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Derleme/*Review*

Ecological-Social-Economical Impacts of Vertical Gardens in the Sustainable City Model

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Abstract: Issues such as utilization of natural resources, environmental problems and global climate change increase the awareness on "green design" in the built environment and give direction to the attempts of creating cities with natural environment. In this context, planting works are done on the facades of the buildings to reduce the negative impacts of urbanization and create a sustainable city model. These practices are called vertical gardens- living walls- green facades. Vertical gardens, which allow growth of various species of plants in the complicated city life, balance urban ecology and enhance the quality of urban life. Strengthening the urban ecosystem and improvement of economic-social balances constitute the essence of a sustainable city model. Vertical garden practices contribute to increasing air quality, reduction of urban heat island affect, increasing energy efficiency, reduction of noise pollution in addition to reduction of stress caused by the urban life by improving city aesthetic and provide new job opportunities in the economy. In this study, it is aimed to determine ecological-economical-social impacts of vertical gardens to create liveable, ideal and healthy environments and to reveal how they contribute to sustainable urban model.

Keywords: Sustainable city, Urban ecology, Vertical gardens

Sürdürülebilir Kent Modelinde Dikey Bahçelerin Ekolojik-Sosyal-Ekonomik Etkileri

Özet: Doğal kaynakların kullanımı, çevre sorunları, küresel iklim değişikliği gibi konular yapılı çevrede "yeşil doku" konusundaki duyarlılığı artırmakta ve doğal ortam koşullarına sahip kentler oluşturma çalışmalarına yön vermektedir. Bu bağlamda hızla gelişen kentleşmenin olumsuz etkilerini azaltmak ve sürdürülebilir kent modeli oluşturmak adına yapı cephelerinde bitkilendirme çalışmaları uygulanmaktadır. Bu uygulamalar dikey bahçeler-yaşayan duvarlar-yeşil cepheler- olarak adlandırılmaktadır. Karmaşık kent yaşamında farklı tür ve sayıdaki bitkilerin doğal olarak yetişeceği dikey bahçeler kent ekolojisini dengelemekte ve kentsel yaşam kalitesini arttırmaktadır. Kent ekosisteminin güçlendirilmesi ve ekonomik-sosyal dengelerin iyileştirilmesi sürdürülebilir kent modellerinin özünün oluşturmaktadır. Dikey bahçe uygulamaları; hava kalitesinin arttırılması, kentsel ısı ada etkisinin azaltılması, enerji verimliliğini arttırması, gürültü kirliliğini azaltmasının yanı sıra kent estetiğine katkı sağlayarak kent yaşamının getirmiş olduğu stresi azaltmakta ve ekonomik anlamda yeni iş olanakları sunmaktadır. Bu çalışmada, dikey bahçelerin kentlerde yaşanabilir ideal çevreler yaratmak ve sağlıklı ortamlar oluşturmak için ekolojik-ekonomik-sosyal etkilerinin neler olduğu ve sürdürülebilir kent modeline nasıl bir katkı sağlayabileceğinin ortaya konması amaçlanmıştır.

Anahtar kelimeler: Dikey bahçeler, Kent ekolojisi, Sürdürülebilir kent

Introduction

"Liveable city" concept emerged as a new urban approach in the 20th century. Rapid and uncontrolled urbanization threatens the future of the third world and the developing countries, while it caused environmental pollution, transportation problems and socio-economic segregation problems in the cities of the developed countries, which are called global-mega-metropolitan-world cities. Integration of the sustainable development policies into urbanization is foreseen as the solution of this complicated situation. Realizing the sustainable city model is a concept with a wider scope than environmental protection. It has economic, social and cultural aspects in addition to environmental ones. It includes

equity among both today's generations and the future ones (Uslu 2009). Geenhuisan and Nijkamp (1994) described the sustainable city as the city in which socio-economic benefits are synchronized with the environment and energy related concerns in order to ensure change in the continuity; while Bayram (2001) described it as a structure in which continuity of change is assured by handling urban, social and economic benefits with environmental and energy related problems.

