16th International Conference on Clean Energy (ICCE-2018)
9-11 May 2018, Famagusta, N. Cyprus

THE FEASIBILITY OF USING ROOF GARDENS IN NABLUS AS A CASE STUDY

Dua Mallah, Mouhammad Ata Yousef, Haithem Ratrout
An-Najah National University, Nablus, Palestine
Corresponding Author: Dua Mallah, e-mail: dua_mallah88@hotmail.com

REFERENCE NO

ARCH-01

Keywords:
Green roof; Computer simulation; Thermal comfort; Building envelope; Palestine.

ABSTRACT

In the Palestinian cities; especially the city of Nablus, there is not enough open green areas. This research aims at developing or creating more green areas and spaces in the city of Nablus by implementing the concept of roof gardens. This research analyzes the current structure of the city (Nablus) roofs. It also determines to what extent people will be satisfied and feel comfortable by the application of green roofs. Computer simulation (Autodesk Ecotect) will be used to find out the effect of green roofs on the city of Nablus by comparing three roofing types (regular roof, green roof and insulated green roof) to clarify the difference in thermal behaviour. Results indicate that the city residents are willing to add green roofs to their buildings, but have some concerns over the cost of green roofs. The simulation results indicate that green roofs reduce the energy consumed for heating or cooling.

1. INTRODUCTION

Green roof has been a part of civilized society; many historic examples have been documented. The concept was invented and used to create an extension of living rooms, presenting place to escape summer heat, insulation, flood control and a place to grow food.

The use of modern green roofs was incorporated in the building design in late 1940's, since then many world cities such as, London, New York, Hong Kong, and Toronto promoted the use of green roofs. The results of many studies conducted in those countries are extremely encouraging, as the use of green roofs will increase air quality and improve city urban appearance; these studies illustrate a number of environmental and economical benefits for green roofs. In general, green roofs are not a single purpose building component, but one with numerous benefits.[6]

This research aims at testing the feasibility of roof gardens in Nablus, in order to provide basic data that may encourage the use of roof gardens in the future.

1.1. Green roof, components and technology.

Roof gardens have existed in human culture and architecture ever since the hanging gardens of Babylon. Roof gardens evolved through the centuries in different civilizations, and they were an essential element in vernacular architecture such as the Scandinavian sod roofs. In modern time, people use green roofs developed from the sod roofs, which are lighter, and more effective.

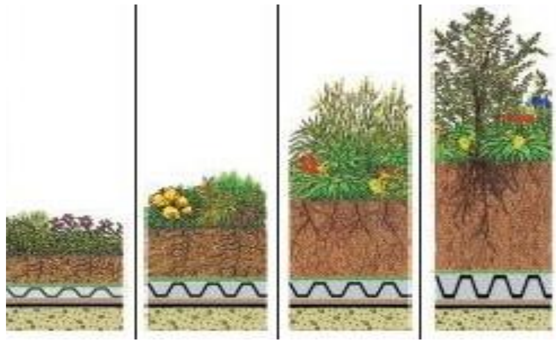


Fig. 1. Section in green roof types from Extensive (left) to Intensive (right), Source: [9]

The vast majority of researchers and authorities identify the green roofs as "vegetated layers that sit on top of the conventional waterproofed roof surfaces of a building.

Whilst green roofs come in many different forms and types, usually a distinction is made between extensive, intensive and biodiverse or wildlife roofs." [15]

Modern green roofs concepts are basically divided into two main types; intensive and extensive. Between these two types, there are a number of green roof technologies derived from these two main types, including semi-intensive and semi-extensive.

2. NABLUS CITY PROFILE

Nablus is one of the northern cities of the West Bank, about 28.57 square kilometres and it lies in a narrow valley between two mountain chains. The mountain chains are about 65 km in length from north to south and about 55 km in width from west to east. The northern mountain, Ebal, is 940 m high, while, the southern mountain, Gerizim, is 881 m high. [11]

2.1. Land use

Housing represents the major use of buildings in the city; about (56%) of its land figure (2). Therefore this study focuses on applying green roof to residential buildings. In Nablus governorate there are two main types of households distributed as the following figure (3) shows. About 70% apartment or multi-storey building. Independent houses or villas occupied about 30% of housing types in the year 2010.

