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Green Infrastructure Systems and Their Importance in Our Life

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Abstract: Green infrastructure systems are artificial engineering systems designed to preserve the ecological balance as naturally. While keeping the ecosystem balance, they provide us natural and semi-natural areas to have a better life quality. Conservation of biodiversity and natural habitats, continuation of ecological balancing, adaptation to climate cahange, storage of CO_2 and removal of greenhouse effect, protection from natural disasters such as storm water and flood, air conditioning and water quality can be obtainable by the green infrastructure systems. They provide significant benefits for local economies through the formation of social tissue with larger green areas without the need for any additional tools make innovative solutions and cope with multiple problems at the same time that it is further supporting naturally based solutions. Green infrastructure systems, urban plant coverings, can absorb all climate pollutants and have a positive impact about the climate changes. Definition of green infrastructure systems, multidirectional benefits of these systems, some applicable sample of them such as green roofs and walls are investigated in this paper. Additionally, with these systems possibilities of the increasing air and water quality by decreasing CO_2, heat island and energy use are examined with some presented scientific and natural solutions while discussion of these kind of chemical subjects in this text.

Keywords*: Green Infrastructure Systems, biodiversity, greenhouse, water quality*

Introduction

In our age, the decline of green spaces in cities and the preference of multi-storey buildings to the gardens and / or green areas pose a great threat to the world and the environment. Unfortunately, today, cities are quite out of green areas and nature. Apart from the buildings, roads and parking lots are also deprived of green spaces. Moreover, these mistakes are often made at the expense of destroying green areas and are common and bad practices known as today's gray infrastructures. However, urban areas should be designed as green infrastructure systems to meet with the buildings (Karaosman, 2005).

Today we can say that one of the most important problems in modern cities is the negative effect of environmental pollution. The first major sources of life such as air, water and soil are much polluted. Another important issue is the impact of global warming and atmospheric greenhouse gas accumulation on cities. It is also known that the greenhouse effect has caused global climate change (Demir *et al*., 2016). To solve these kinds of environmental pollution problems, architectural scaling should be considered in order to increase the green areas that are getting smaller every day. From this point of view, we can consider that the green roofs and the living green walls are meeting points of buildings and urban spaces with lush green vegetation. Designed and built for this purpose, the buildings can help improving the cities and even the world, and creating a better qualified living space for all living things (Ayçam & Kınalı, 2013). Eventually, green infrastructure systems should be considered as problem solving keys unlike gray infrastructure systems.

Definition and importance of green infrastructure system

The "green infrastructure systems" are defined as a network of natural areas and open spaces considered fundamental for the ecological functioning of the territory, contributing for the preservation of the natural ecosystems, the wildlife and the quality of the air and water as well as the citizens' life quality (Benedict & McMahon, 2002). A similar definition can be found in the European Commission. It defines the green infrastructure as a tool to help ecological, economic and social

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benefits with nature-based solutions, to help people understand the benefits of nature, and to mobilize investments that drive and sustain these benefits (Access 1, 2017). It is known that the green infrastructure systems can provide multiple functions and benefits on the same spatial areas. These functions and benefits can be ecological (protecting biodiversity, adapting to climate change, and increasing air quality and etc.), social (creating water drainage or green areas and etc.) and economical (increasing employment and cheaper cleaning the environment and *etc*.; Ayçam & Kınalı, 2013). Compared to gray infrastructure systems that perform a single function such as drainage or transport, the potential of green infrastructure systems to cope with multiple problems at the same time makes them attractive (Access 2, 2017). But the classical gray infrastructure systems are still indispensable and necessary for us, temporarily. So, these systems have to be further supported by naturally based solutions.

Among the benefits of naturally solution green infrastructure systems are carbon storage, providing high air quality, reducing city heat islands, improving natural habitats, and improving recreation and recreation areas (Karaosman, 2005).

Samples of green infrastructure systems

Sustainable rainwater management, green roof systems and green walls are given as samples in this manuscript.

Sustainable rainwater management

Management of rainwater includes rainwater flow prevention, storage and reuse (Zhou, 2014). Green infrastructure systems are artificial engineering systems designed to preserve the ecological balance. These kind of engineering systems are called sustainable drainage systems (SuDS) in the UK and also named as high-performance landscape infrastructure in some countries.