Sustainable urbanization concept has three main objectives. First one is improving the quality of life of the city dwellers in their relation with the city, and utilization of public areas and public services. Second one is strengthening the ability of the city to survive as a settlement. Lastly, questioning the production and consumption patterns in overconsumption and transformation of resources in the cities (Yazar 2006).

In the literature, "sustainable cities" are cities or urban lands in which economic, social and physical systems aiming the highest life quality with minimal environmental load based on a sustainable social basis are internalized in appropriate urban policies (Palabıyık 2005). According to this view, sustainable urbanization can be described as "urbanization and urban development promoting and protecting economic opportunities, social capital increase and a healthy environment" (Bayram 2001).

Sustainable urban development approach covers all the issues related to social justice, sustainable economy and environmental sustainability. In a sustainable city model, increasing housing need due to the increasing population is fulfilled with horizontal development instead of vertical as a space-saving solution. New tools are developed for enhancement of urban ecology and improvement urban life quality. One of them is the vertical gardens. The vertical gardens do not only improve the environmental quality within the city, but also reduce environmental costs and poses positive socio-physiological impact.

Aim of this study is to reveal the contributions of plant usage on building facades, as in the case of vertical gardens, in the urban ecology by creating liveable environments in the cities in order to create sustainable healthy environments.

Description and Features of Vertical Garden

One of the ecological and aesthetic solutions, named as vertical garden- green wall- wall garden- green facades- living walls in the literature, developed to minimize the devastating impacts of rapid urbanization and provide green space alternatives to the city dwellers includes planted facade design and practices (Yüksel 2013). Vertical gardens are divided into two main categories: green facades and living walls (Figure 1). These categories have subcategories. Green facades develop directly on the walls or specially designed supporting structures with climbing plants, while the roots are in the ground and the shoot system grow upwards along the building. On the other hand, vegetation and growing medium is established using polypropylene plastic containers, geo textiles and irrigation systems in modular panels of the living walls (Green Roofs Organization 2008; Sharp 2007; Yüksel 2013) (Figure 2-3). Vertical garden implementations are done on the panel system (hydroponic panel system and earthed panel system), the metal fence system, the modular system and the suspended system (Yüksel 2013). These systems are mostly implemented on the buildings and wall facades and require intense maintenance. In the panels, framings, modular and fences systems, nutrients required by the plants are provided additionally.