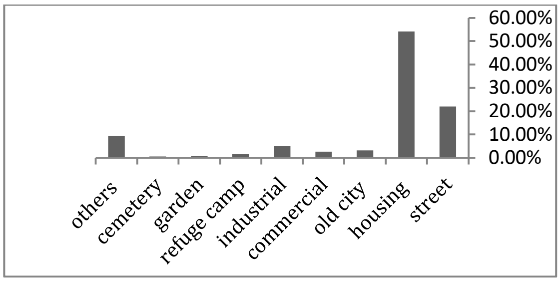


Fig. 2. Land use percentage, Source: [13]

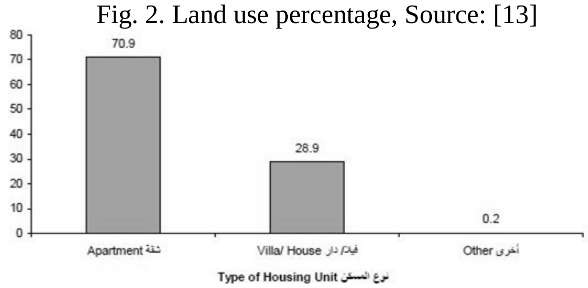


Fig. 3. Percentages of distribution of households in Nablus Governorate by type of housing unit, Source: [13]

Table 1. Comparison between green roof types.

Source: [1] [16] [18] [12] [7] [17] [5] [10]

characteristic	Extensive Green Roof	Semi-intensive Green Roof	Intensive Green Roof	Mix green roof	Rooftop Garden
Substrate depth	5 to 15 cm	12 to 25 cm	20 to 200 cm	vary	vary according to the planting container
Weight	light(30-150kglm2)	medium 120-200kg/m2	high 180-970 kg/m2	30-500 kg/m2	vary according to the planting container
Cost	low($100-200/m²)	medium	high(more than $200-2000/m²)	high	low
Plants utilized	sedum-herbs and grass	grass-herbs and shrubs	shrubs and trees	grass-herbs shrubs and trees	grass and shrubs
Plant diversity	low	medium	high	high	medium
Accessibility	often	may be partially accessible	usually accessible	partially accessible	accessible
Energy Efficiency	low	middle	high	over middle	low
Thermal Insulation	middle	middle	high	high	Low/(no thermal insulation)
Maintenance	low	periodically	high	special	special

2.2. Weather data

The climate of the city of Nablus is commonly known as Mediterranean which is hot and dry summer with moderate, rainy winter.

Over the past 10 years, temperatures in Nablus have been increasing, and the citizens notice that the city centre is usually warmer than other areas. The following diagrams show the difference between the average maximum and minimum temperatures from 1997 to 2010.

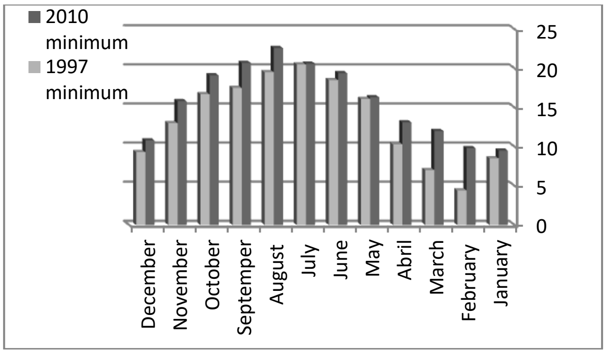


Fig. 4. Minimum temperature from 1997 to 2010 in Nablus, Source: [13]

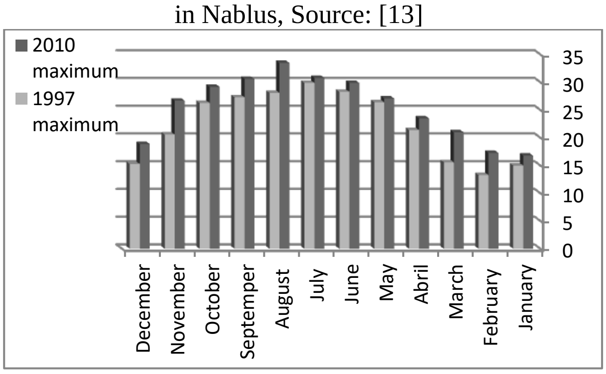


Fig. 5. Maximum temperature from 1997 to 2010 in Nablus, Source: [13]

2.3. Buildings structure.

The most common type of roof structure in the West Bank is concrete flat roofs[14], and as the city of Nablus is part of the West Bank the common way of constructing roofs in it is also concrete structure. Roofs are usually designed to sustain extra weight up to 400kg/m2 dead load and 300 to 500 kg/m2 for live load [2]. By applying this information to the data from table (1), figure (6) was created, showing the intersection between the extra weight the roof can sustain and the extra weight added by the green roof. Extra loads added by the different types of green roofs (darker shade horizontal lines), the standard extra weight the roofs in the city designed to sustain (rectangular lighter shade area) and the intersection representing the type and weight could be used for adding green roofs to the city buildings without structural reinforcement. Figure (6)

3. QUESTIONNAIRE

A survey was conducted to establish attitudes towards green space and green roof technology within the sociodemographic of the citizens of Nablus.

248 city citizens were covered by this survey, 111 male and 137 female, percentages are almost equal 55% for female and 45% for males.

