Performance of Urbanised Ecosystems

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This study contains data on urban ecosystems and their features, and natural ecosystems. Every natural ecosystem features a specific structure (i.e., the steady framework of external and internal interactions). Conditions for the existence of ornamental plants, especially for those that have been introduced, thus being different than for natural flora, are ensured by human practical activity. In urban ecosystems the biotic circulation is accelerated and simplified due to economic activities. In turn, stability of circulation is reduced, and ecological optimisation is more complex.
Key words: urban ecosystems, natural ecosystems, functioning, ecological status.

Šiame straipsnyje pateikiama urbanizuotų ir natūralių gamtinių ekosistemų palyginamoji analizė. Kiekvienai gamtinei ekosistemai būdinga savita struktūra, t. y. nusistovėjusi išorinių ir vidinių ryšių dinaminė sistema. Dekoratyvinių augalų augavietės urbanizuotose ekosistemose radikaliai skiriasi nuo natūralių. Joms nebūdinga augalų migracija, kolonizacija ir konkurencija, rūšių sudėtis nėra sąlygota augalų genotipinių savybių. Urboekosistemose dėl ūkinės veiklos yra supaprastėjęs, paspartėjęs biotinis apytakos ratas. Ryšium su tuo sumažėjęs apytakos stabilumas, sudėtingesnė ekologinė optimizacija.
Reikšminiai žodžiai: urbanizuotos ekosistemos, natūralios ekosistemos, funkcionavimas, ekologinė būklė.

Introduction

The performance of ecosystems is considered to be related to an increase in energy flows and reduction of entropy, and sustentation of energy balance that is based on the adaptation process of live plants. Because pre-eminence of one plant/animal population vis-a-vis another is a function of the greater ability to assimilate energy sources and factors of living environs in view of natural selection: only the groups of plants and animals capable of maximum utilisation of the energy flow remain in the ecosystem (Жученко, 1990). Stability of an urbanised ecosystem, affected by an abundance of anthropogenic factors, is one of the key requirements in order for the ecosystem to function. Stability is a special characteristic of a bio-system, contributing to its resistance to various external influences. Numerous authors maintain that the bio-system stability increases, depending upon its complexity and diversity.

A more complex and diverse bio-system is less vulnerable, and adapts easier (Бигон, 1989). Every natural system features a specific structure (i.e., the steady framework of external and internal interactions). The substance of these interactions includes the transfer of nutrients, energy, and information–the exchange between its individual blocks and sub-systems. Such interaction(s) takes place via different channels, processes, energy transformation, gravitational transport of substances, water circulation and decomposition of organic substances. None of the natural systems is absolutely resistant to technological impact. Therefore, it is very important to preserve the core features common to the entire system (e.g., resistance, reliability, vitality, adaptability, self-organisation, and sensitivity, etc.).

The trophic and energy networks of biogeocenosis appear as elementary flows of information, directly or indirectly interconnecting biological components of the ecosystem. This is a basis for self-adjustment of the quality and quantity of food resources, formation of primary information links, types of mutual interactions (i.e., competition, mutualism, parasitism, commercialism, predation), etc. Most often, the biological dominants change because of rapidly proliferating harmful organisms; and finally, the ecosystem's regression rates increase (Жученко, 1990; Prapiestienė, 2003). Conditions for the existence of ornamental plants, especially for those that have been introduced, thus being different than for natural flora, are ensured by human practical activity. In the vegetation realm, ornamental plants surrender to the laws of natural communities, yet form a special community that may be called, to a certain extent, 'urbo-phytocenosis', or perhaps even 'agro-phytocenosis'. Formation of agro-phytocenoses in landscape is influenced by two (2) major factors: adaptation, and natural selection of organisms. Such biocenotic structure of ornamental plants resembles the natural ecosystems that form under extreme conditions, featuring a simple structure of trophic networks, a low number of species, and individuals of detached populations. However, even the natural ecosystems forming under extreme conditions develop into self-sustaining systems (Nekrošienė, 2008).

The aim of this research – to analyse differences between natural and urban ecosystems.

Material and methods

There was studied a literature, there are presented summarized data of 10 years research works of the author.

