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Estimating the Effect of Urban Trees on Summertime Electricity Use and Air Quality Improvement in Urban Areas –Amman as a Case Study

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Abstract
The importance of trees as an urban microclimatic modifier is well known, but little work has been done on semi-arid climates in general, while no similar studies have been done on a local level in Jordan. Conducting such studies, especially on the local level, will provide useful data on trees as a shading device and their role in mitigating the urban heat island effect and in minimizing the continuous rising temperature in city cores and dense areas. This study aims at providing professionals as well as architects with the impacts of shade trees on air conditioning electricity use for residential buildings in Amman, hence an awareness of this issue is encouraged reflecting on both professionals and city residents. The study suggests a tree planting design guideline based on the computer simulation results for new and existing residential construction. Based on the outcomes, energy savings calculated for 50 typical residential buildings in Al-Hashmi Al-Shamali district, indicate that after planting 100 Pistacia atlantica (Mount Atlad Pistachio) medium size trees based on a specific criteria in respect to the landuse regulations for residential C; planted trees succeeded in lowering the cooling loads where the energy savings in summer were about 43.34%, 42.4% and 28.11%, for east, west and south elevations, respectively. These results indicated that the effect of planting trees around these building succeeded in lowering the total cooling loads by 35.87 %. This could be generalized to East Amman areas where the climatic conditions, building characteristics and lot setbacks are very similar to Al-Hashmi Al-Shamali.
Keywords: Amman, energy savings, revit, tree benefits, cooling energym semi-arid climate.

1. Inroduction

As a part of a complex global system, Jordan is challenging climate change and energy saving issues (Abdulla et al., 2004) (Abdalla, 2010) (Harrison, 2009) (Preston, 2012). Innovative urban planning methods and procedures are required in order to shift from the typical building scale to the urban level (Zanon and Verones, 2013) (Sadownik and Jaccard, 2001) (Dobriansky, 2009). Urbanization if haphazard can increase the urban temperature, energy use, carbon emissions, pollutants, municipal water demand, ozone level and human discomfort and diseases (Simpson, 2002). Planners must seek effective ways to reduce the impact of human activities on the climate; fossil fuel consumption reduction must be considered while planning as well as GHG emissions reduction strategies. Appropriate urban policies must therefore be activated innovating the manner in which buildings and cities are designed, constructed and managed in order to improve their performance in energy use and to provide greater support for diffuse energy production (Zanon and Verones, 2013).

City centers are affected from the Urban Heat Island (UHI), that is resulted from the small portion of trees and vegetation in cities and from the darker surfaces which are responsible for the large solar radiation absorbance. These differences affect climate, energy use, and habitability of cities. Architects, planners and researchers should focus on the role of vegetation on climate and how they could benefit of urban trees not only as a microclimate modifier but rather as a tool to reduce energy consumption in buildings. Urban trees planting is a frugal measure that may contribute in reducing summertime temperatures, with the designed model in this study, the indirect effects of urban trees on energy use will be assessed, which will provide guidelines for architects, planners and residents to maximize the benefits of urban trees not only in direct contributions but also indirectly.

1.1 Study Problem:

Energy fuels economic growth and it is an essential ingredient for the quality of life. Jordan suffers from shortage of energy recourses and depends on imported fuel. The rising prices of fuels alongside with the shortage in Jordan income, environmental pollution and climate change make architects, engineers and planners understand the importance of finding new sustainable strategies to minimize the dependence on energy.

In the urban environment, environmental sustainability issues become very important and the urban microclimate become a critical variable in terms of both human comfort and energy implications that encourage the preservation of natural systems within the city, from this point, Jordan must seek new sustainable planning approaches. Planting urban trees in cities may be a cost-effective solution that may contribute in conserving energy. Previous studies showed that UHI effect increases mainly because of the reduced density of green areas, the trend in urban materiels and urban forms (such as the spatial configuration of the built forms and of the open spaces). Many researchers discussed the importance of urban vegetation role in heat island mitigation. In this respect, this study will investigate the role of urban trees as a passive cooling strategy in the urban context in East Amman. Knowing that increasing urban tree numbers is an effective and easy way to adapt the climate change in the urban environment but it is much important to quantify these benefits and to understand the properties and processes that influence the magnitude of these benefits in areas such as Amman.

1.2 Study Objectives:

There are four main objectives regarding to this study topic which can be used as guidance along the study process. These objectives are; (1) to examine whether positioning urban trees properly can impact space cooling energy consumption during summer and peak electricity demand, (2) to quantify the indirect effects of trees on minimizing carbon emissions, according to minimizing power plant usage, (3) to enhance community awareness of the impact of trees on energy usage and (4) to suggest energy conserving planting program in Amman through developing tree selection, studying tree-sun-building relationship and setting helpful recommendations for residents.

This study assumes that; on an urban scale properly positioned trees can reduce summertime electricity use, urban trees can reduce carbon emissions both directly and indirectly due to decreasing electricity use and urban tree programs that stimulate citizens' participation can increase their conscious responsibility, and can reduce the cost of tree planting programs.