When people were asked about accessibility to a private ground level garden and accessibility to the building roof, the results indicate that more people had access to the building roof than people with access to a private garden. Figure (7)

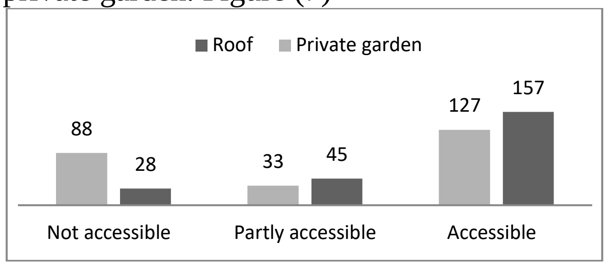


Fig. 7. Comparing accessibility to a private ground level garden and accessibility to the building roof

Figure (8) shows that up to 70% of the total respondents had heard about green roofs, but more than 70% of those did not have technical knowledge regarding green roof types.

Have you ever heard of roof gardens? If yes do you know the types of roof gardens?

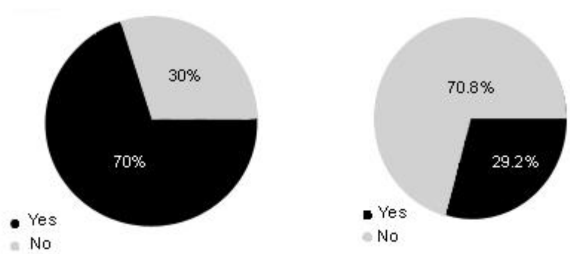


Fig. 8. Green roof knowledge.

The respondents were asked to assess the benefits provided by green roofs. Green roofs are stated to provide all of the benefits by many researchers. Figure (9)

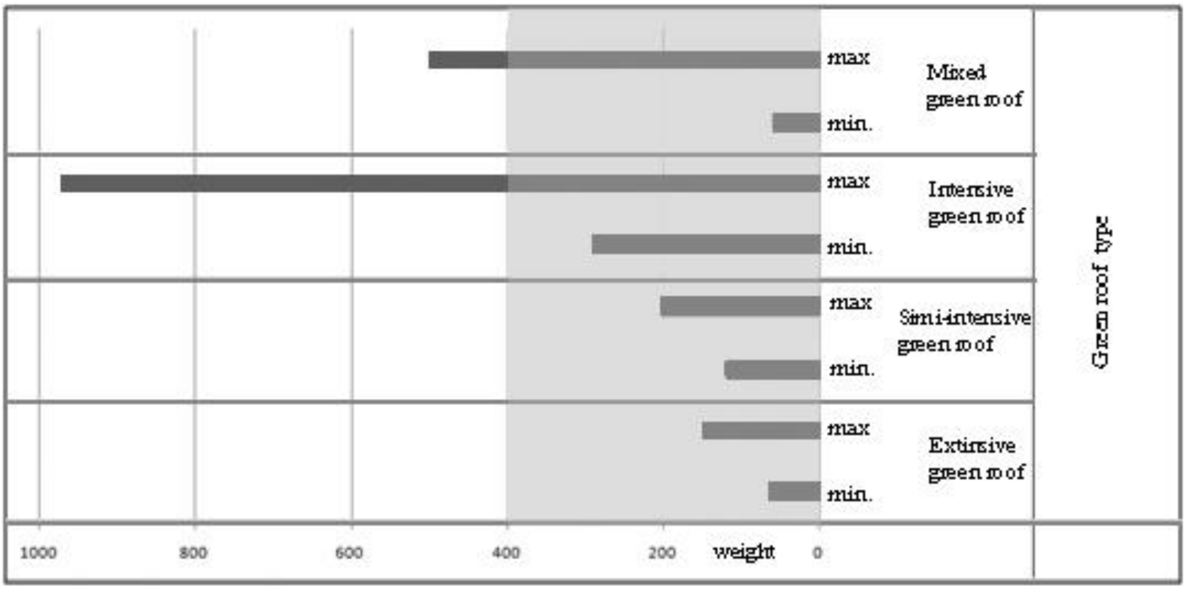


Fig. 6. Extra loads added by the different types of green roofs in darker shade horizontal lines; rectangular lighter shade area is the standard extra weight the roofs in the city designed to sustain and the intersection representing the weight could be added to the city buildings without structural reinforcement.