Results and discussion

Artificial biocenoses of ornamental plants are unable to form a self-sustaining ecosystem, and thus differ from natural biocenoses. Their stability depends upon: micro-organisms (naturally existing in them), fauna, flora, soil and atmospheric conditions, and on anthropogenic factors, as well as land cultivation, fertilisation, and application of protective means for ornamental plants (Šlapakauskas, 1998). Interactions between the organisms and environment determine, not only the structure and functions of the ornamental vegetation communities but also, their growth, development, and homeostasis. Urbo-phytocenosis features a low degree of homeostasis. This is a young ecosystem, with low variety of species, and only some types of species dominate more distinctively. Therefore, urbo-phytocenosis may be considered as a mono-dominant ecosystem. Affected by varied environmental conditions, individual plants of such biocenosis grow differently; their interaction with soil water, air, and micro-organisms is different, and the plant itself uses solar energy, water, and nutrients in a different way. All of this affects adjacently growing genera and species, and the entire community of flora. Change of trophic provokes the changes of type diversity and composition.

In urban ecosystems, the biotic circulation is accelerated and simplified due to economic activities. In turn, stability of circulation is reduced, and ecological optimisation is more complex (Бумблаускис, 1996, Кроссли и др., 1987). Significant changes are observed in the urbanised Lithuanian landscape. Synantropisation of natural communities and vulgarisation of species composition take place.

Ecosystem features two inherent processes: circulation of both energy and nutrients (i.e., biogenes). Energy circulation is mono-directional; whereas the circulation of nutrients is cyclical (Kormondy, 1992). However, in artificial biocenosis of ornamental plants, these processes are affected by human activity. Alternatively, natural ecological processes affect vegetation no less than human agrarian activity (i.e., plant maintenance) (Полуэктов, 1991). Internal metabolism in natural ecosystems markedly exceeds the supply of nutrients from the atmosphere and their loss, by washing them away from soil; the balanced metabolism is achieved due to the diversity of plants, animals, and other organisms in this territory. Whereas in artificial ecosystems, where green spaces are often formed from only a few biological types, such balance is impossible to achieve in substance (Table 1). This is why transport of minerals and organic substances from such ecosystems should be continuously replenished by means of fertilisation. Nevertheless, full harmony in artificial ecosystems is unachievable (Полуэктов, 1991; Бумблаускис, 1996; Кроссли и др., 1987; Коулман, 1987, Кант, 1988). In order to make the richer biodiversity in urbanized environment, the need to avoid monocultures and fragmentation of vegetation. Trees should be planted not at individually, but together with shrubs and herbaceous plants (Miklušytė et al, 2009).

Table 1. Features of natural and artificial ecosystems affecting their stability and ability of accumulating nutrients (according to Вудменси, 1987).
1 lentelė. *Gamtinių ir dirbtinai suformuotų ekosistemų požymiai, turintys įtaką jų stabilumui ir galimybei kaupti maisto medžiagas (pagal Вудменси,1987)*

Features / Požymiai	Natural Ecosystems / Natūralios ekosistemos	Artificial Ecosystems / Dirbtinai suformuotos ekosistemos
Biotic */ Biotiniai*		
Internal metabolic circle of plants / Augalų vykdomas vidinis apytakos ratas	Higher / Aukštesnis	Lower / Žemesnis
Synchronisation of plant and microorganism activity / Augalų ir mikroorganizmų aktyvumo sinchronizacija	High / Aukšta	Low / Žema
Variety of biological activity in time / Biologinio aktyvumo įvairovė laiko atžvilgiu	High / Aukšta	Low / Žema
Ratio of plant and microorganism activity / Augalų ir mikroorganizmų aktyvumo santykis	1	Less than 1 / Mažiau 1
Vegetation variety / Augalijos įvairovė	High / Aukšta	Low / Žema
Genetic variety / Genetinė įvairovė	High / Aukšta	Low / Žema
Potential of renewal / Atsinaujinimo potencialas	High / Aukšta	Low / Žemas
Abiotic */ Abiotiniai*		
Speed of infiltration / Infiltracijos greitis	High / Aukšta	Low / Žemas
Amount of outflow / Nuotėkų dydis	Low / Aukšta	High / Aukštas
Erosion / Erozija	Slow / Lėta	Fast / Greita
Vegetation litter / Augalijos paklotė	Significant / Reikšminga	Little / Maža
Fallen objects and other remains / Nuokritos ir kitos liekanos	Many / Daug	Little / Mažai
Loss of soil humidity by evaporation / Dirvožemio drėgmės nuostoliai garavimo metu	High / Aukštas	Low / Žemas
Soil colloids / Dirvožemio koloidai	Many / Daug	Little / Mažai
Nutrient loss by washing-out / Maisto medžiagų nuostoliai	Small / Maži	Big / Dideli
Soil temperature / Dirvožemio temperatūra	Lower / Žemesnė	Higher / Aukštesnė