2. Materials and Methods

2.1 Introduction to the study area

Amman is the most densely populated region in Jordan with 38% of the total population live there (Potter et al., 2009). It is challenging many problems including; poor air quality, water shortages, UHI effect, and stormwater runoff. These challenges alongside rapid population growth and traffic problems are putting Amman in a huge problem concerning urban sprawl and sustainability. While the amount of forest and tree cover in the Greater Amman Municipality (GAM) accounts for less than 1% of total land, if both natural and planted areas are included (GAM, 2008). Amman must find suitable solutions to protect and restore environmental quality. As the tree canopy is a valuable component of Amman's urban ecosystem; increasing tree canopy cover could be part of the solution to social and environmental problems. Table (1) below summarizes the climatic data for Amman city. This study will focus only on summer season (from May to September); because what is anticipated from such study is to figure out the magnitude of trees shade on summer time electricity use through minimizing the reliance on air conditioning.

Table 1. Climatic data for Amman city (1975–2006). Source: (Potter et al., 2009).

Month	Average minimum daily temperature (°C)	Average maximum daily temperature (°C)	Relative humidity (am)	Relative humidity (pm)	Average precipitation (mm)	Average wet days (0.25 mm)
January	4	12	80	56	69	8
February	4	13	78	52	74	8
March	6	16	57	44	31	4
April	9	23	53	34	15	3
May	14	28	39	28	5	0.8
June	16	31	40	28	0	0
July	18	32	41	30	0	0
August	18	32	45	30	0	0
September	17	31	53	31	0	0
October	14	27	53	31	5	1
November	10	21	66	40	33	4
December	6	15	77	53	46	5

2.2 Study area:

The study area is located in Al-Hashmi Al-Shamali district with coordinates 31°58′25″N, 35°57′46″E. It is located within 1 km of the city center and therefore it is under the UHI effect. It experiences hot summer with a number of days where peak air temperatures exceeding 53°C, check Table (1). The site includes 50 test buildings that are relatively uniform with fairly similar characteristics (areas, number of floors, height, material and construction), see Figure (1) below. All buildings were three stories, pre-1980 construction, with a livable area of

120 m2 and there is no tree appearance in the study area, even there were no street streets so almost all of these buildings will be unshaded from trees. Buildings distribution on the site, setbacks from the street, topography is illustrated in Figure (2). Noting that all study area variables were considered to be a good representative of those found in residential C and D neighborhoods.

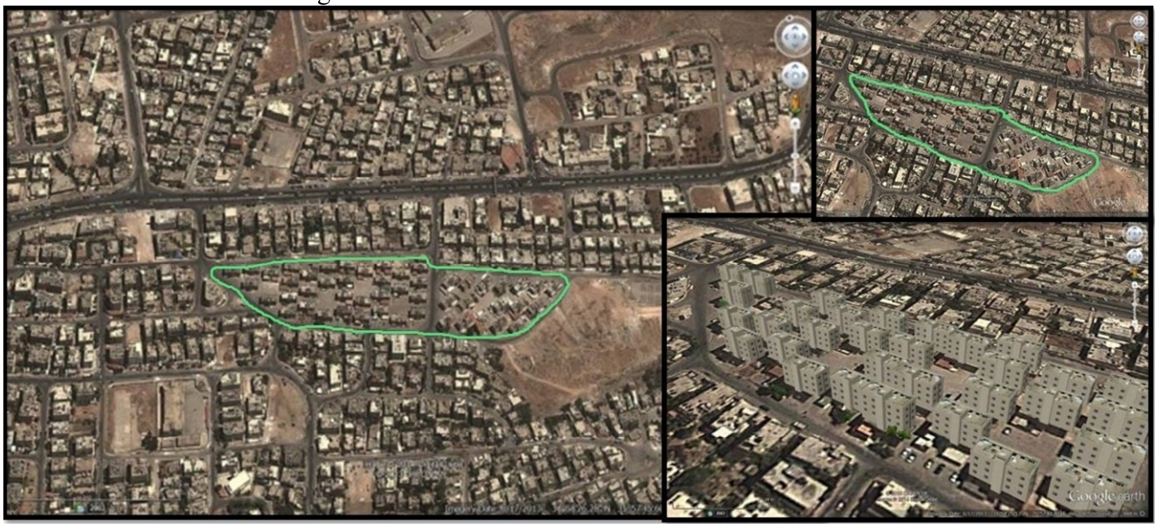

Figure 1. Study area within Hashmi Al-Shamali, Amman. Source: (Google earth, 2013).