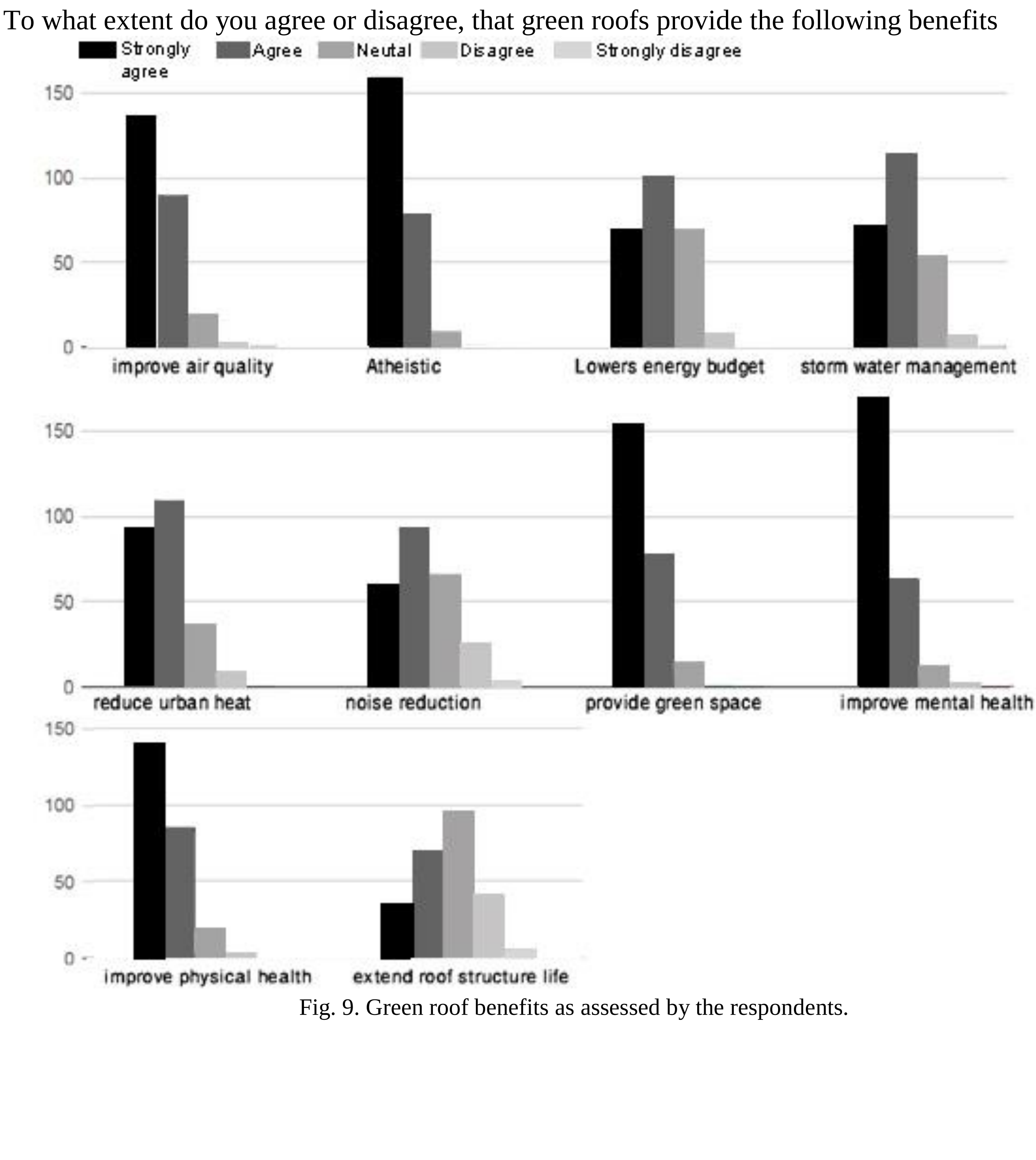


Fig. 9. Green roof benefits as assessed by the respondents.

Respondents believed that green roofs could provide some benefits as they strongly agreed with improved air quality, atheistic quality, providing green space, and improving mental and physical health. Respondents were less likely to agree with, lowering energy budgets, storm water management and reducing urban heat, whilst, noise reduction and extended roof structure life were more likely to be disagreed with. It was clear that respondents connected the benefits of green roofs with those provided by trees and plants.

The final question was; would you alter your roof to make it a green roof. 79% of the respondents said yes, while the other 21% had their reasons for saying no such as, lack of knowledge and working experience regarding green roofs, lack of space or fully occupied roofs, shared roof or the roof is a private property for the last floor, fear of additional load and cost, and people having a private ground level garden are less likely to add green roof to their building.

4. COMPUTER SIMULATION

Autodesk Ecotect Analysis was used to carry out this study. It is a program used for environmental analyses, simulating buildings' performance, providing analysis functions along with interactive display. Ecotect Analysis also offers integrated analysis tools such as: solar radiation, luminance level, shadows, water usage, heating loads, cooling loads, and energy consumption. Autodesk network identify Ecotect Analysis as “the most comprehensive and innovative building analysis software on the market today. It features a designer-friendly 3D modelling interface fully integrated with a wide range of performance analysis and simulation functions.”[3]

The simulated buildings in figure (10) are representative samples of typical residential buildings in Nablus. Drawings for these building were provided by local engineering office Arab Experts for Consultation and Engineering. (ARABEX).

