ASSESSMENT OF BENEFITS OF URBAN FORESTS UNDER THE ECOSYSTEM SERVICES FRAMEWORK: A LITERATURE REVIEW

by

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Abstract

It is reported that approximately 53.4% of world population live in the urban areas and urban population is still increasing at an annual rate of 0.5%. However, urban areas are now facing two main challenges: one is the decreasing of air quality, and another is unpredictable global climate change. In order to overcome challenges, people have been increasingly concerned about finding more integrated methods to manage urban areas. As a result, urban forestry has experienced a rapid development within last two decades especially in North America and Europe. Many studies have shown urban forests can provide the urban community with a range of ecosystem services such as air filtration, heat relief, aesthetic values, and food production. Ecosystem services refers to the benefits that human directly or indirectly derive from the urban ecosystem. The main objectives of this paper are to review and characterize the effects and values of urban forests using framework of ecosystem services and explore the current statue of Ecosystem Services studies in urban areas. It presents a literature review of related and accessible scientific publications and four case studies, with a focus on the studies in North America and Europe. With applications of GIS and i-tree, ecosystem services especially environmental services such as wildlife habitats, air pollution reduction are easily and well assessed. However, economic services like food production and social services like urban forests potential role in policy-making process are rarely assessed. Finally, recommendations will be given towards community involvements in the future studies of urban forestry and the critical role of urban policy makers in creating a nicer urban living environment.

Keywords: Urban Forestry, Urban Forests, Ecosystem Services, Policy making, Community involvement

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1 Introduction

According to the World Urbanization Prospects report, approximately 53.4% of people around the world live in urban areas, and the urban populations are still increasing at an annual rate of 0.5% (DESA, 2014). Although developing countries have a relatively low rate of urban population compares to developed countries, it is predicted that the proportion will be 60% in developing countries by the year 2025 (DESA, 2014).

However, the economic and industrial development within the last century led to the dramatic increases of air pollutants emissions (D'amato et al., 2010). Air pollution has become one of the most severe environmental problems throughout the world. According to the World's Worst Polluted Places report, one of the worst pollution problems is urban air quality (Blacksmith Institute, 2008). Laboratory studies have indicated that air pollution adversely impacts human's lung functions (D'amato et al., 2010). It is estimated that urban air pollution causes approximately 1 million premature deaths and 1 million pre-native deaths annually (Kura et al., 2013). Approximately 2% of GDP in developed countries and 5% of GDP in developing countries was lost because of urban air pollution (United Nations Environment Programme, 2016).

Global climate change resulting from greenhouse gas emissions poses serious threats to urban areas and their growing populations (Jones et al, 2007). Urban populations face greatest risks from the increase of extreme heat events. It is reported that extreme hot days have dramatically increases in over 200 cities around the world from 1973 to 2012 (Mishra et al., 2015). Extreme heat events have already led to the increase of mortality all around the world, even in developed countries. In western Europe during 2003, extreme heat events resulted more than 70,000 heat-related deaths (Robine et al., 2007).

As a result, people have been increasingly recognizing the importance of urban forests, which can be an effective way to improve the urban living environment. Growing awareness about investigating how urban forests affect urban communities contributes to the rapid development of urban forestry all around the world. Ecosystem services provided by urban forests are increasingly used to describe how urban forests benefit the urban communities (Elmqvist, 2011). In order to assess how urban forests will improve urban living environment, it becomes important to determine the extent of ecosystem service research and application in cities. And according to the recent systematic review of the global scientific discourses on urban forestry, scientific studies related to Ecosystem Services in urban areas are mainly distributed in North America and Europe from 1999 to 2014 (Ostoić et al., 2015). Thereby, urban forestry studies in North America and Europe are the two main source of evidences, which I will discuss the in the following sections.

2 Background

Concepts and definitions of Urban Forestry

The concept of urban forestry originated in North America in the 1960s. Jorgensen first coined the term of “Urban Forestry” in 1965 in response to his graduate students’ interest. A definition was not given until a paper published by Jorgensen in 1974, wherein urban forestry was defined as (Jorgensen, 1974) “ *a specialized branch of forestry (that) has as its objective the cultivation and management of trees for their present and potential contributions to the physiological, sociological and economic well-being of urban society.*”

Since then, a variety of definitions of urban forestry existed, but a precise definition. In North America, one of the most broadly accepted definitions of Urban Forestry is " *The art, science, and technology of managing trees and forest resources in and around urban community ecosystems for the physical, sociological, economic, and aesthetic benefits trees provide society* " (Helms, 1998).