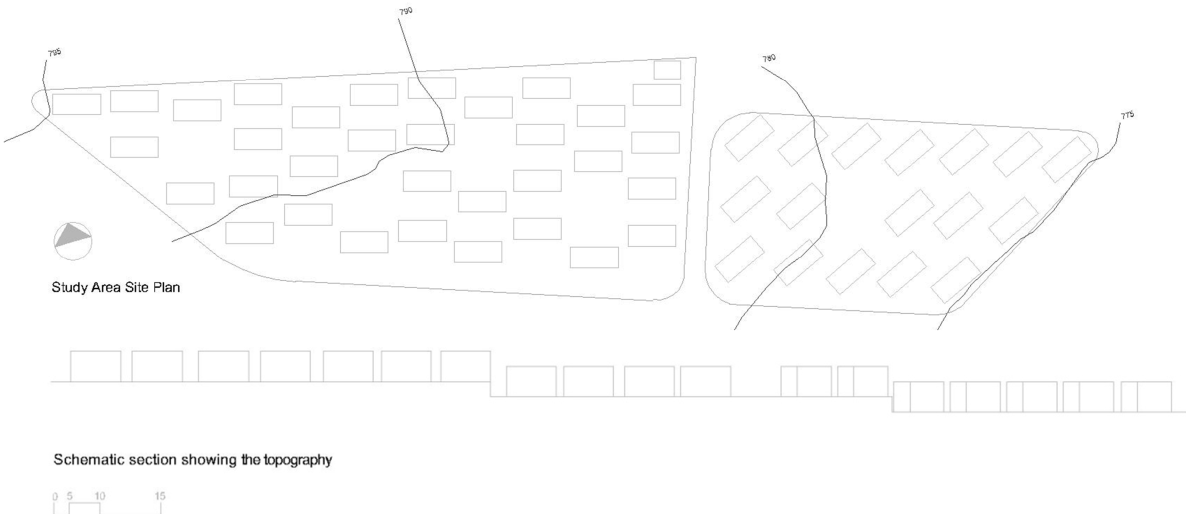

Figure 2. Study area site plan. Source: (The Authors, 2014).

2.3 Study area selection criteria:

The study area was chosen for a number of reasons; (1) It should be located within the city center and under the UHI effect. Armson, Stringer and Ennos (2012) clarified that an area located within 3 km of the city center will still be under the UHI effect, (2) the availability of data needed for modeling and simulation (building height, material, age and orientation, lot size, tree characteristics, etc), (3) the study area is preferred to be flat, relatively void of topographical features which could seriously affect the simulation results, (4) a good representative of residential category C or D, since this study targets low income people, who lives in dense areas, (5) the study area, maybe a new neighborhood or an old one with virtually no tree cover, in order to assess the magnitude of planting trees on electricity use, (6) the study area must typically experience warm summers and (7) the proximity of the study area to the researchers workplace and home, in order to enhance the ability to collect data and investigate site problems.

3. Methodology and research methods:

This study is intended to measure the effect of urban trees shade on electricity use and air quality improvement in urban areas. It was conducted at Hashmi Al-Shamali district in Amman, Jordan. Methodology constitutes of four main steps; (1) literature review to maintain a theoretical background on environmental pollution, climate change, energy consumption and urban trees benefits, (2) design a new model to investigate the impact of trees shade on electricity use in residential buildings, (3) analyze data to judge if the results support the study hypothesis or not and (4) finally the study will set up recommendations for professional concerned.

In order to fulfill the main research objectives as stated in chapter one; research methods to be used in this study has six components; (1) study area selection based on the discussed criteria; (2) characterizing the existing tree cover within the study area through site visits and aerial photographs derived from Google earth; (3) collecting data about buildings materials, construction, orientation, size and condition through observation, infield measurements and contacting the designers; (4) selecting sample trees that will be modeled later; (5) buildings and tree modeling will be done using Autodesk® Revit® Architecture software; (6) shadow and cooling laods simulations also the electricity use reductions will be simulated through DesignBuilder software.

3.1. Simulation tools:

In order to simplify the computer model and exclude the influence of many other environmental factors; the surrounding buildings around the study area will not be modeled and in order to effectively model; (1) building characteristics (material, condition, height, construction techniques, openings... etc.) and (2) suggested trees physical form abstraction (height, crown type and size); the Autodesk® Revit® Architecture software will be used. And in order to; (a) stimulate the generated shade from suggested trees; (b) generate realistic results that would be confirmed by measured data; (c) stimulate cooling loads without trees and with the suggested trees; DesignBuilder software will be used.

For modeling phase many experimentations were done to effectively establish the most suitable method should be followed in order to produce the required output. Revit® was used in modeling phase for some reasons; to model the real condition of the site and buildings (including the layers of walls, elevations, windows, doors, slabs and roof). Because this study is focused on the evaluation of an existing site and condition, ensuring the reality of evaluation and simulation is critical. Additionally, Revit® can pass the geometry, as well as the thermal properties of materials and other variables, into analysis packages like DesignBuilder using the gbXML file format. While DesignBuilder was selected in this study for several reasons; (1) it has the ability to flexibly import models from Autodesk® Revit® Architecture, (2) it responds to shading elements effectively, (3) it can stimulate what this study is looking for and (4) it is easy to learn and use.

3.2 Simulation Variables

3.2.1 Building characteristics:

Building characteristics generally included house size, lot size, house age, summer time electricity use and the presence of air conditioning. In the selected study area, there are 50 residential buildings that are almost identical in terms of areas, heights, types, and volume with a slight difference between them; newly added balconies, Table (2) summarizes building variables.