There are two types of primary i.e. 'producents' (producers) in the artificial ecosystem. These are 'ornamental plants' (i.e., planted by humans), and 'self-growing flora' (i.e., the so-called 'weeds'). Both types provide nutrients consisting of inorganic components, energy to graminivorous or primary consumers–heterotrophes. The primary consumers may be plant pests, and pathogens. Entomophagous insects (e.g., ladybirds, *Carrabidae* bettles, *Chrysopas*, and others), as well as various small mammalians, reptiles, and birds, are attributed to secondary consumers. The latter may be also tertiary consumers when they feed on entomophagous insects. Because an artificial ecosystem is most often closely related to other natural ecosystems surrounding it, predators may be also included in the list of secondary consumers. Tertiary consumers (i.e., predators feeding on other predators) can be parasitic entomophages in such an ecosystem. These are some mites, hymenopterous or dipterous insects. Consumers of other trophic levels can feed on these predators. But, there are only a small number of all level predators in an ecosystem, as it is difficult to find shelter for them, due to scarce variety of plants.

Another group of heterotrophs consists of 'reducers'. They feed on the remains of plants and animals. In an urban ecosystem, these are very scarce remnants of ornamental plants and weeds, as well as small bodies of phytophages and entomophages, etc. These remains constitute food for various soil animals, micro-organisms, and bacteria. Human activity changes the distribution of nutrients among the ecosystem components. Transport of nutrients from producers to primary consumers is reduced, due to the use of insecticides and/or pesticides. Other plant protection agents and agro-technical means used during the vegetative period of plants slow the rate of transport of nutrients to reducers (Кроссли и др., 1987). Metabolism between the plants and micro-organisms in natural ecosystems is continuous. Meanwhile, urban ecosystems feature long gaps of time when micro-organisms lack the remains of mineralised plants (i.e., the plants do not grow) (Вудменси, 1987). On the other hand, various organic remains dug or ploughed into the soil at the end of the vegetation period may become an impulse for activation of reducents' activity (Кроссли и др., 1987).

One more link is introduced into the metabolic cycle in an urban ecosystem. These are materials used by humans for the improvement of ornamental plant quality, organic and mineral fertilisers, and calcareous materials for the reduction of soil acidity. In cultivated soils, in comparison to natural soils, more nutrients (especially N and K) are assimilated into the plant harvest, and their infiltration into the deeper horizons is more noticeable; biological metabolism is active and open, therefore these elements must be supplemented for normal existence of agrocenoses.

Plants, as factors of soil formation, in urban ecosystems loose their dominating role, giving way to human production activity. The applied agro-technical means do not guarantee the achievement of a closed-circuit metabolic system (Janušienė, 1995).

The impact of human economic activity upon the circulation of organic substances, factors of production and destruction in urban ecosystems is tremendous. Fertility of soil, and thus the productivity of ornamental plants growing in the community, highly depends on the amount and quality of taken and returned organic substances (Janušienė, 1994). Soil is a biological system where the metabolic processes are tightly related with the activity of micro-organisms. Plant nourishment depends on microbiological transformation of nutrients, humus synthesis, and accumulation of physiologically active substances in soil (Žekonienė et al., 1995). The conclusion became evident from the many years of continuing research of artificial biotypes, that the abundance of live organisms, biomass, and variety of types there depends on the intensity of land cultivation, use of mineral, organic fertilisers, and pesticides. If the mineral fertilisation system, especially higher rates of nitrogen, is used for a long period and systematically (e.g., 12 years), the tendencies of biological actions change, and mineralisation becomes prevailing.

Ecosystems are balanced by the optimising of the material and energy flows, and of the metabolism. One of the more important regulation mechanisms of the biogeocenotic process is concentrated in the agrochemical features of soil. In addition to other factors, the plant's resistance to diseases, pests, and, simultaneously, its destiny in population, and community is determined also by: the concentration of nutritional elements, especially in nitrogen, phosphorus, and potassium (Niemela, 1999; Nekrošienė, 2005; Stravinskienė, 2005).