Figure 1. Sustainable rainwater management systems (Access 3)

Green roof systems

As it is known the rooftops and sidewalks in gray substructure systems can be stored up thermal energy under sunlight during the day and radiate the heats during night. This energy transfer in the manner adversely affects the quality of life. As a result, a decrease in water resources, large temperature differences between urban and outdoor areas, formation of heat islands, soil degradations, changes in weather conditions and loss of green leaves in urban areas can be occurred. So, the green roofs can provide solutions to these kind problems at a large extent (Fernandez-Canero et al., 2013). The green roofs do not compensate for the forests and parks, but they can make a place nicer and more restful and create additional habitats for ecological environments and the quality of life. It has been reported that the green roofs have also the ability to improve the quality of the air and water by imitating natural formations instead of gray buildings (Getter and Rowe, 2006). Green roofs, first, is a good habitat for microorganisms and plants grown in environments with less weight. Beyond that the green roofs improve the energy performance, air quality and urban ecology of the building without the need for additional tools and provide innovative solutions to problems created by rainwater. Moreover, it can be said that instead of dirty gray concrete and asphalt surfaces, people and other living things have a more comfortable life with green roofs.

Green wall systems

The vertical gardens are made up of cages designed as magnificent architectural constructions by using the green walls. They can be mounted vertically or used as their independent formulations

(Erdoğdu and Çetiner, 2014). The vertical green walls used indoors are important for the acoustic balance of the ambience. Hence, these vertical green wall systems using live or inanimate materials can reduce the noise in buildings. More importantly, these walls are eco-friendly systems used to reduce water consumption by providing drainage and recycling of water. It is reported that the vertical gardens have already contributed to biodiversity by creating a living space for all living things and have created new urban agriculture practices while reducing the impact of urban heat island like green roofs. They are actively developing the aesthetic perception of human psychology and creating new alternative jobs. It is important that the priority of rainwater usage and natural source of light while designing and applications of vertical green walls in which should be done without energy requirements. For this reason, vertical green walls should also be used to increase the urban quality like green roofs in our life (Başdoğan and Çığ, 2016).

Figure 2. Green roof systems (Access 4)

Figure 3. Green wall systems (Access 5)

Benefits of green infrastructure systems

Natural and managed green areas both in urban and rural places can be created by using of the green infrastructure systems. Linking of the open areas to each other by converting the "grey" substructure to green through restoration of watersheds is a good strategy. In this way, there may be storage of rainwater. They have many benefits. In general, these benefits of green infrastructure systems can be calssified in terms of economic, psychological and social and also environmental aspects.

Economic benefits

Green infrastructure systems play an important role in adapting to climate change and improving thermal comfort in urban areas, basically. It is known that the green roofs are known to provide very effective insulation in varying levels depending on the intensity of sheet thickness of soil and green vegetation. Consumed energy generated for heating-cooling is reduced indirectly by using green roofs, which contribute to reducing global warming and air pollution (Karaosman, 2005; Oberndorfer et al., 2007). The green infrastructure is not only an ecologically superior solution, but it is also financially attractive. In 2012, 479 green infrastructure projects were reviewed in a research conducted by American Rivers, The Water Environment Federation, The American Society of Landscape Architects and ECONorthwest. According to this reseach report, although about 1/4 of them were more expensive than gray infrastructure, the cost of 31% of them were equal to gray infrastructures costs

and 44% of them were cheaper than them (Odefey et al., 2012). The economic benefits of green infrastructure systems can be listed basically as follows:

-Increasing value of domains,
-Increasing the life cycle cost savings,
-Reducing the cost of building infrastructure and aging,
-Increasing the promotion of economic development

Psychological and social benefits

Green infrastructure systems support the social activities of the people and increase their good feelings. Psychological, sociological and educational research shows that green infrastructure, which promotes more active, healthier life and high-quality education in adapting to climate change and the world, has very positive consequences for climate change and reduces carbon emissions (Demuzere et al., 2014). To improve the quality of life, the psychological and social benefits of green infrastructure systems can be listed basically as follows:

- Healt benefits,
- Individual and social benefits,
- Creation of walking and cycling routes,
- Raising awareness of the community in rainwater management,
- Reduction of urban heat islands,
- Enhancement of roof gardens and urban green spaces.

Environmental Benefits

All living should be kept in a living environment as a whole. Hence, environment should be preserved by using natural applications. Protections of the environment using natural aplicants keep the balance of ecosystem. Green infrastructure systems have the most significant impact on the ecosystem due to their environmental benefits. The environmental benefits of green infrastructure systems can be listed basically as follows:

- Reducing the amount of CO_2
- Controlling the air quality and management
- Increasing the quality of water by rainwater management
- Reducing the flooding and drought problems with water flow regime.
- Increasing the thermal comfort by improving climate conditions and reduce energy use.