Table 2. Descriptive statistics for selected independent building variables. Source: (The Authors, 2014)

Variable	**Mean**
House area (m^2)	120 m^2
House height (m)	10.30m
Number of floors	3 floors
House age (years)	Around 30 years
Pool area (m^2)	There are no pools

3.2.2 Building modeling:

The test buildings have no shading devices, without special finishing and considered to be a good representative for buildings present in residential C and D zones. A summary of building characteristics, geometry and materials are summarized and modeled. These critical properties have been measured or assumed. Taking into consideration that these buildings are assumed to be sited on a flat, homogeneous surface without adjacent buildings.

*3.2.3 Climatic variables***:**

The latest ASHRAE worldwide design weather data and locations (4429 data sets) are included with the DesignBuilder software, and over 2100 EnergyPlus hourly weather files are available for free using the DesignBuilder 'Install on Demand' feature (Designbuilder, 2014). Because of the unavailability of climatic data file for the Amman in DesignBuilder, Energy Plus data files (free version), the climatic weather data file for Jerusalem, Palestine will be used. The climate of Jerusalem (31°52'N, 35°13'E, 757 m) is similar to Amman (31°59'N, 35°59'E, 779 m); the annual average temperature is16.2°C , 17.1°C respectively (Climatemps, 2014).

3.2.4 Thermal variables:

In order to generate thermal analysis, many variables must be defined and inserted into the model. To maximize the degree of accuracy, this study will use Revit® for modeling phase taking into account building operational factors such as; infiltration rate, ventilation and internal heat gains. These variables are summarized in Table (3).

Table 3. Thermal analysis defined variables.

Hours of operation	24 hours
Humidity	43.6%
Comfort band	18° C to 26° C
Clothing level	0.4 col
Occupancy	7 persons
Activity	70 W/m²
Lightening level	300 Lux
Active system (HVAC system)	Cooling and heating system
Internal heat gain	10 W/m²
Latent gain	2 W/m²
Infiltration rate	2.0 Air Changes per hour

3.3 Tree variables:

Trees have different crown forms and sizes, numbers and location regarding buildings. It is important to define trees variables; in order to ease the modeling process and being able to assess the impact of trees' shade on building energy consumption. In subtropical steppe/ low-latitude semi-arid climate that is hot all year like Amman (Kottek et al., 2006), it is important to highlight the means by which trees are planted around the buildings to achieve energy savings and thermal comfort by increasing summer shade and funneling summer breezes toward the home.

The cooling load reduction due to shade will be calculated from tree and building data with DesignBuilder. DesignBuilder calculates the percentage of each wall and roof surface shaded for each hour based on building and tree dimensions, orientation and distance of trees and adjacent structures from buildings, local time zone, latitude and longitude, and time of year. Shading was determined at monthly intervals for summertime to be compatible with the building energy use simulation model.

3.3.1 Tree characterization:

In order to characterize the tree cover of the Study area, aerial photographs from Google earth are used in addition to site visits. What made this easier to be obtained is the small amount of existing trees in the study area; there were only five small trees in the entire study area boundary that will be neglected; due to their relatively small size and poor condition

3.3.2 Tree selection criteria:

To evaluate energy saving by reducing radiation through planting deciduous trees, sample tree will be selected. The selection should take in mind that this type of tree is; Deciduous tree; Quick growing rate and lush shadow; Trees with large crown width; Commercial availability; Relatively low cost; Abundant foliage; Mostly used around buildings; Disease resistance; Compatibility with climatic conditions, Soil characteristics.

The study suggested *Pistacia atlantica* (Mount Atlad Pistachio), medium size (bole height 2.1m, crown height 8.5, tree height 10.6 and crown width 8.4m). It is a deciduous tree that is used to provide shade, specimen, and works as windbreaks. It is a low cost tree, commercially available, compatible with Amman climatic conditions and can adopt draught (Mahadin, 2006), see Figure (3).

Figure 3. *Pistacia atlantica* tree. Source: (Mahadin, 2006).

3.3.3 Tree modeling:

The study is concerned with trees shade and energy use in residential buildings, thus it must calculate trees' shadows on any surface (wall, facade, and roof). In order to make it simple and in the first place realistic; a tree model must be constructed carefully. Generally, trees can adopt many geometrical shapes with many varieties even with trees within the same species. Physical form abstraction is important to perform the simulation. The selected tree (*Pistacia atlantica*), will be simulated by a geometric simplification of the form of the tree, represented by the aspect ratio between its height and foliage span.

This study will adopt Simpson and McPherson (1998) method in modeling trees. In their study the suggested trees were modeled at their mature size, respecting the predicted growth rate, that will affect trees characteristics such as; mature shape, bole and crown height, crown diameter and shade coefficient for the selected trees. These variables are summarized in Table (4) below.

Table 4. Characteristics for suggested mature trees. Source: (Simpson and McPherson, 1998).