Europe has a long and rich tradition of urban green space planning and design, but the concept of urban forestry reached Europe until the 1980s (Johnston, 1997). Researchers from Britain were inspired by the urban forestry concept during their study visit in North America, and then quickly applied this concept to their urban forests' management. Since then, urban forestry in Europe has undergone a substantial development as an independent academic field (Konijnendijk et al., 2006). However, the definition of urban forestry is still under debate within Europe. Because of the diverse languages, cultural histories and landscapes within this continent, it made even harder to translate urban forestry concept into a term. In general, there are two streams of opinion towards how to define of urban forestry in Europe (Konijnendijk et al., 2006). The broad definition describes urban forestry as " U*rban forestry is a multidisciplinary activity that encompasses the design, planning, establishment and management of trees, woodlands and associated flora and open space, which is usually physically linked to form a mosaic of vegetation in or near built-up areas. It serves a range of multi-purpose functions, but it is primarily for amenity and the promotion of human well-being"* (Ball et al., 1999, p. 325; Konijnendijk et al., 2006). The narrow perspective is similar to the traditional town forestry, which describes urban forestry as management practices at woodlands within or close to urban centers (managed for amenity values). The two streams have totally different views towards the definition for urban forestry. Thus, the definition of urban forestry underwent an emergency of standardization and harmonization in Europe.

What are "Urban Forests"?

Urban forests incudes all green space within the boundaries of cities, towns or neighborhoods. Such forests consist public and private owned trees as well as plants, which naturally grow or planted in urban sites like parks, streets, school or residential areas.

Instead of defining urban forests trees or vegetation within or near cities, an urban forestry research group of UBC described urban forests as the green space within urban sites. In this report, they separate urban sites into several categories (See Table 1): Parks, Streets, Private Garden, Green elements on buildings and other places like golf courses and community gardens (Nesbitt et al., 2015). Urban forests include all the green space within those urban sites, where were presented with more detailed components.

Table 2. Components of Urban Forest

Urban Forests / Urban Greenery	Parks	Recreational parks/sports fields
		Woodlands
		Pocket parks
		Rooftop parks
		Urban orchards
	Streets	Street trees and landscaping
		Greenways
		Urban orchards
	Private gardens	Trees/shrubs
		Urban agriculture
		Urban orchards
	Green architecture	Green roofs
		Green walls
	Other	Golf courses
		Cemeteries
		Community gardens

Ecosystem Services & Urban Forests

Varies definitions for the term Ecosystem Services existed (Fisher et al. 2009) as it is applied in different research fields such as agriculture, biology and ecology (Escobedo et al., 2011). As

Costanaza et al. (1997) noted, the definition of ecosystem services refers to “benefits human populations derive, directly or indirectly, from ecosystem functions”. Urban Forests is a crucial type of ecosystem (Bolund & Hunhammar 1999). Urban green areas also can provide ecosystem services to urban residents (Costanza et al. 1997; TEEB website n.d.). For instance, trees can provide air filtration, heat relief, carbon sequestration and storage, aesthetic values, spiritual or religious enrichment wildlife habitat maintenance and enhancement, educational and recreational benefits to urban societies. The Millennium Ecosystem Assessment separated the benefits that human get from ecosystem into four categories: provisioning services (food and timber), regulating services (climate regulation and air purification benefits), supporting services (wildlife habitats preservation) and cultural services (aesthetic and spiritual benefits) (MEA, 2005). Many other studies divide Ecosystem Services of urban forests into three categories of benefits: social, economic and ecological / environmental (Konijnendijk, 2005; Ignatieva et al., 2010; Clark and Nicholas, 2013).

3 Purposes and Scope

The purpose of this report is to review and characterize the effects and values of urban forests using framework of ecosystem services. It presents a literature review of related and accessible scientific publications, with a focus on the studies in North America and Europe. This review summarizes Ecosystem services provided by urban forests regarding specific benefits, which are included into three main categories: social, economic and environmental services.