In these simulations all elements, but the roof, are given fixed thermal characteristics. To investigate the difference in thermal behaviour of the building, three types of roof layers have been simulated 1st regular (conventional) roof, 2nd green roof, and 3rd green roof with thermal insulation.

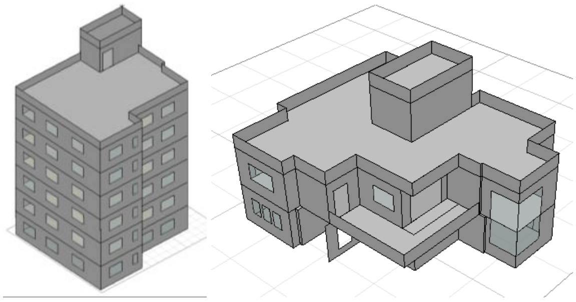


Fig. 10. Image of the buildings generated in Ecotect (Left) multi storey building (Right) villa.

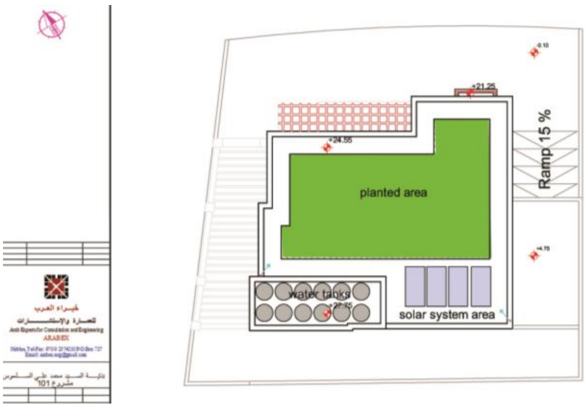


Fig. 11. Site plan of the multi storey building used in simulation.

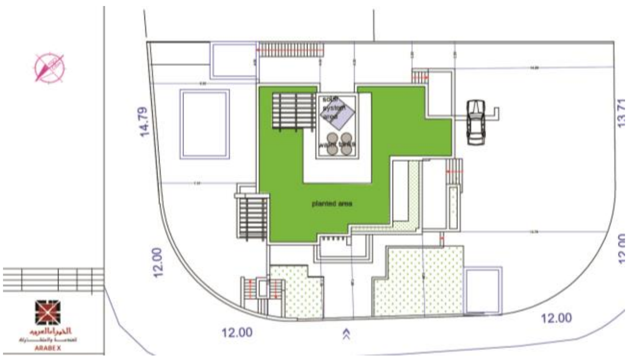
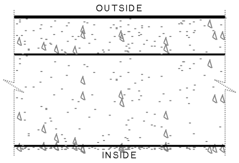


Fig. 12. Site plan of the villa building used in simulation.

Table 2. Roof materials and types.

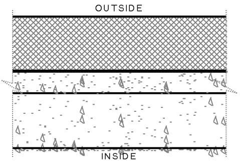
Roof type | **Section** | **Layers**

Regular roof
U-value 0.95



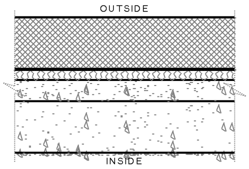
	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	Bitumen / Felt Layers	0.003	1700.0	1000.000	0.170
2.	Foam Slag	0.100	500.0	960.000	0.160
3.	Concrete	0.250	2000.0	656.900	1.170
4.	Plaster	0.010	1570.0	840.000	0.530

Green roof
U-value 0.49



	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	soil media	0.250	1700.0	1000.000	0.250
2.	Bitumen / Felt Layers	0.003	1700.0	1000.000	0.170
3.	Foam Slag	0.100	500.0	960.000	0.160
4.	Concrete	0.250	2000.0	656.900	1.170
5.	Plaster	0.010	1570.0	840.000	0.530

Insulated green roof
U-value 0.29



	Layer Name	Width	Density	Sp.Heat	Conduct.
1.	soil media	0.250	1700.0	1000.000	0.250
2.	Bitumen / Felt Layers	0.003	1700.0	1000.000	0.170
3.	Polystyrene	0.050	28.0	1130.000	0.035
4.	Foam Slag	0.100	500.0	960.000	0.160
5.	Concrete	0.250	2000.0	656.900	1.170
6.	Plaster	0.010	1570.0	840.000	0.530

4.1. Direct solar radiation

In the first part of the simulation, direct solar radiation was calculated; "Ecotect" was used to simulate data for cumulative incident solar radiation on a horizontal surface, of the testing models, both monthly and yearly. The average value of the solar radiation is given in Wh/m2. The following figures show the result of the simulation of the building model during summer, winter, and whole year.