Tree classification		Bole[a] height (m)	Crown height (m)	Tree height (m)	Crown width (m)	Shading coefficient[b] in summer	Shape[c]
Size	Growth rate						
Small	Moderate	2.1	5.5	7.6	7.6	0.175	Umbrella
Medium	Moderate	2.1	8.5	10.6	8.4	0.175	Umbrella
Large	Moderate	3.0	12.2	15.2	13.0	0.175	Umbrella

(a) Average height from ground to bottom of crown.
(b) Fraction of irradiance transmitted through tree crown.
(c) Simpson and McPherson adopted the ellipsoid shape, but this study will adopt the Umbrella shape due to modeling options.

3.4 Simulation structure:

In order to study the relation between energy consumption and tree shade of Hashmi Al-Shamali in summer, and after simulation tools being selected and simulation variables were addressed this structure was designed:

1) Modeling the real condition of the study area using Revit software.
2) Perform simulations with DesignBuilder software. The first scenario will be for the current situation of the study area. DesignBuilder can calculate the cooling loads, heat balance, energy consumption and heat gain for each zone, and the output will appear is graphs.
3) The amount of shade (on walls and roofs of each building) will be calculated according to the adjacent buildings in the first scenario and in the second scenario, it will be calculated according to the immediately surrounding suggested trees in addition to the adjacent buildings.
4) Tree Planting criteria: Locating trees around buildings and within property should follow a specific criteria and guidelines. This study will adopt Sacramento Municipal Utility District (SMUD) tree-sitting guidelines (Simpson and McPherson, 1998) with modification in respect to the study area see Figure (4);
   a. Do not plant trees in north locations (it does not receive much solar radiation all year);
   b. As a minimum locate smaller mature tree size 2.4 m (8 ft) away from the building, and larger mature size 4.6 m (15 ft);
   c. Spacing between smaller trees must be 2.4 m (8 ft) minimum, while larger trees must be 4.6 m (15 ft) apart.
   d. All trees are deciduous, medium size; the characteristics for suggested mature trees are available in Table (11).

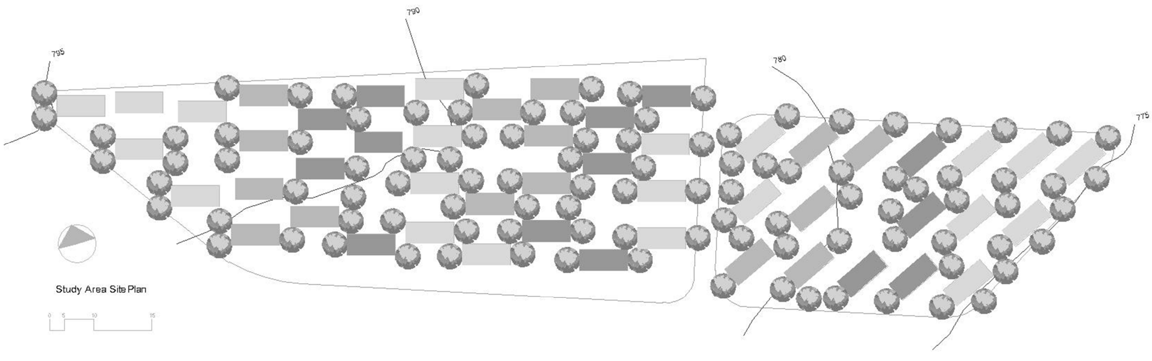

Figure 4. The suggested trees within the Study area. Source: (The Authors, 2014).

5) The effects of suggested trees on cooling energy will be calculated as the difference between energy use in the two scenarios. Check Appendix B and C for detailed calculations. Trees block incident solar radiation reaching building surfaces and elements therefore the heat gain through building materials is reduced, thus cooling loads in summer is reduced.

4. Results

Results indicated that after planting about 100 *Pistacia atlantica* (Mount Atlad Pistachio) tree around 50 buildings in Al- Hashmi Al- Shamali district the cooling loads for theses building has been reduced by 35.87% during summer season, see Figure (5) that compares between the two scenarios and shows the total cooling energy saving for the whole study area.

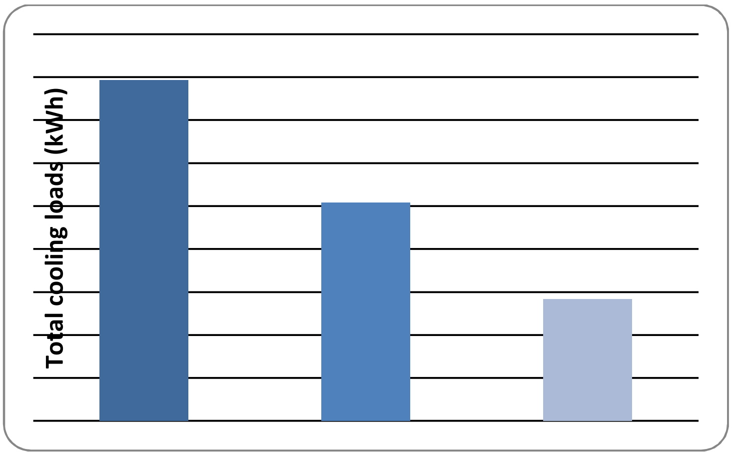

Figure 5. Total cooling loads (kWh) for all buildings (in both cases). Source: (The Authors, 2014).