For the purposes of illustrate current status of research, how the ecosystem services were assessed and what lessons we can learn from, I present four case studies of the recent research of Ecosystem

Service in North America and Europe. It is reported that environmental services of urban forests have been given the main focus in North America, while social services have been prioritized in European studies (Konijnendijk, 2006). Thus, I choose one recent study from the USA to illustrate the current statue of study on environmental services of urban forests. And one recent experiment from Europe was selected to illustrate the current status of social services. Besides, both in Europe and North America, researches has increasing concerns urban forestry to improve urban food production and safety as well as the potential role of urban forests in meeting policy targets (e.g. Clark et al, 2013; Baró et al, 2014). Therefore, another two cases were also discussed in this report. One is to explore whether urban food forestry can potentially increase urban food security. Another case is to investigate urban forests' potential role to meet policy targets.

Finally, I identify challenges for current research as well as the opportunity for future research of urban forestry. Also, recommendations will be given towards community involvement and policy makers' critical role in creating a nicer urban living environment.

5 Benefits of Urban Forests

- **Economics**

Forest Products

Compared to rural forests, urban forests can produce types of forest products like food and medical plants. Foods can be nuts, fruits, and mushrooms. It is reported that food trees were commonly planted in developing countries such as in Panama, vegetable crops can be found everywhere even in downtown areas (CATER, 1993, 2011; Sheikh, 1976). Medical plants was seen as valuable economic and cultural resources in Pacific Islands (Thaman, 1987). It recorded that more than 90 types of medicinal plants were found in urban natural areas in Fuji, Tonga, Kiribati and Nauru (Thaman, 1987). But in other countries, medical plants seldom found in urban forests but in many urban farms (Smit, 1992). Urban forests can also produce limited timber when some trees that affected by natural disturbances.

- **Ecological**

Air filtration

It is reported that urban trees and green spaces can significant improve urban environment in term of air filtration. Planting trees and shrubs along streets can improve air quality by intercepting and absorbing gaseous pollutants. Those gaseous pollutants are Sulfur Dioxide (SO2), Ozone (O3) and Nitrogen Oxides (NOx) through the pores on the leaf surfaces (Chen et al., 2005) Also, trees can absorb, trap particulate pollutants (dust, ash, pollen and smoke). It is reported that trees in one urban park can remove up to 48 pounds of particulates, 9 pounds of Nox, 6 pounds of SO2, 0.5 pounds of carbon monoxide and 100 pounds of carbon every day (urban forestry network, 2015). Nowak et al. (2006) mentioned that urban trees in the US could remove about 711,000 metric tons of pollutants and create a dollar value with USD $ 3.8 billion annually.

Studies indicate that pollution removal values of urban forests vary among different areas and cities, which depends on the tree cover, pollution concentration, length of leaf season and other factors like amount of precipitation and tree transpiration and deposition velocities.

Climate Change Mitigation

It is reported that urban trees can mitigate climate change in term of carbon storage and sequestration

(Nowak et al., 2002). CO_2 can be stored as biomass by urban trees during photosynthesis process. Studies show that urban trees in the US can create a gross carbon sequestration with 25.6 million tons and a net carbon sequestration with 18.9 million tons per year (Nowak et al., 2013).

Research in US cities also indicated that urban soils have the potential to store carbon as organic matter decay and forms soil. (Pouyat et al. 2006) Urban trees can alter microclimate, energy use and albedo, which also contribute to carbon emission reduction (Middel et al., 2015).

Urban vegetation relief urban islands effect by providing shading (McPherson et al., 1997). A study in Phoenix indicated that increasing tree coverage in urban areas could be an effective heat relief approach.

Wildlife Habitat

Snag and den wood in urban areas is a vital nesting resource for cavity nesters such as woodpecker, flicker, and raccoon. Vegetation grows along streams create crucial riparian habitats for wildlife such as insects and fish. Riparian woodlands provide food, nesting sites for wildlife, but also protect wildlife habitat in term of stabilizing stream banks and avoiding soil erosion.