As shown in the site plan of the testing model, 76% of the villa roof, and 55% of the multi storey building roof was covered with a green roof. Before and after green roof results are shown in the following figures.

About 50% reduction on the total all year direct solar radiation in the villa and 62% reduction is achieved in the multi storey building, Figure (13)

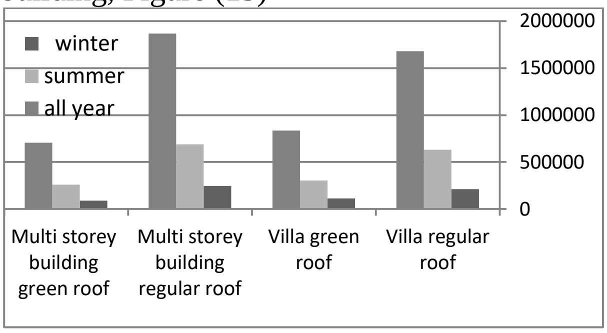


Fig. 13. Comparison between direct solar radiation for a green roof, a regular roof on the villa and multi storey building. (Source: Result of Ecotect simulation)

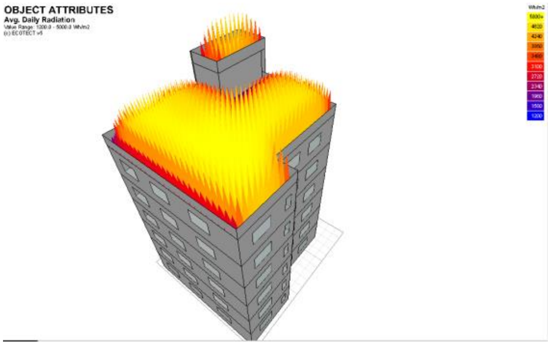


Fig. 14. Direct solar radiation for all year (Regular roof)

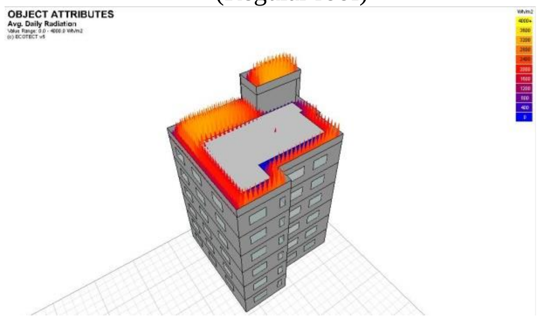


Fig. 15. Direct solar radiation for all year (green roof)

Reduction of the direct solar radiation leads to a reduction on the internal gain through the roof which can be calculated by the following rule.

$$\frac{Wh}{m^2} * (m^2) = Wh \quad (1)$$

$$\frac{Wh}{(m^2)} = Internal\ solar\ gain \quad (2)$$

Source [4]

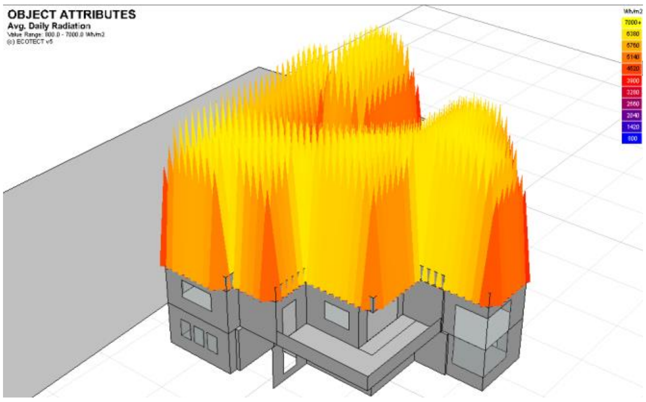


Fig. 16. Direct solar radiation for all year (Regular roof)

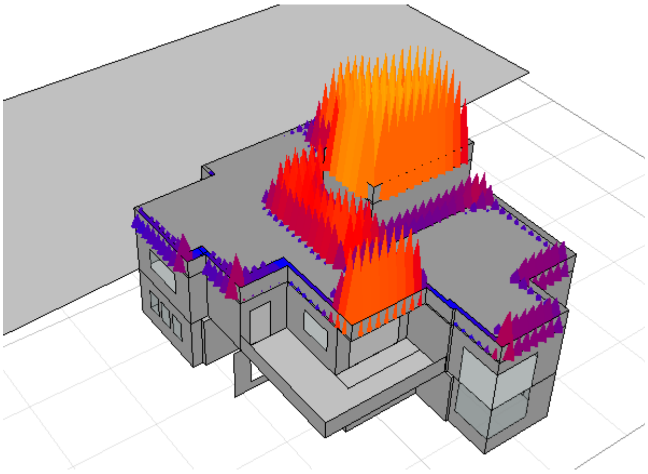


Fig. 17. Direct solar radiation for all year (green roof)

Table 3. Internal solar gain Wh/m2

Villa	Villa	Multi-storey building	Multi-storey building
regular roof	green roof	regular roof	green roof
659297.4406	327991.7646	310878.0633	117346.3533

Reduction of the internal solar gain by the green roof was up to 50% for the villa and 62% for the multi storey building.

