises; and 3) developing demonstration sites, including, e.g., sustainable lawn-roof-wall prototypes.

Biodiversinesque approach can be revolutionary in terms of attempting to reevaluate the existing unsustainable excessively costly landscape architecture practices and turn them into a green industry (i.e, sustainable lawn industry).

Societal values of biodiversinesque approach

The societal value of the outcome of biodiversinesque approach is that it will provide the means to promote ecosystem services in cities on the basis of concrete recommendations to stakeholders on the planning, management and design of sustainable green infrastructure, in particular lawns, green roofs and green walls. Green areas in cities are valuable for many reasons, e.g., as places for people to meet, as memorial parks or sports fields, as habitat for many other species. They can improve the urban environment, e.g., contributing to carbon sequestration, water infiltration and noise reduction, access to green areas important to people's health. Because of their dominance of urban green areas, lawns, more than any other vegetation, provide most citizens their daily contact with nature, which in turn greatly influences their understanding of nature. To be able to promote the generation of ecosystem services provided by lawns, today and in the future, it is crucial to understand how their present planning and management affect different services. This is particularly so in times when cities are constantly growing at the expense of urban green areas. Biodiversinesque style can also have positive economic impact by creating new job opportunities and helping to feed people in challenging economic times (through guidelines for integrating edible plants into urban landscapes). The next generation of lawns, green roofs and green walls will be an important part of sustainable urban living, not just sustainable green infrastructure.

Concluding remarks

Globalisation process contributed to homogenization of green areas at different levels from the master plan to the finest scale of created biotopes such as flower bed or lawn. Today even small street biotope is using "global" plant material from foreign nurseries and hard material which have resulted in creating similar urban habitats globe wise. Modern urban green infrastructures in many cities around the world has not applied unified comprehensive planning approach and comprise a random combination of green areas: parks, gardens, parkways, cemeteries, abandoned wastelands, which connected to each other by roads, railways and rivers.

Most people of the Western world view green elements of the urban landscapes without questioning their functional, ecological or aesthetic value. There are very few studies of the biodiversity, environmental impact, and influence on human health or public opinion about and the historical and contemporary motives for planning, regulations (law) and horticultural management of different elements of green infrastructure.

One of the ways to find more sustainable solution for design and management of urban green areas could be the development of a new landscape architecture style – *biodiversinesque*, as an alternative to the existing global homogenized picturesque-gardenesque approach.

Since lawns are covering up to 70% of green areas in cities we see this type as one of the most important objects for future research together with the other two structural spatial elements –green roofs and green walls. Among major tasks should be evaluation of environmental services provided by these elements of green infrastructure, its contribution to biodiversity loss, influence on hydrological urban cycle and affects according to water prizes and economic costs.

Our new landscape architecture biodiversinesque approach is based on the best achievements of innovative and alternative landscape design solutions such biodiverse lawns, pictorial meadows, low impact design vegetated devises (greens walls and rain gardens), biodiverse walls and roofs which will allow to incorporate faunal component as well. Research and implementation of this new approach required an interdisciplinary collaboration, including stakeholders, policy makers and horticultural managers. Studying urban lawns, green roofs and green walls should incorporate different perspectives – social as well as ecological in order to understand their roles in sustainable urban planning, design and management. Potential alternative sustainable solutions are impossible to find without an understanding of social motives behind the strong attachment of the modern Western society to curtain unsustainable elements such lawns of urban green areas or attraction of having green roofs and green walls.

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Did her Master in Landscape Architecture in St. Petersburg and PhD in botany and urban ecology in Moscow State University. In Russia, then in the USA, New Zealand and now in Sweden Maria continued working on the investigation of different urban ecosystems and developing principles of ecological design. Her latest research projects are dedicated to problems of urban biodiversity and design in the era of globalization particularly lawns as social and ecological phenomenon.

KARIN AHRNÉ

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Did her PhD in ecology studying effects of urbanization and local green area management on pollinators mainly bumble bees. She is now working as researcher and coordinator within an interdisciplinary project studying lawns as social and ecological phenomenon.