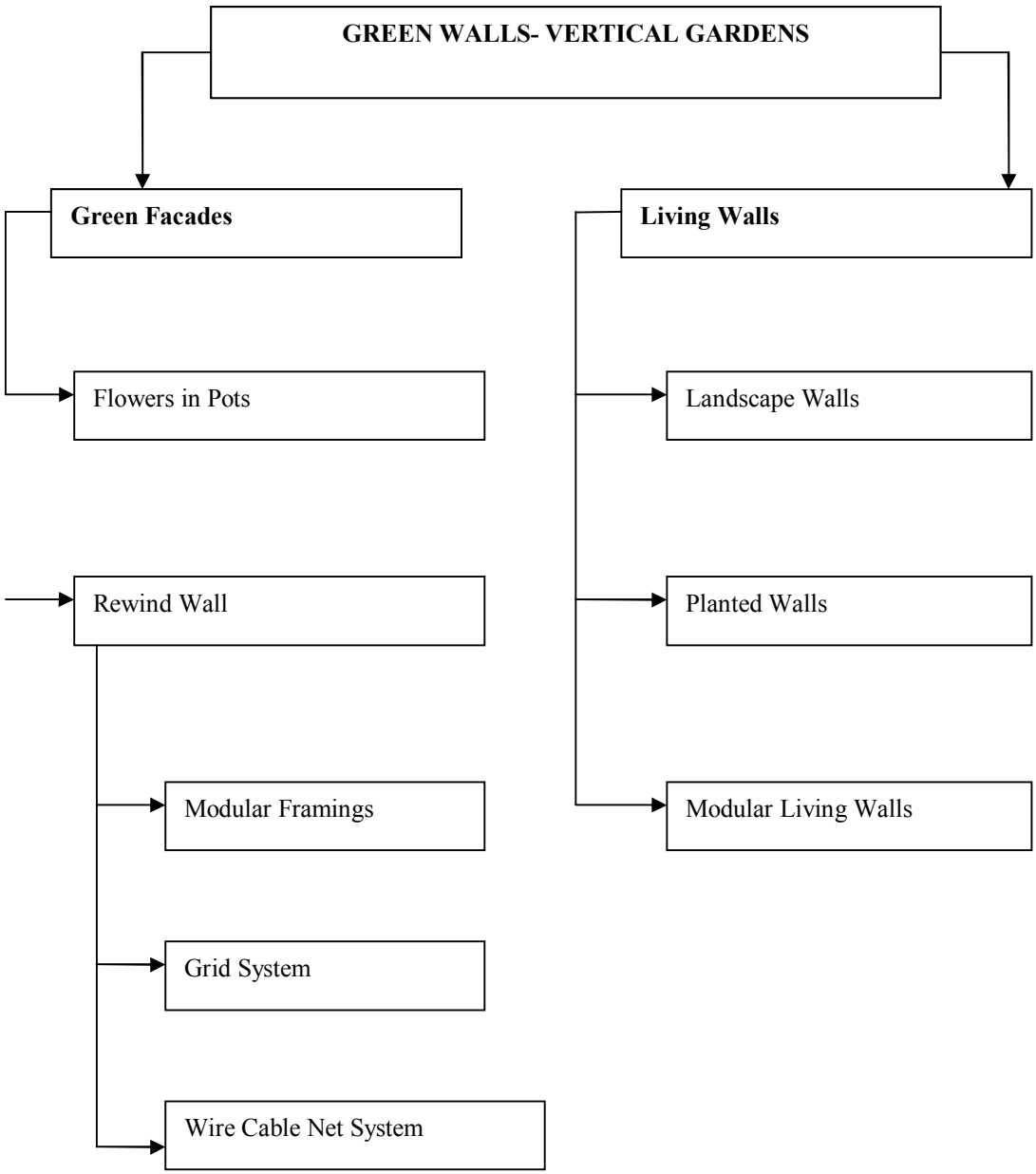

Figure 1. Types of vertical gardens (Yeh 2012; Green Roof Organization 2008; Köhler 2008; Yüksel 2013).