4.2. Energy consumption

To investigate the effect of green roofs on energy consumption by HVAC (Heating, ventilation and air conditioning) analysis was conducted to calculate and compare the results of the three roofing types, regular roof, green roof and insulated green roof. (See tables (4) and (5)).

The results indicated that the insulated green roof had the lowest energy consumption rate, with a reduction of approximately 18% for the building, where the green roof provides about 17% reduction.

Analysis of data from the Ecotect model suggests that adding soil media (green roof) to the regular roof has a great effect on the heat transmittance. Also this additional layer decreases the U-value of the roof which will decrease heat loss and improve thermal efficiency of the building.

4.3. Thermal computation

Thermal calculations were used to compute the entire energy savings for the whole building, formulas were used to calculate heat transfer for both building types and construction components depending on many variables: U-value of the surface, average temperature differences between outside and inside, and the area of the wall.

Table (6): Energy consumption reduction

Villa	**heating**	**cooling**	**Total**
Green roof	4%	4.9%	8.9%
Insulated Green roof	4.6%	5%	9.6%
Multi story building			
Green roof	7.5%	10.2%	17.9%
Insulated Green roof	7.52%	10.7%	18.32%

Then energy consumption for roof, walls, widows and infiltration from doors and windows cracks. Thermal comfort temperature was assumed at 21˚C to calculate heat transfer and energy consumption. [8]

$$Heat\ transfer = Area \times U - value \times \Delta T\ (21^{\circ}C - outdoor\ temp.) \quad (3)$$

$$Energy = Heat\ transfer \times Time \times Days \quad (4)$$

This calculation was conducted on the three types of roofing used in the simulation. The total saving was up to 26% of total energy consumption for a green roof, and 37% by adding insulation to the green roof layers.

Table (4): Villa energy consumption

Regular roof			**Green roof**			**Insulated green roof**		
MONTH	HEATING (Wh)	COOLING (Wh)	MONTH	HEATING (Wh)	COOLING (Wh)	MONTH	HEATING (Wh)	COOLING (Wh)
Jan	2421114	0	Jan	2310420	0	Jan	2295154	0
Feb	4954786	0	Feb	4736478	0	Feb	4705672	0
Mar	6534640	0	Mar	6257849	0	Mar	6217759	0
Apr	7279880	184635	Apr	6984967	154555	Apr	6941095	153540
May	7426098	669325	May	7135395	616092	May	7089830	620557
Jun	7428286	842685	Jun	7137903	783245	Jun	7092348	786806
Jul	7428286	1497166	Jul	7137903	1396655	Jul	7092348	1401658
Aug	7428286	2536207	Aug	7137903	2411781	Aug	7092348	2411788
Sep	7436769	3169438	Sep	7147171	3007231	Sep	7101634	3005012
Oct	7464426	3413582	Oct	7175818	3246276	Oct	7130306	3242974
Nov	8141713	3413582	Nov	7819986	3246276	Nov	7770576	3242974
Dec	9330343	3413582	Dec	8953812	3246276	Dec	8897086	3242974

Table (5): Multi-storey building energy consumption

Regular roof			**Green roof**			**Insulated green roof**		
MONTH	HEATING (Wh)	COOLING (Wh)	MONTH	HEATING (Wh)	COOLING (Wh)	MONTH	HEATING (Wh)	COOLIG (Wh)
Jan	5160754	0	Jan	4795668	0	Jan	4795964	0
Feb	10596252	0	Feb	9875435	0	Feb	9876721	0
Mar	14010439	0	Mar	13057328	0	Mar	13057228	0
Apr	15496010	470638	Apr	14441037	420180	Apr	14440285	417885
May	15681424	1618299	May	14596002	1480958	May	14595105	1468234
Jun	15681424	2152437	Jun	14596002	1960552	Jun	14595105	1935852
Jul	15681424	3809823	Jul	14596002	3368298	Jul	14595105	3342259
Aug	15681424	6221176	Aug	14596002	5539412	Aug	14595105	5505732
Sep	15681424	7496884	Sep	14596002	6721183	Sep	14595105	6681468
Oct	15682995	8034813	Oct	14596002	7211900	Oct	14595105	7171262
Nov	16889974	8041266	Nov	15682773	7218353	Nov	15680638	7177716
Dec	19227964	8041266	Dec	17785486	7218353	Dec	17780650	7177716

5. CONCLUSIONS

One should not undermine the benefits offered by Green Roofs towards improving the quality of space and ensuring human psychological comfort.