Reducing the amount of CO_2

Carbondioxide, an important share in climate change, is one of the greenhouse gases used by plants in photosynthesis systems. In this way, it is directly collected by photosynthesis of plants from the atmosphere, and it is possible to store and decompose by passing through the soil and underground through the plants used in the green infrastructure systems. Green infrastructure systems are very useful, eco friendly to reduce this kind of dangerous gas and also it is a natural solve of the problem (Avdan et al., 2015).

Increasing the quality of water and reducing the flooding and drought problems

It is known that basins, wetlands and forests are the best buffers to overcome such environmental problems in hard winter seasons. Therefore, enlarging these areas not only reduces flood and drought problems, but also increases water quality due to their ability to remove pollutants from water (Avdan *et al*., 2015).

Controlling the air quality

It has been reported that green infrastructure systems increase air quality due to the ability to absorb particulate-size pollutants; furthermore, they support thermal confort in the cities owing to the ability to reduce the temperature of the ambient (Ayçam & Kınalı, 2013). The short-lived climate pollutants such as black carbon absorb light and can cause the heating of atmosphere by absorbing sunlight and emitting radiation (Avdan et al., 2015). For this reason, short-lived climate pollutants also play an important role in global warming and climate change. Green infrastructure systems, which

are urban plant coverings, absorb climate pollutants and have a positive impact about adaptation to climate change.

Some part of the pollution in the cities causes from nitrogen compounds in exhaust fumes of industry and traffic. These kinds of pollutants can be captured by plants and used as nutrients. If all of these pollutants can not be kept by the plants, the excesses of them can be washed with rain water and mixed with waterways, flows and finally lakes and seas. According to the literatüre, on a tree-lined street, there are more than 1000 dust particles in 1 liter of air, the dust may be 3-4 times higher than this value on treeless streets and reach up to 12000 dust particles. Moreover, it can be said that the improvement of outdoor and indoor air quality is related to the change of the roof surface temperature. Since green roofs improve air quality by using evaporation and filtration both inside and outside (Karaosman, 2005).

Exchange of carbon dioxide and oxygen

The impact of greenhouse gases on the formation of air pollution and the degradation of the balance of nature are quite great. It has been reported that known as greenhouse gases are nitrogen dioxide, sulfur oxides, hydrocarbons, carbon dioxide, carbon monoxide. There is also scientific evidence that 50% of nitrous oxides and hydrocarbons are derived from fossil fuels, 90% of which are sulfur oxides. It is known that one is the greatest factor and has the most important role in degrading of the nature balance; all of which also causes pollution (Karaosman, 2005).

What is the biggest factor that destroys the nature? The most important and biggest factor in the degradation of nature's balance is carbon dioxide. Although not chemically harmful to health, it is the biggest factor that is thought to cause major problems in increasing the temperature due to its properties known as greenhouse effect (Karaosman, 2005). According to the environmental researches, there is similar reported information that carbondioxide is the biggest factor in increasing the temperature of the universe, however not chemically harmful to health.

It is possible to prevent this big environmental problem of the world by natural means; the green roofs can be the best solution for destroying the harmful effect of carbon dioxide. Since carbon dioxide is also used as nutrients by green roof plants (Karaosman, 2005). For this reason, the main idea should be that the adverse effects of pollution in air, water, soil and the world can be reduced by green infrastructure systems.

Results and Discussions

Green roofs and living walls provide positive effects on urban ecosystem, air quality and noise levels. Thanks to the plants on the living walls, airborne particles are exposed to rain and also filtered out from the plant surface by the rain. Thus, they can be preferred to use as natural methods to improve the air quality. As well as conservation of natural water, green infrastructure systems have the capacity to prevent the dust rise and to reduce the heat transferring to the habitat in high temperatures. Moreover, owing to these systems it is possible to extend the service life by protecting existing water insulation from natural influences (Getter & Rowe, 2006; Oberndorfer *et al*., 2007; Köhler *et al*., 2002).

The settle areas are warmer than the surrounding rural areas due to the lack of soil and flora, high energy use, big crowds of people, dark colours use and etc. In some cities and even in different parts of the city there may be temperature differences and these differences can be up to 12 degrees. This provides negative effects on all living things, both in global warming (Yüksel and Yılmaz, 2008). Because of that it should not be forgotten that green roofs and green walls reduce the temperature and thus the effect of the urban heat island.

Green infrastructure systems are effectively used in various regions of the world. One of them is the Puget Gulf region. It has been reported that the sewage system in Seattle are overflow after the heavy rains and it leads to the mixing of about 4 billion liters of wastewater into the Puget Gulf every year. If the motor oils, chemical substances placed on the grass, polychlorinated biphenyls (PCB), heavy metals, pet and home wastes are considered as additional pollutants, it turns out that the zone has a different ecological pollution (McGarvey, 2014).