- **Social**

Aesthetic Value and Spiritual Value

It is no doubt that urban forests have very high aesthetic values. Aesthetic values associate with people enjoying different color combinations, structures, textures of urban trees and plants (Tyrväinen et al., 2005). Aesthetic values of urban forests highly depend on visitors' educational, cultural, age, gender and also hobbies. Many pervious studies indicate that aesthetic experience in green space has positive effects on people's mental and emotional status (Kaplan and Kaplan 1989).

Besides, fresh air and open green space also beneficial to human's mental health and positive mood. Preference studies especially in Europe have indicated that urban green space has strongest positive benefits on human's mental health (Barton and Pretty, 2010)

Educational and recreational Value

Urban parks have a huge education potential for people of all age (Cater, 1993). Urban parks especially botanical gardens offer multiple types of educational potential (Krasny and Tidball, 2009). Urban forests would be a great place for field trips, where students can learn about science knowledge such as plant or tree identification as well as learning about management and policy issue (Krasny and Tidball, 2009).

6 Case Studies

Case 1: Bird habitat assessment in ten northeastern cities in the USA

In spite of the impact of climate change, urban land use alteration also has a significant impact on global biodiversity. In the USA, urbanization has caused the endangerment 275 species (Thompson & Jones, 1999; Sam, 2011) To date, many studies were conducted to explore the effects of urbanization on the bird population. However, their findings likely cannot be applied to the urban planning and management due to the lack of a method to quantify bird habitat potential. As a result, several US research stations like Northern Research Stations, Department of Environmental Conservation of the University of Massachusetts engaged in the urban forest assessment of bird habitat potential in ten northeastern US cities by using i-tree model. The ten cities are Baltimore, Boston, Jersey City, Moorestown, New York, Philadelphia, Scranton, Syracuse, Washington, and

Woodbridge.

How were ecosystem services assessed and valued?

Ten northeastern US cities were selected as a study area for two reasons. The first reason is they have available and accessible i-tree database of urban forests, which potentially reduced the cost of the study. Another reason is that ten cities in different states of US can provide a better representation other than a particular city. The increase in sample size can be beneficial for the future application in urban conservation planning measurement by urban foresters, landscape designers.

This study focused on the assessment of supporting (habitat) ecosystem services that provide by an urban forest. In the assessment the bird habitat potential in cities, i-tree wildlife tool was used to quantify the characteristics of urban forests, and Suitability Index (SI) score was calculated to evaluate the habitat suitability for different land uses for various bird species. Those available i-tree data were collected in the same plot in 2001 and 2009. Nine candidate bird species that have higher frequency during breeding season from 1990 and 2000 were selected to represent all bird species that potentially use urban habitats. Also, common types of land use in each city were taken into consideration when calculating SI score. Those land uses are commercial and Industrial lands, parks, residential areas, transportation-use lands and vacant lands.

Local habitat variables are required to calculate SI while i-tree did not model them. Habitat variables refer to factors that affect species abundance. Researchers of study summarized variables based on some publications about habitat relationships. Two to five variables were used to determine the final SI score. Basal area was utilized in each SI calculation while other variables were determined by the particular condition of bird species or land use.

SI ranges from 0 to 1, whereby 0 refers to undesirable bird habitat, and 1 relates to most suitable bird habitat. SI score was assigned to per species per i-tree plot; Mean SI score was calculated for per species per city and mean SI score was also calculated for per land use per city. Also, GIS analyzes were used during the analysis of i-tree variables.

What can we learn from this study?

Results of this study indicated that urban forest provides essential bird habitats, whereas different city has different suitability for various bird species. Moreover, suitability of bird habitats changed a lot through time. Among those ten northeastern cities in the USA, Baltimore and Syracuse were seen a significant decrease of suitability for almost all bird species. Another important finding of this study is that dead wood areas in urban areas can be a critical source of habitat for nesters. Philadelphia, one of the ten study cities, has the highest proportion of dead wood within i-tree plots and has the highest potential to support cavity nester species, such as black-capped chickadee and red-bellied woodpecker.

This study can be a useful guidance for urban foresters, planners, and landscape designers to have a better decision with how to improve the sustainability of urban birds habitat. More specifically, managers can review i-tree data and habitat value (such as SI) to determine the conservation plans for specific bird species. Also, dead woods in the urban forest can be a critical source of habitat for nesting birds, so it is very necessary to take dead wood management into consideration when establishing new urban planning and management policies.