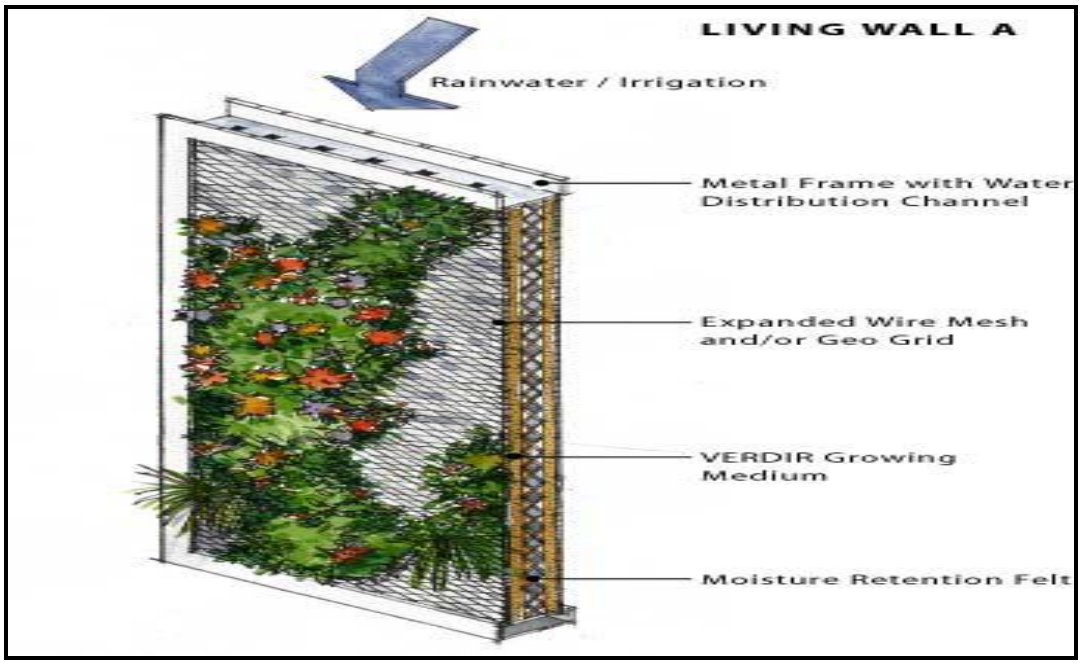

Figure 2. Living wall detail (Cooney et al. 2004; Yüksel 2013).


Figure 3. Examples of green facades and living walls (Greenroof 2016; Vertical Garden 2016).

Benefits of Vertical Gardens

Urbanization induced environmental pollution spread the idea that vertical gardens would have positive impacts on the urban life quality. Social, ecological and economic impacts of the vertical gardens are: Energy conservation, carbon sequestration, oxygen production, noise isolation, habitat creation for wild life, particle filtering, reduction of the impact of rain water, creating urban agriculture area, positive impact on human.

Social, Ecological and Economic Impacts of the Vertical Gardens

Social Impacts

Social impacts include physiological, aesthetic and health impacts. Social impacts present the relationship between the human behaviour and activities and vertical gardens. Positive impacts are observed more than negative impacts in the vertical gardens.

Psychological Impact

Psychological impact is difficult as it is based on subjective responses and attributes. Interaction of the people living in the urban environment with the nature is limited and this causes depression and anxiety (Darlington et al. 2001). Horticulture has a therapy field regulating human-plant relationship to reduce stress, fear, anger, blood pressure and muscle tension (Brown et al. 2004). Vertical gardens take attention like the natural environments and affect the negative thoughts like meditation (Peck et al. 1999). Benefits of the gardens in the working places are also identified. A study showed that green plants in the working places reduce absence of the employees by 5-15%. The plants in the classrooms reduced the stress level and increased productivity of the student by 12% (Butkovich et al. 2008). When we look at these examples, it is not surprising that people prefer nature dominant places to the urban environments, which lacks green spaces.

Aesthetic Impact

Many buildings in the city surround the city and create a cold, artificial and aesthetically week look. Corroded building surfaces, grey facades and soulless structures adversely affect the aesthetics of the city. These unwanted impacts can be reduced with vertical gardens. Urban aesthetics increases with the vertical garden practices, deformed structure surfaces can be covered with plants and urban image can be renewed.

Health Impact

Impact of the vertical gardens on health can be experienced by people and might be related to time spent around them (Butkovich et al. 2008). Every year Sick Building Syndrome (SBS) costs American economy 15-40 billion dollars. SBS is a collection of nonspecific systems such as eye, nose, skin and throat irritations, headache, fatigue and skin rashes. Vertical gardens can reduce interior levels of volatile organic compounds (VOCs) and SBS related compounds (Butkovich et al. 2008). From a physiological perspective, vertical gardens might have an impact of reducing heart rate and stress (Peck et al. 1999). It is reported that symptoms such as headache might be reduced by at least 20% (Bringslimark et al. 2009). Humidity is an important factor in the working environment. Its level is 45-65% in an ideal working environment (Cooney et al. 2004). Another important factor affecting the comfort of the occupants is noise. It is known that noisy environments are stressful and annoying and prevent people from working at the full capacity (Huang 2011). Vertical gardens can be considered as an additional layer absorbing the external and internal noise (Peck et al. 1999).