These results indicated that trees planted on the east, lowered the cooling loads for the 50 buildings located in the study area from 37890.19 kWh, where the site was bare of trees to reach 21469.58 kWh after planting trees around buildings in summer season, shown in Figure (6). The value of cooling load reduction on west elevation comes in the second place with 45730.29 kWh in scenario A to reach 26345 kWh on scenario B, see Figure (7) and south elevation comes last with 74906.92 kWh before planting trees and reduced to reach 53848.01 kWh after planting trees around buildings, see Figure (8). Therefore, energy savings in summer are 43.34% on the east elevation, 42.4% on west elevation and 28.11% on the south elevation, check Figure (9).

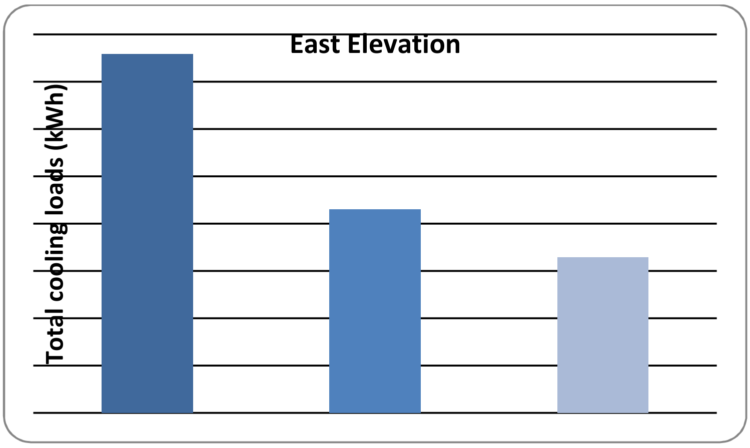

Figure 6. Total cooling loads (kWh) for East elevation (in both cases) and energy savings. Source: (The Authors, 2014).

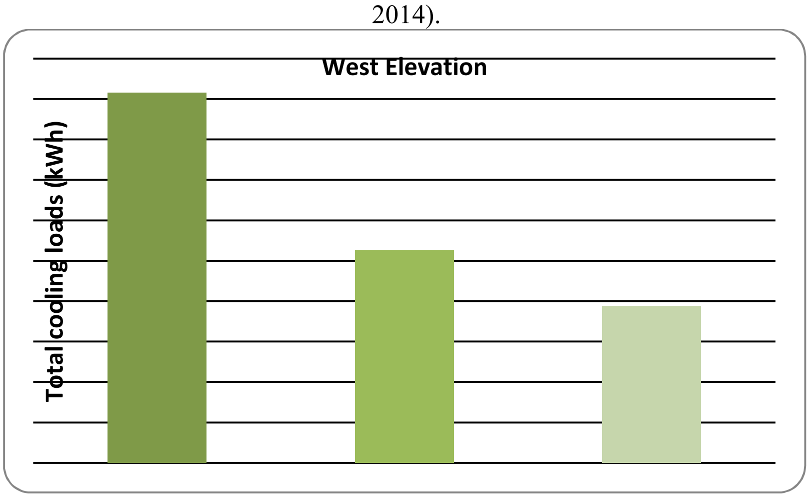

Figure 7. Total cooling loads (kWh) for West elevation (in both cases) and energy savings. Source: (The Authors,

2014).

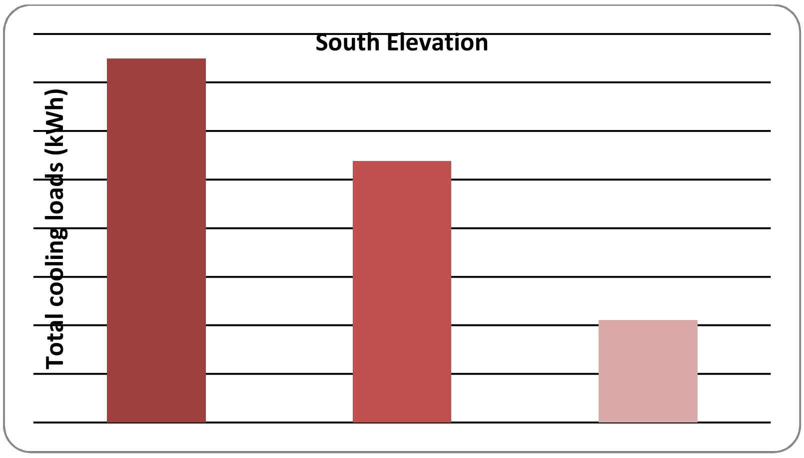

Figure 8. Total cooling loads (kWh) for South elevation (in both cases) and energy savings. Source: (The Authors, 2014).