In the specimens of breathing tubes of the whales, fungal and antibiotic resistant bacteria and viruses, that are formely only on land, have been found (Schroeder *et al*., 2009). The other adverse situation was that oyster beds were closed at regular intervals due to contamination of wastewater.

And, of course, it has been a green infrastructure system that brings an ecological solution to the city of Seattle, which has a serious problem and threatens the entire Gulf ecosystem (Dunn, 2010).

Green infrastructure systems basically perceive ecological systems and offer guiding elements on sustainable practices of built construction to promote biodiversity on an urban environment. Since green infrastructure systems are composed of various natural solutions aimed at the starting point of solving the problem, these natural assets create healthy communities and sustain the local economy. These systems are largely responsible for the natural water retention and filtering properties of trees and other crops. For this purpose, plants, used in these systems supply for stopping and filtering of the polluted water and evaporating without entering the streets and sewage systems. Owing to these kind of benefits, special "rain gardens" consisting of trees and local plants that have been exposed to excess rainwater have begun to be used in most where. As a similar way, systems have been developed to transfer rainwater to private water tanks, not to urban networks (Hager, 2003).

For example, in order to stop the mud and scum on the active slopes of the rainwater, the bush-shaped plants and water-loving plants such as poplar willow have been used in pit areas where water was collected in Coupeville as slightly different route. With this natural system, the roots of the trees can easily filter out the copper dust from the ammonia, nitrates and brake pads and clean the waters and finally the thousands of liters of water can be cleaned by this filtration of trees every day (Access 6, 2017).

Since the ecological balances are degraded in today's world, green infrastructure systems are most popular applications that provide important contributions to the world's industry. Problems such as the reduction of underground resources, the cost of energy resources, old and inadequate sewerage systems and increasing technology and air pollution make green infrastructure systems a focus of attention. For example, green roof applications are frequently used in Western Europe, North America and Asia. In Europe, it is known that Germany is a leading and successful country in the green roof applications. Similarly, the leader country is Japan in Asia for the applications of green roof technology (Karaosman, 2006).

Green spaces also contribute to the cultural and historical environment and determinate to the identity of the urban environment in which people live and work. We have to constantly protect the world where we pollute with technology to get more livable and durable areas. Care and conservation of green areas should be done more thoughtful with some rules. For that reason, the green infrastructure systems that we deserve and value in order to create a better, a greener and a cleaner environment must also be protected by making legal sanctions.

Conclusion

Environment is the most important thing in our life. Every living creature should have the right to breathe in a clean and livable environment. We have to provide a living environment for every living thing, because of not being any place without birds, butterflies, living things that have many responsibilities in eco systems. According to the Native American Chief Seattle, in the cities where the white man set up, the sweet sounds of the blossoming and the wing flapping of butterfly can not be heard. He says when the last river dried up, when the last tree goes, and when the last fish died; the white man will understand that money is something that can not be defeated. As a final word, we must add that man's words to the account and make the world a better material with green infrastructure systems, so the universe can give us the best things it has.

References

Avdan ZY, Yıldız D, Çabuk A, (015) Yağmur suyu yönetimi açısından yeşil alt yapı sistemlerinin değerlendirilmesi, *ISBS 2nd INTE.*

Ayçam I, Kınalı M, (2013) Ofis Binalarında Yeşil Çatıların Isıtma ve Soğutma Yüklerine Olan Etkilerinin Analizi, *Tesisat Mühendisliği*, **135**: 26-34, http://docplayer.biz.tr/2239195-Abs-tract-key-words-idil-aycam-mine-kinali.html (24.07.2017).

Benedict MA, McMahon ET, (2002) Green Infrastructure: Smart Conservation for the 21st Century, *Renewable Resources Journal*, **20**, 12-17.

Başdoğan G, Çığ A, (2016) Ecological-social-economical Impacts of Vertical Gardens in the Sustainable City Model, *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi*, **26**, 430-438.

Demir R, Avdan, ZY, Avdan U, Yıldız, ND, (2016) Yaşayan Duvarların Kentin Isı Değişimine Etkisi, *6. Uzaktan Algılama-CBS Sempozyumu*, 1089-1098.

Demuzere M, Orru K, Heidrich O, Olazabal E, Geneletti D, Orru H, Bhave AG, Mittal N, Feliu E, Faehnle M, (2014) Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure, *J. Environ. Management*, **146**, 107-115.