Land is a tool of manufacture, and a raw material for production of organic substances. There would be no green plants without mineral substances provided by land, and without green plants it would be impossible to turn the solar energy into organic products. Stock of nutrients available for plants in soil slightly increases when minerals are putrefied. Nutrients that are available from rocks in natural conditions enter the biological circle and are used by plants; and when plants are decomposed, they release mineral substances which again become the food for plants. Therefore, the top layer of soil is enriched. Different things happen in artificial ecosystems. Nutrients are removed from biocenosis together with remains of ornamental plants. For their restoration, the soil must be fertilised with mineral and organic fertilisers. The ratio of soil nutrition elements determines the conditions of plant growth. Whereas biochemical and chemical characteristics of soil ($N\text{-}NO_3$, $N\text{-}NH_4$, P_2O_5, K_2O) are directly related with their physical characteristics: structure and friability.

When the circulation of nutrients and energy takes place in agro-ecosystems, then the physical and chemical environment concurrently interacts with the biotic environment. Each organism, living among others, affects others, and is being affected by them. These are biotic interactions that may be very diverse: nutritional, reproductive, defensive, etc. The most important biotic interactions are mutualism, competition, predation, parasitism, commensalism, and neutralism (Кроссли, 1987; Kormondy, 1992).

Changes of plant communities on populations are related to competition of plants for forward and space resources, with different reaction of individuals and community components to the environmental stimuli (Šlapakauskas, 1998). Competition (i.e., mutual relations between the different or same types of individuals purporting to the same resource, which amount is limited) play a special role in preservation of ecological stability of ecosystems and high level of productivity (Жученко, 1990).

It is proposed to distinguish a partial (based on a specific resource) or integral (based on a group of resources) competition. Competitive abilities of plants are determined genetically, and the features enabling better competition (e.g., for light) differ from features enabling the better use of water or nutrients. Competitive abilities of each plant or animal type or ecotope vary, depending upon the other biotic or abiotic environmental factors (Жученко, 1990). Therefore, regading the resistance of organisms to biotic or abiotic stresses, one should consider the interrelations of organisms, because (for example) plants disabled by pests or diseases, are less resistant to draught or cold, especially in the introduction of foreign plants. Plant resistance to negative factors manifests by the resistance of separate organs, or even tissues (Жученко, 1990).

It is difficult to estimate the specific impact of each factor for the functions of urban ecosystems, because all live organisms are not only mutually linked, but also related to the abiotic environment surrounding them. The outspread of plants and via nutritive links (sometimes also directly) of pests that feed on them, of pathogens and other organisms: are determined by climatic and edaphic (soil) factors (Stakvilevičienė et al., 2004). Prevalence of organisms is affected by chemical and physical characteristics of soil. Chemical characteristics are as follows: soil pH, minerals, carbonates, sodium salts, soluble salts of heavy metals, and physical characteristics and mechanical composition of substrate, and its mobility (Nekrošienė, 2005; Nekrošienė, 2006; Nekrošienė, 2008). In urban ecosystems, where the physical and even the physical and chemical factors vary during their vegetative period, climate conditions are highly significant regarding the abundance of organisms, their distribution and mutual relations: air temperature, and rainfall amount.

Biotic and abiotic components of urban ecosystems, the same as in natural ecosystems, are directly significant in accumulating and maintaining the necessary nutrients. But in different ecosystems, these components manifest differently.

The decorative plants do not feature the migration, colonisation, and competition of natural plants. Furthermore, the variety of species is not determined by genotype characteristics of plants, local climate and ecological conditions, but rather is determined ‘from the top’. Because there are no natural communities of plants in the city, nature cannot ‘prompt’ which species of trees can be cultivated here. The issue becomes even more-complicated when attempting to prepare an assortment of plants that are suitable for different-purpose Green Areas in the city. The selection is primarily limited by specific urban conditions. Cities have an extremely-high adverse effect caused by salt; whereas illnesses and pests become ‘cosmopolitan’. The heating of the climate, not only affects the seasonal development of plants but also, changes the biotic and abiotic conditions of their life (Whitlow, Bassuk, 1988; Herms, Mattson, 1997).