Results obtained from the experiment and analysis on the possibility of applying Green roofs in the city of Nablus, confirmed that this solution will increase the green areas in the city of Nablus, as it will provide many benefits, such as, improving the physical environment, and making gardens accessible to everyone.

Moreover, many benefits can be achieved on architectural, environmental, and aesthetical levels. The results also revealed that green roofs are feasible from an economical point of view.

Taking the advantage of these benefits into concern was very crucial for this research. This was addressed by investigating the development of the physical and environmental profile of the city. To determine if the city's buildings could accommodate green roofs, after studying the common construction method in the city and the building structure, it is clear that the city existing buildings can sustain extra load added by the lighter types of green roof without structural reinforcement.

From the human perspective, results confirmed that the citizens are willing to add green roofs to their buildings but have concerns over the cost of green roofs. Furthermore, the participants linked the benefits of green roofs with the benefits provided by plants and green areas in general, but not to specific green roof benefits, such as, the reduction of energy used in heating and cooling, or reducing urban heat.

Calculations confirmed that applying green roofs to buildings will reduce the energy used

for heating or cooling. Results obtained from Ecotect program showed that about 62% reduction of the actual direct solar radiation will be achieved, and 18% reduction in the energy used for cooling and heating when applying insulated green roof.
Thermal computation resulting from different U-value calculation results showed that a total saving up to 26% of total energy consumption by green roofs, and 37% by adding insulation to the green roof layers.
Indeed calculations and results indicate that green roofs can be cost effective on the long term, as the increase of construction cost can be returned back from the saving through the reduction of energy loads.
Studying and researching green roofs application is not an easy topic to be tackled. More research is needed to be established regarding green roof application to the city of Nablus, such as irrigation and plant types.

ACKNOWLEDGEMENTS
The authors would like to thank the citizens who participated in the questionnaire.

NOMENCLATURE

$\frac{Wh}{m^2}$ Total Solar Radiation

m^2 Total Area

U-Value the rate of transfer of heat through a structure

Wh The watt-hour a unit of energy equivalent to one watt (1 W) of power expended for one hour (1 h) of time.

REFERENCES

[1] Almusaed, A., *Biophilic and Bioclimatic Architecture*, *Green Roofs*, 1st Ed., London: Springer-Verlag, 2011, pp. 187-203.
[2] Dwiekat, M., Interview, (R. Sukker, Interviewer), 2015.
[3] Ecotect Analysis, Autodesk website, 2016.
[4] Saeid, E. J., *Effect of Green Roof in Thermal Performance of the Building an Environmental Assessment in Hot and Humid Climate*, Master, The British University of Dubai, 2011.
[5] FLL, *guideline for planning execution and upkeep of green-roof sites*, FLL website, 2002.
[6] Gartner, M., structural implication of green roofs, terraces, and wall, SEAOC 2008, Los Angeles, CA: SEA, 2008.
[7] Gedge, D., Newton, J., Cradick, K., Cooper, P., Partington, T., Grant, G., et al., Living Roofs and Walls, Technical Report: Supporting London Plan Policy, London: Greater London Authority, 2008.
[8] Goussous, J., Siam, H., and Alzoubi, H., Prospects of Green Roof Technology for Energy and Thermal Benefits in Buildings: Case of Jordan, *Sustainable Cities and Society*, Vol. 14, 2014, pp. 425–440.
[9] Green Roof Technology website, 2006.
[10] Lawlor, G., Currie, B. A., Doshi, H., & Wieditz, I., Green Roofs A Resource Manual for Municipal Policy Makers, Canada: Canada Mortgage and Housing Corporation, 2006.
[11] Nablus Municipality website, 2012.
[12] Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., et al., Green Roofs as Urban Ecosystems: Ecological, Structures, Functions, and Services, *BioScience,* Vol. 57, NO. 10, 2007, pp. 823–833.
[13] Palestinian Central Bureau of Statistics (pcbs), *Palestinian Central Bureau of Statistics*, 2011.
[14] Salameh, W., *Towards Sustainable Construction Systems of External Walls of Buildings in The West Bank Of Palestine*, Master, An-Najah National University, 2012.
[15] The green roof centre website, 2014.
[16] Townshend, D., *Study on green roof application in HONG KONG*, Architectural services department, HONG KONG, URBIS LIMITED, 2007.
[17] Weiler, S. K., & Scholz-Barth, K., *green roof system*, Hoboken, New Jersey: John Wiley & Sons, Inc, 2009.
[18] ZinCo, ZinCo Global Website, 2014.