Dunn, A.D., 2010, Siting Green Infrastructure: Legal And Policy Solutions To Alleviate Urban Poverty and Promote Healthy Communities, Boston College Environmental Affairs Law Review, **37**, 41-66 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1517909 (24.07.2017).

Erdoğdu E, Çetiner İ, (2014) Düşey Yeşil Sistemlerin Enerji Etkinliklerinin Değerlendirilmesi, *7. Ulusal Çatı & Cephe Sempozyumu*, http://catider.org.tr/pdf/sempozyum7/11_%20_Bildiri%20erdogdu.pdf (24.07.2017).

Fernandez-Canero, R, Emilsson T, Fernandez-Barba C, Machuca MAH, (2013) Green roof systems: A study of public attitudes and preferences in southern Spain, *Journal of Environmental Management* **128**: 106-115.

Getter KL, Rowe DB, (2006) The Role of Extensive Green Roofs in Sustainable Development, *Hort Science*, **41**, 1276-1285.

Hager MC, (2003) Lot-level approaches to stormwater management are gaining ground, *Stormwater*,

Karaosman SK, (2005) Yeşil Çatıların Ekolojik Yönden Değerlendirilmesi, *Çatı Cephe Fuarı*, http://catider.org.tr/pdf/sempozyum/bildiri_9.pdf (24.07.2017).

Karaosman SK, (2006) Yeşil Çatılar ve Sürdürülebilir Bina Değerlendirme Sistemleri, http://catider.org.tr/pdf/sempozyum/Bil11.pdf (24.07.2017).

Köhler M, Schmidt M., Grimme FW, Laar M, Paiva VLA, Tavares S, (2002) Green roofs in temperate climates and in the hot-humid tropics-far beyond the aesthetics, *Environ. Manag. & Health*, **13**, 382-391.

McGarvey N, (2014) Stormwater Management Trade-Offs for Portland, Seattle and Vancouver, BSc Thesis, Submitted in partial fulfillment of the requirements for the degree of MS. Planning in the Faculty of Graduate and Postdoctoral Studies the Un. British Columbia.

Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R.R., Doshi H., Dunnett, N., Gaffin, S., Köhler, M., Liu, K.K.Y., Rowe, B., 2007, Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services, *BioScience*, **57**(10): 823-833.

Odefey J, Detwiler S, Rousseau K, Trice A, Blackwell R, O'Hara K, Buckley M, Souhlas T, Brown S, Raviprakash P, (2012) Banking on Green: A Look at How Green Infrastructure can Save Municipalities Money and Provide Economic Benefits Community-Wide, *American Rivers, The Water Environment Federation, The American Society of Landscape Architects and ECONorthwest*, http://stormandstream.com/wp-content/uploads/2014/03/Banking-on-Green_FINAL.pdf (24.07.2017).

Schroeder JP, Raverty S, Zabek E, Cameron CE, Eshghi A, Bain D, Wood R, Rhodes L, Hanson B, (2009) Investigation into the Microbial Culture and Molecular Screening of exhaled breaths of Endangered Southern Resident Killer Whales (SRKW) and Pathogen Screening of the Sea Surface Microlayer (SML) in Puget Sound, *Published in Proceedings of the 2009 Puget Sound Georgia Basin Ecosystem Conference*, 1-8.

Yüksel ÜD, Yılmaz O, (2008) Ankara Kentinde Kentsel Isı Adası Etkisinin Yaz Aylarında Uzaktan Algılama ve Meteorolojik Gözlemlere Dayalı Olarak Saptanması ve Değerlendirilmesi, Gazi Üniv. Müh. Mim. Fak. Der. **23**, 937-952.

Zhou Q, (2014) A Review of Sustainable Urban Drainage Systems Considering the Climate Change and Urbanization Impacts. *Water*, **6**, 976-992.

WEB Links

URL1.http:// ec.europa.eu/environment/nature/ecosystems/index_en.htm - 24.07.2017.

URL2.http://ec.europa.eu/environment/nature/ecosystems/docs/Green_Infrastructure.pdf - 24.07.2017.

URL3.https://almergroup.files.wordpress.com/2014/03/yac49fmur-suyu.jpg - 08.08.2017.

URL4.https://www.nparks.gov.sg/skyrisegreenery/projects - 08.08.2017.

URL5.http://www.pinsdaddy.com/green-wall-exterior_0saR3FzSuTUuTU3fkC52xoVCJ4ORoOKTEif*UqnPPtY/ - 08.08.2017.

URL 6.https://ekogazete.wordpress.com/2012/09/23/cevre-kirliligine-dogal-cozumler/ - 24. 07.2017.