Conclusions

1. Urbo-phytocenosis are unable to form a self-sustaining ecosystem, and thus differ from natural biocenoses.
2. Such biotic features, as internal metabolic circle of plants, synchronisation of plant and microorganism activity, variety of biological activity in time, ratio of plant and microorganism activity, vegetation and genetic varieties, potential of renewal are lower in urban (artificial) ecosystems, compared with natural ecosystems.
3. Speed of infiltration and loss of soil humidity by evaporation are lower in urban (artificial) ecosystems, compared with natural ecosystems. There are a little vegetation litter, fallen objects and other remains, soil colloids in urban (artificial) ecosystems too.
4. Urbo-phytocenosis features a low degree of homeostasis. This is a young ecosystem, with low variety of species, and only some types of species dominate more distinctively.
5. In urbanised ecosystems, the habitats of 'decorative' versus 'natural' plants are radically different: the decorative plants do not feature the migration, colonisation, and competition of natural plants. Furthermore, the variety of species is not determined by genotype characteristics of plants, and ecological conditions.

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Urbanizuotų ekosistemų funkcionavimas

Santrauka

Augalijos pasaulyje dekoratyviniai augalai paklūsta gamtinių bendrijų dėsniams, bet sudaro specifinę bendriją, kurią iš dalies galima vadinti urbofitocenoze ar net agrofitocenoze. Agrofitocenozių formavimasis landšafte vyksta veikiant dviem pagrindiniams faktoriams: organizmų adaptacijai ir natūraliai atrankai. Tokia dekoratyvinių augalų biocenozių struktūra primena ekstremaliomis sąlygomis besiformuojančias gamtines ekosistemas, kurioms būdinga paprasta trofinių ryšių struktūra, mažai rūšių ir pavienių populiacijų individų. Tačiau net ir ekstremaliomis sąlygomis besiformuojančios gamtinės ekosistemos išsivysto iki savireguliuojančių sistemų. Žmogaus sukurtos dekoratyvinių augalų biocenozės nepajėgios suformuoti savireguliuojančios ekosistemos ir tuo skiriasi nuo gamtinių biocenozių. Jų tvarumas priklauso nuo jose natūraliai egzistuojančių mikroorganizmų, faunos, floros, dirvožemio ir atmosferos sąlygų, taip pat ir nuo antropogeninių veiksnių: žemės dirbimo, tręšimo, dekoratyvinių augalų apsaugos priemonių naudojimo. Organizmų ir aplinkos santykiai nulemia ne tik dekoratyvinių augalų bendrijų struktūrą ir funkcijas, bet ir jų augimą, vystymąsi, homeostazę. Urbofitocenozei būdingas žemas homeostazės laipsnis. Tai jauna ekosistema, kurioje skurdi rūšių įvairovė, ryškiau dominuoja tik pavienės rūšys. Taigi urbofitocenozę galima laikyti monodominantine ekosistema. Kintančių aplinkos sąlygų paveikti tokios biocenozės individai kitaip auga, skiriasi jų sąveika su dirvožemio vandeniu, oru, mikroorganizmais, kitaip augalas panaudoja saulės energiją, vandenį, maisto medžiagas. Visa tai veikia šalia augančius tos pačios genties ir rūšies atstovus ir visą bendriją. Trofinių veiksnių pokytis sukelia rūšių gausumo ir kompozicijos pokyčius. Augalų, kaip ir gyvūnų, reakcijos į aplinkos sąlygų pokyčius, į ligas, kenkėjus dažniausiai yra siejamos su kvėpavimo intensyvumo padidėjimu. O padidėjus kvėpavimo intensyvumui, mažėja augalų fotosintezės intensyvumas. Tai rodo augalo sugebėjimą konkuruoti mitybinėje erdvėje. Dekoratyvinių augalų augavietės urbanizuotose ekosistemose radikaliai skiriasi nuo natūralių. Joms nebūdinga augalų migracija, kolonizacija ir konkurencija, rūšių sudėtis mažai sąlygota augalų genotipinių savybių, vietos klimato bei ekologinių sąlygų, o apsprendžiama “iš viršaus”.

Urbanizuotame Lietuvos kraštovaizdyje pastaruoju metu stebimi žymūs pokyčiai. Vyksta gamtinių bendrijų sinantropizacija, rūšinės sudėties vulgarizacija. Biotiniai ir abiotiniai urboekosistemų, kaip ir natūralių gamtinių ekosistemų komponentai turi tiesioginę reikšmę kaupiant ir išlaikant būtinas maisto medžiagas. Tačiau skirtingose ekosistemose šie komponentai pasireiškia skirtingai.