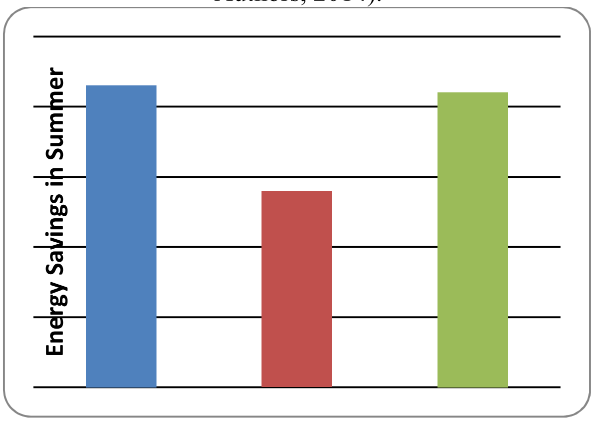

Figure 9. Energy saving percent resulted from the suggested trees in the summer time. Source: (The Authors, 2014).

These results showed that, urban trees can affect electricity consumption of air conditioning usage at Al-Hashmi Al-Shamali district and succeeded in lowering the total cooling loads by 35.87 % as shown in Figure (10).

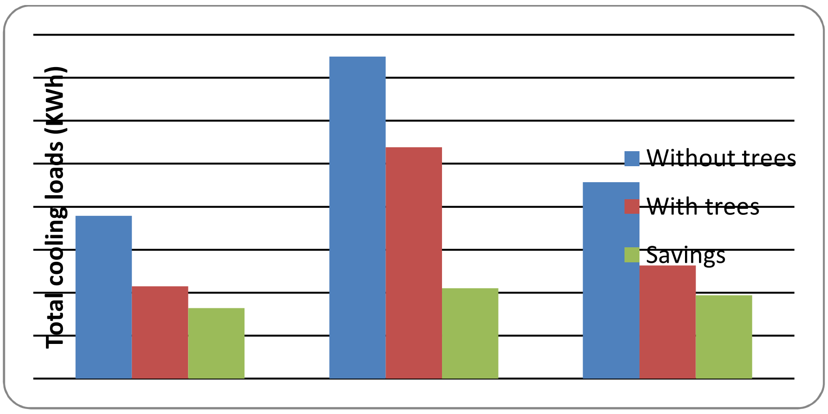

Figure 10. Summary for cooling loads (kWh) for the three elevations (in both cases) and energy savings. Source: (The Authors, 2014).

5. Discussion

Climate change is associate from the lack of conventional energy and environment pollution; that is related directly and indirectly to man-made activities, extraordinary natural phenomena and increasing CO_2 emissions from fossil fuels burnings. Statistics indicated that the residential sector represents the second major energy consumption sector in Jordan after transportation sector (Abdalla, 2010), thus buildings are of the main contributors of environmental problems associated with consuming energy taking into consideration that cooling and heating energy is the largest consumer of energy in buildings.

Planting trees is the most effective method of passive solar design for the purpose of energy saving. Its responsible of many environmental benefits that improves our surroundings. These benefits include shade, beauty, wind break, privacy, reduce pollution, less noise, less glare and higher property values. But the key for the best benefits is to choose the right trees and plant them in the right place. Planting trees near buildings for the purpose of achieving thermal comfort is associated with studying incident solar radiation and heat transfer between the building and the outdoor environment.

This study clarified the aspects of reducing energy consumption focusing on one strategy of implementation passive solar design. Taking in mind that the main problem is the shortage of energy resources in Jordan that makes the imported fossil fuels the main source of energy.

Achieving passive solar design strategies in the buildings include: site and orientations selection, building forms, materials, glazing and opening that related to natural ventilation and lightening, shading devices and finally landscape shading. Urban trees have a great influence on blocking incident solar radiation and can provide cooling effects through evapo-transpiration process.

Increasing energy consumption and environmental problems were the main motivation for this study that was conducted using Revit and DesignBuilder to investigate the effect of trees on building thermal performance.

The study found that properly placed trees around the building in the study area has a major role in reducing the summertime electricity consumption, thus reducing pollutants and emissions from energy generation and improving air quality. Taking into account that the magnitude of this effect depends on trees attributes (width, height) and its location regarding the building. Moreover, it will be more beneficial if the trees planted inside plot area are fruitful trees.

However, this study also found that planting trees in the east side of building provides the greatest energy efficiency in the summer, but the west side is more important to shade than the east side because of the need of trees shade afternoon more than early morning. As well as, south side of a building provides lower energy efficiency in summer.

In areas such as Al-Hasmi Al-Shamali simulated trees helped reduce cooling loads by (35.87%). This result could be generalized to areas within Amman that share similar characteristics with Al-Hasmi Al-Shamali; these areas might be in East Amman areas where the climatic conditions, building characteristics and lot setbacks are very similar to our study area; taking in mind that most residential lots in East Amman areas are classified as residential C or D.

In residential C plots, the distance between trees are set to the minimum because the setbacks are minor (front must be 4m long, side setbacks 3m and rear setback 4m) this will be the same for residential D because the setbacks are even smaller (front 3m, side setbacks 2.5m and rear setback 2.5m) (Department of Statistics, 1999).