Case 2: Urban forest and Stress Relief -A field experiment in Helsinki, Finland

Compared to rural residents, urban residents have approximately 20% higher risk of anxiety and disorders (Anxiety org, 2013). Many studies have indicated that natural environment has a positive effect on human health and well-being compared to urban environments (Hartig et al., 2003; Hartig, Mang, & Evans,1991; Morita et al., 2007; Tsunetsugu et al. 2013). Studies also have indicated that city residents can gain valuable aesthetic and spiritual experience during working through urban green space. Those experience can potentially lower blood pressure, reduce stress, enhance parasympathetic nervous activity (Lee et al., 2012; Park et al., 2010; Tsunetsugu et al., 2013). In previous studies, very few of research focused on how the real environmental settings affect residents' stress level. A field experiment was conducted in Helsinki, Finland with the aim to measure the relationship between different urban environment settings and stress relief level.

How were ecosystem services assessed and valued?

This study focused on the assessment of social ecosystem services of the urban forest. Stress relief benefits and restorative effects of three types of urban settings were investigated in this experiment. About 77 residents got involved by visiting three different urban sites: a built- up city center, an urban park, and urban woodlands. Participants of this experiment were healthy, no-smoking adults (6 males and 71 females), whose age rang from 30 to 61 years old. They all worked 39.25 hours per week at Metropolitan Area. The experiment was conducted during working day after 3 pm in three different seasons: the autumn of 2011, the spring of 2012, late summer of 2012 (mid-August to mid-Septemeber). The methodology of this study is using psychological scales to indicate the participants' self-reported restorative experience, mood and perceptions.

Two scales were used to measure restorative experience. One is the Restoration Outcome Scale (ROS) (Korpela et al., 2008) and another one is the Perceived Restorativeness Scale(PRS) (Hartig, Korpela, Evans, & Gärling,1997). The Postive and Negative Affect Scale (PANAS) measured the self-reported mood of participants (Watson, Clark, & Tellegen, 1988). The Subjective Vitality Scale (SVS) measured the self- reported perceptions (Ryan & Frederick, 1997). And the Creativity Scale measured the participants' creativity or ideas that were inspired by different environment settings. Those psychological measures range from 1 (not at all) to 7 (completely).

What can we learn from this study?

Urban environment settings impact restorative quality differently ((Herzog et al., 2003; Korpela et al., 2010; Tyrväinen, Silvennoinen, et al., 2007; Tyrväinen, Mäkinen, & Schipperijn, 2007). Compared to a built urban site, urban green areas increase participants' feelings of restoration, vitality, and positive mood. There are very few differences between the urban park and the urban woodlands regarding their potential stress relief benefits. Urban residents especially people who work in a built urban area have experienced a much higher risk of anxiety and mental disorders than rural residents. It is very necessary for urban workers to spend some time walking and exercising in urban green areas after work. Additionally, accessible urban parks and woodlands are a crucial factor to increase urban residents visits, which should be considered for urban planning.

Limitations

Gender imbalance within participants is one of the limitations of this field experiment. Because of the uncertainty and no control of who get the invitation letters, it is very difficult to control gender balance. Although gender imbalance did not affect this experiment's overall results and conclusion, it is still necessary to avoid gender imbalance in the future study of gender difference of natural perception.

Case 3: New concept of Urban Forestry - Urban Food Forestry

With an increasingly urbanized future, how to meet the demand of present urban population and the future population has become an increasingly urgent topic in academic studies, urban planning and policy-making processes. Lund University Center for Sustainability Studies conducted an experiment in Burlington, US to investigate the potential urban food forestry capacity.

Unlike traditional concepts of urban forestry, they combine integrating elements of urban agriculture, urban forestry and agroforestry to develop a new concept, which they call as Urban Food Forestry (UFF). They define Urban Food Forestry as a new approach that strategic use wood Perennial food-producing species such as apple trees within available urban public lands to improve the sustainability of urban communities.

How were ecosystem services assessed and valued?

Ecosystem services like food production and improvement of food security were assessed in this study. Those benefits were identified through quantifying the number of people who can benefit from eating fruits.