Job Opportunities

Many projects are developed on a sustainable urban model and to re-create nature and city relationship. Vertical gardens create a different perception and open a place for themselves with their different design concept. New business and job opportunities are created in the market when the local governments and

private sector started vertical garden practices for urban memory and identity in the institutional green market.

Environmental and Ecological Impacts

Vertical gardens positively contribute to both living space and the city by creating a living environment inside. The plant composition reduces intra-urban radiation and heat caused by the building surfaces. Environmental impacts of the vertical gardens in general can be summarized as: reducing urban heat island effect, improving air quality, improving energy conservation, reducing noise, increasing biodiversity, providing space for wildlife and creating space for urban agricultural practices.

Reduction of Urban Heat Island Effect

Urban areas are warmer than the rural ones due to absorption of heat in the impervious surfaces and this phenomenon is called Urban Heat Island Effect. This factor, adversely affecting the lives of the urban dwellers, leads to placement of a different emphasis on the vertical gardens (Yeh 2009). Water loses in the plants through evapotranspiration reduces the temperature in the surrounding atmosphere. In a research carried out in the Physics Institute in Berlin, it was revealed that daily cooling capacity of 56 potted plants in a 4-storey building is 157 kWh. In the warm climates, it is possible to save the air conditioning energy cost by reducing inner temperature using plant cover on the buildings, in addition to reduction of ambient air temperature and urban heat island affect. For example, 8-9°C temperature reduction is foreseen in a valley with 10 meters height and 15 meters length in an urban area of Hong Kong by greening the facades and rooftops of the buildings (Alexandri and Jones 2006).

Improvement of Air Quality

Plants absorb the sun light and produce glucose and oxygen by splitting the carbon dioxide produced by living things and water. Vertical garden practices in interior and exterior spaces filters chemical particles in the air such as CO_2, NO_2, SO_2, VOC, and CO. Furthermore, plants increase the oxygen level declining during the day by converting carbon dioxide gas in the atmosphere into oxygen. In addition to this gas circulation, plants absorb harmful aerosols in the air such as Volatile Organic Compounds (VOCs).

Improvement of Energy Efficiency

Vertical garden simply limits the heat transmission into the wall and reduce the surface temperature (Bass 2007). The vertical garden, creating an air gap between the garden and the wall, slows down the vertical movement of heat, and thus heat is captured during cold weather and isolated during hot weather. Table 1 shows the average energy consumption of a five story building with and without the installation of the vertical garden (Binabid 2010).

Table 1. Average energy consumption of a Five-Level Building with and without vertical garden (Binabid J. 2010; Shiah and Kim 2011)

Energy Consumption	Average Energy Consumption (kWh)	Average Energy Consumption with Vertical Garden Installed (kWh)
Heating from Natural Gas	220.000	216.000
Cooling from Electricity	78.000	66.000
Lighting from Electricity	27.000	27.000
Hot Water from Natural Gas	70.000	70.000
Total	395.000	378.000

Noise Reduction

Noise insulation property of the plants is the objective of the afforestation along the highways. Utilization of the plants as noise barrier on the highways is a reference for the vertical gardens with its function of dispersing the noise compared to reflectivity of the surfaces. Moreover, it is known that planted rooftops convey sound into the inner space less than the unplanted ones. Thus, it is a reality that plants play an

aesthetic and functional role in dissemination and absorption of the noise created both in the dense urban structure and on the highways (Loh 2008).

Increased Biodiversity

Green walls should be used to increase biodiversity and their benefits should be explored. Most of the urban studies focus on green roofs and providing habitats for plant-animal species. Green walls are natural extensions of these environments with their potential connection to the roof (Green Roofs Technology 2008). Green wall designers need basic knowledge on biodiversity and ecological restoration for plants as well as on fauna for animals. Climbing *hydrangea* (*Hydrangea anomala petiolaris)* and morning glory *(Ipomoe tricolor)* attract butterflies and hummingbirds (Green Roofs Technology 2008). Storm water ponds and filtration systems help in reconstruction of the habitat with certain leaved plants. Additionally, vertical gardens provide shade (Green Roofs Technology 2008).