In plot areas classified as residential C, the crown size of the selected trees should not exceed 6m in width (the minimum distance between 2 facades in residential C) and may be up to 8m. Taking into consideration that, why the number of trees inside plot areas are affected due the same reason. When tree-building distance is too small then the benefits will be maximized in the summer season while will affect energy consumption negatively is winter.

These results will be maximized in West Amman areas because comparing East to West Amman, we will find that West Amman due to its large setbacks, availability of backyards, and gardens will increase the benefits of trees as energy component, as well as, these areas are not dense compared with East Amman areas.

To maximize the benefits of urban trees it is suggested to give more attention and increase availability of street trees and even imbed planting those trees in governmental strategies. In a matter that does not conflict with pedestrian circulation, vehicles, power lines and other utilities, but in a way that enriches and enhances the experience. Street trees are preferred to be evergreen trees, with high stems to work as wind breakers in winter and shade providers in the summer and these trees are preferred to be unfruitful.

Local policies should be formed to enhance the urban green spaces and to increase the urban forest areas within Amman. A guidance strategy should be suggested to help local Authorsities and municipalities to manage these spaces due to their lack of climate change issues.

A planting tree program should be suggested and implemented in Amman and should include all areas focusing on dense residential areas. The cost of these programs including; trees cost, maintenance cost and watering cost, should be low and should be suggested by professionals.

Spreading awareness about the magnitude of energy savings of planting trees. This will encourage citizens to plant shade trees around their buildings and will help in implementing tree planting programs.

These potential savings are clearly a function of climate; in climates like Amman, deciduous trees shading a building can save cooling-energy use, in cold climates, evergreen trees shielding the building from the cold winter wind can save heating-energy use.

6. Conclusion

Knowing the multi benefits of planting trees in Amman raise up the point of spread this criteria all over Jordan especially in new communities and projects. Also taking in mind the ultimate benefits of increasing the forest areas, green spaces and open spaces.

This study will suggest criteria for landscape architects, urban planners, municipalities as well as the community members for planting trees around residential buildings in Amman:

- The preferred building-tree location, tree numbers and tree specification all depend on the purpose of planting trees.
- For energy saving purposes, plant wide spreading crowns trees near residential buildings.
- For energy saving in the summer, plant shade trees near west and east sides, and then comes the south side. The east side is less important than the west side because there is no need to cool buildings with cooling devices during early hours in the morning.
- To achieve thermal comfort in summer as well as winter, it is recommended to plant deciduous trees more than evergreen trees.
- To provide the maximum amount of shade for buildings while protecting the building foundations, plant trees within 2 m to 3 m far from the building.
- While selecting tree species to plant, consider that the tree size at maturity is suitable for building's volume and height in order to cast a sizable shade on building facades.
- For west and east facades, it is preferred to increase the planted trees number in such a way that they do not block wanted views and lights also assuring that they do not negatively affect adjacent buildings.
- For energy saving purposes, do not plant trees on the north side because it does not receive much solar radiation all year
- In plot area and even on street, plant trees away from power lines, underground water, sewer lines and other utilities.
- For wind speed reduction, plant evergreen trees as a belt to minimize the unwanted wind that generally rises up the infiltration rate from outside the building into it.
- To get energy saving benefits from planting trees, the tree-building distance should not exceed 10.7 m.

As a minimum locate smaller mature tree size 2.4 m away from the building, and larger mature size 4.6 m. Spacing between smaller trees must be 2.4 m minimum, while larger trees must be 4.6 m apart (Simpson and McPherson, 1998).

7. Recommendations

This study can be a start for local studies concerning the relationship between trees, energy consumption and environment, valuable recommendations is suggested to the municipalities, architects, planners and the community:

- Replacing asphalts and dark surfaces with greenery in Amman areas, as well as Jordan in general, is a plus point in mitigating the UHI effect, thus reducing energy consumption and improving air quality, the same thing for the idea of increasing urban forest areas.
- An indirect benefit of planting trees around residential buildings in Amman is the role of trees as windbreakers that would reduce the infiltration of hot air outside air into the buildings.
- Planting trees could improve the aesthetics of the urban environment in Amman, enhance Ammani citizens' loyalty to these spaces. Moreover, it would probably increase land value and many other non-energy benefits, hence, they should be integrated more into the Ammani urban context.
- The local planning system in Jordan ought to emphasize on trees planting programs, urban green space and urban forest, simply through better understanding of its complex nature and learning from international experiences on how to work with it best.
- It is advised here for future efforts to assess the impact not only for urban trees on energy saving, but also for urban forest and green spaces and conduct further more detailed studies concerning their role in reducing summertime electricity use and air quality improvement.
- It is recommended to conduct more studies concerning trees shade impact on energy use during winter in Amman as well as Jordan.
- A more comprehensive approach towards Amman is advised. More effort should be put in trying to assess trees shade impact on energy not only for residential building, but rather for different buildings function and typologies.

- Trees role in improving air quality by dry deposition to absorb directly gaseous pollutants from the air is not measured; future studies are recommended to measure its magnitude.

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