Firstly, available GIS data of the city of Burlington was used to extract available urban public space. Then, calculating the productive capacity of those available public lands to determine the total mass of apples can be produced. Finally, estimating the number of people could benefit from eating apples. Two scenarios involved in this study. One scenario is to estimate the number of very food security (VFS) people who can benefit for eating apples. VFS people refer to people who have very low food security. Another scenario is the estimation of planting land size that its apple production can meet the minimum daily fruit recommendation of all cities' population.

What can we learn from this study?

Results of this experiment shown that 4840 VFI individuals in Burlington could be supported when planting apple trees at only 50 % of available urban public lands. The entire city population's minimum daily fruit recommendation could be meet when 69% of Burlington's urban public lands are planting with fruit trees. This case forwards a new development potential of urban forestry. Urban forestry not only provide varies environmental benefits like air filtration, wildlife habitat, but also provide fruits and increase cities' food security.

Case 4: Ecosystem Services of urban forests contribute to meet policy Targets

In the last decades, the European Union had put a lot of efforts to improve air quality and mitigate climate change. However, urban decision makers rarely realized the potential role of urban green space in contributing to meet air quality and climate change mitigation targets ((Nowak 2006 ; Escobedo et al. 2011). Yet, many studies have concluded that effective management of urban forests can be a method to achieve specific policy targets. Recent research has analyzed urban forests' potential contribution to meet air quality and climate change mitigation policy in Barcelona, Spain.

This study was to investigate regulating ecosystem services and disservices provided by urban forests. Regulating ecosystem services include air purification and global climate regulation. The ecosystem disservices refer to vegetation emit biogenic volatile organic compounds (BVOC) that contribute to the formation of air pollutants such as O_3 and CO. BVOC includes isoprene (C_5H_8) and monoterpenes (C_{10} terpenoids).

How were ecosystem services assessed and valued?

The i-Tree Eco tool (Nowak and Crane, 2000) was used to measure the ecosystem services and disservices in Barcelona. 579 plots were randomly selected using a GPS device within the municipality of Barcelona. Data collection was carried out from May to July 2009. After collecting all field data, i-tree Eco tool was used to quantify the ecosystem services of air filtration and climate regulation as well as disservices of BVOC emissions.

For equating the air purification provided by urban forests, the i–tree estimated the dry air pollutant that trapped by urban trees and shrubs. Climate regulating benefits were measured by the gross and net carbon sequestration, and carbon storage. Ecosystem disservices were estimated through applying incremental reactivity scales (e.g. certain amount of BVOC emission can produce such amount of O_3).

Those ecosystem services and disservices also were evaluated by adding economic values based on the pervious studies in the USA.

What can we learn from this study?

In Barcelona, urban forests can remove approximately 300 tons of pollutants and create an economic value of 2.38 million USD each year; Urban trees and plants can store 5187 tons carbon with an economic value of 0.4 million USD per year. Although results of biogenic emission analysis show that urban green and natural green and low residential areas have high level of BVOC emission, the overall results suggest that urban forests potentially contribute to meet the GHG emission policy targets. This study provides a solid understanding of the environmental ecosystem services of urban forest. Managing urban forests could be a cost-effective way to meet specific environmental standards and policy targets. Additionally, air pollution has already badly impacted urban residents health, it is very important to account ecosystem services into urban policy-making process.

7 Recommendations

As we have seen urban forests provide humans with a variety of ecosystem services, they can improve urban food security, contributes to meet specific environmental policy targets, maintain urban biodiversity, as well as improve human's health.

With applications of GIS and i-tree, ecosystem services especially environmental services such as wildlife habitats, air pollution reduction are easily and well assessed. However, economic services like food production and social services like urban forests potential role in policy-making process are rarely assessed. In spite of the need of future research on economic services and social services, the involvements of community and support from local urban policy makers are also important to future studies. For instance, all the above cases were conducted by a small group of people to explore methods to improve the urban living environment. However, urban areas are the home of half of the world people. Everyone should involves to build a nicer urban living environments, in all stages throughout exploring, designing, managing and protecting urban forests.

All scientific studies are just the first step. They are only small groups but the group who care a lot to explore a happy future. They need our support and involvements to overcome new challenges. We have to work together to create a future that we will glad to live in.

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