Urban Agriculture

Rapid urbanization and reduction of rural areas adversely affect the agricultural areas. New food production techniques are tested due to increasing population and urbanization. One of them is vertical agricultural practices emerged due to the reduction of horizontal spaces. This way, fresh and safe food can be produced and it can be a contribution to sustainable urban model.

Economic Impacts

Profitability is the main factor on usage of technologies. Economic analyses are carried out for the investment cost of the technologies and their profitability during their lifetime. Installation cost vary between 100$ to 1200$ (Curtis and Stuart 2010; Inhabitat 2007). Urban heat island phenomenon is common in concrete buildings. Heat is absorbed by the building during the day and building temperature rises compared to its surrounding and creates a heat island. Vertical garden can act like a cooler due to plant canopy and plant evapotranspiration. Evapotranspiration creates a cooling effect due to evaporation of the water in the leaves. For example, 2.5 MJ energy is required to evaporate 1 kg of water (Ottelé 2010). A vertical garden can reduce impact of the wind by 75% and heating demand by 25% (Peck et al, 1999).

Storm Water Management

Vertical gardens can be affected from heavy rain and strong wind. They can clean the water along planters filled with plants (Peck et al. 1999). Furthermore, they reduce waste water as rain water collected in the hydroponic system is used for plant irrigation (Ottelé 2010).

Bio-filtration of Indoor Air Quality

A vertical garden in a building can act as a bio-filter and oxygen generator. For example, 27 g oxygen can be generated in 25 m^2 leaf surface in an hour. This is equal to human consumption and 150 m^2 leaf surface can provide human in take for a year (Peck et al 1999).This huge amount of oxygen is produced by a small leaf. If the plant is at an adequate size, its impact is stronger. Moreover, a 60 m^2 vertical garden can filter 40 tonnes of harmful gases and 15 kg heavy metal (Vertical Ecosystems 2011). Plants in the interior vertical gardens can degrade VOCs, benzene, toluene and other toxic fumes (Darlington et al. 2001). People suffering from asthma and other respiratory diseases can benefit from these aspects. Furthermore, 3.5 kw per person can be saved during peak seasons (Cooney et al. 2004).

Other Economic Impacts

Vertical gardens increase the value of the building they are applied on, due to their aesthetic and functional properties. Furthermore, they provide accessibility to fresh and cheap food by agricultural production (vegetable gardening).

Results

Minimizing the pressure on the limited/ non-renewable resources in order to convey them to the future generations describes the concept of sustainability. *Sustainable city* is where social-economic-ecologic approaches become compatible with the city in order to ensure the continuity of the change-transformation-development. In this context, one of the examples of sustainable city approaches in practice is vertical gardens.

Vertical gardens ecologically contribute to urban life quality by insulating noise, increasing biodiversity by creating habitat for birds and insects, reducing urban heat island effect and creating opportunity for urban agricultural practices. They improve aesthetic perception by providing a positive psychological effect on people and create new job opportunities. They also raise awareness by contributing to the urban identity as living materials.

Economically, vertical gardens provide energy efficiency and if rainwater is used for irrigation, water efficiency can also be provided. Economic contribution constitutes the keystone of a sustainable city model. Thus, economic value gains importance as a basis in the vertical garden practices.

Vertical garden practices, ecosystem continuity and renewable production constitute the design priorities in the sustainable city model. In some practices, provision of required water, light and nutrients from outside, especially for maintenance, is inconsistence with a sustainable approach. Thus, in the design and implementation of vertical gardens, priority should be given to implementations minimizing dependency on outside, using rainwater for irrigation, providing the light naturally and minimizing the requirement for maintenance.

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