BAU Journal - Creative Sustainable Development

Volume 4 | Issue 1
ISSN: 2664-9446

Article 4

November 2022

TREE PROVISION ACHIEVING KID'S THERMAL COMFORT THROUGH FINISHING MATERIAL PERFORMANCE IN SUBTROPICAL OUTDOOR PLAYGROUNDS. COMPARISON BETWEEN KING FAHED AND AL BIAA GARDEN IN TRIPOLI, LEBANON

Houda Kabbara
PhD candidate, Faculty of Architecture-Design and Built Environment, Beirut Arab University, Beirut, Lebanon, kabbarahouda@gmail.com

Eslam M. Elsamahy
Assistant Professor, Faculty of Architecture. Design and Built Environment, Beirut Arab University, Beirut, Lebanon, i.samahy@bau.edu.lb

Mary Felix
Associate Professor, Faculty of Architecture. Design and Built Environment, Beirut Arab University, Beirut, Lebanon, m.felix@bau.edu.lb

outdoor thermal comfort, chinaberry tree, playground finishing material, Tripoli kids.

TREE PROVISION ACHIEVING KID'S THERMAL COMFORT THROUGH FINISHING MATERIAL PERFORMANCE IN SUBTROPICAL OUTDOOR PLAYGROUNDS. COMPARISON BETWEEN KING FAHED AND AL BIAA GARDEN IN TRIPOLI, LEBANON

Abstract

Outdoor playgrounds are one of the most spaces needed for kids to make different types of activities, and enhancing thermal comfort in such space consist a critical value due to its impact on kids' health. Unfortunately, the acceleration of urban heat island (UHI) in outdoor spaces, caused by the presence built-up area has affected the temperature of outdoor spaces especially playgrounds. Many researches highlighted the importance of studying outdoor playground materials to achieve kid's thermal comfort. Nevertheless, analyzing the impact of providing trees on material performance consist a new research perspective. This research highlight on the importance of using trees as natural element to decrease temperature in outdoor playgrounds to achieve kid's thermal comfort. The aim of this research is to achieve kid's thermal comfort by enhancing the performance of outdoor playgrounds finishing materials through providing trees. The study will focus on the variation of playground surfaces temperature through simulating different scenario applied in Malek Fahed and Al Biaa garden in Tripoli, Lebanon. The simulation will be applied in subtropical climate using Envi-Met software. The present study provides an overview of outdoor playgrounds finishing materials and its relations with kid's thermal comfort. Research findings define the performance level of each playground finishing material in chinaberry shading during summer. Results demonstrate that natural surfaces such as sand, grass and stone enhance kids' thermal comfort more than artificial ones like concrete during summer days.

Keywords

outdoor thermal comfort, chinaberry tree, playground finishing material, Tripoli kids.

1. INTRODUCTION

Outdoor playgrounds are considered an important recreational kid's zone with different types of modern, traditional and adventure design elements like climbing devices, swings and slides. As well as natural elements like greenery and trees (BehnamNabavizadeh, 2021). According to different researches, thermal comfort is the term that represent the satisfaction of peoples in outdoor thermal environment (PirMohammad, 2021). In outdoor thermal environment evaluation, the micro climatic condition, physiological components (such as the metabolism rate), and behavioral elements are essential for better thermal comfort (S.Y. Chan, 2017). Different factors affect the thermal comfort in outdoor space: air temperature, humidity, wind speed, solar radiation, terrestrial radiation, metabolic heat, and clothing insulation (Mazhar, 2015).

Nowadays, many outdoor playgrounds suffer from unsafe thermal ambiance for kids such as temperature and pollution especially during summer and hot seasons (Vanos J. , 2015). Several studies refer this situation to the increase of urban heat island (UHI) (WoongKim, 2021) and lack of using tree elements that is used as shading devices (Bowler et al. 2010).

In a way to improve kids' thermal comfort of outdoor playgrounds, the research will study the use of tree elements and its impact on temperature performance of playground finishing materials such as tartan (rubber), sand, grass (El-dinKamel, 2013), wood and concrete (K.Vanos, 2016). The study will be conducted in Lebanon subtropical climate which is characterized by hot and dry summer (Britannica, 2018).

1.1. Impact of Urban Heat Island on Kids' Outdoor Thermal Comfort

Many reasons explain the critical value of outdoor playgrounds for kids. Playing outdoor is an important factor to develop children's skills and learning ability, by using their own emotional and physical capabilities (El-dinKamel, 2013). But Changes in land use and cover might conceivably increase the temperature of the neighborhood and surfaces with a few degrees such as outdoor playgrounds (WoongKim, 2021).A few studies affirmed that the presence of buildings can speed up the impact of Urban Heat Island (UHI), while water elements and greenery in public spaces can decrease the UHI force.

Kids are the most outdoor playground users affected negatively by UHI, because they are closer physically to ground elements and surfaces, due to their need for scrutinizing and learning about environments by their direct senses (Dee, 2007).

Outdoor playgrounds thermal safety consists an important point to achieve kids' health. Unfortunately, the majority of traditional outdoor playgrounds isn't designed according to kid's thermal safety. These outdoor playgrounds are harmful for kids concerning heat and harmful sun radiations (Vanos J. , 2015). Many factors compose kid's thermal comfort in outdoor playgrounds: humidity, sun radiation, temperature, wind speed, metabolic heat and clothing insulation (Naveed Mazhar, 2015).

Maintaining the design of traditional outdoor playgrounds can decrease the infection of kids like sun burns, thermal burns, body heat and respiratory problems during summer season (Z. Xu, 2013).

1.2. Impact of Trees on Playground Finishing Material

Outdoor playgrounds include different zones like greenery area, sand box, playing surfaces that allow many types of activities such as running, playing with balls, etc. it's important to provide natural shading elements for different sort of kid's activities to enhance the performance of finishing materials and maintain kid's comfort (BehnamNabavizadeh, 2021).

1.2.1. Finishing materials temperature

The albedo term or solar reflectance of materials (Karimi, 2020), is the definition of the total amount of reflection of finishing materials, by taking into consideration the hemispherical reflectance of radiation, and integrated over the solar

spectrum. It is defined as the specular and diffuse reflectance (Sleiman, 2014) related to infrared emittance (Pisello, 2017). In the other hand, when the finishing material of ground cover has a high albedo in outdoor areas, the heat and the temperature of surface will increase when the material is exposed to sun. Resulting in less surfaces are shaded from sun, then air overheating close to the outdoor surfaces (Erell, 2014) and finally lead to reduce urban heat (Mohammad, 2019).

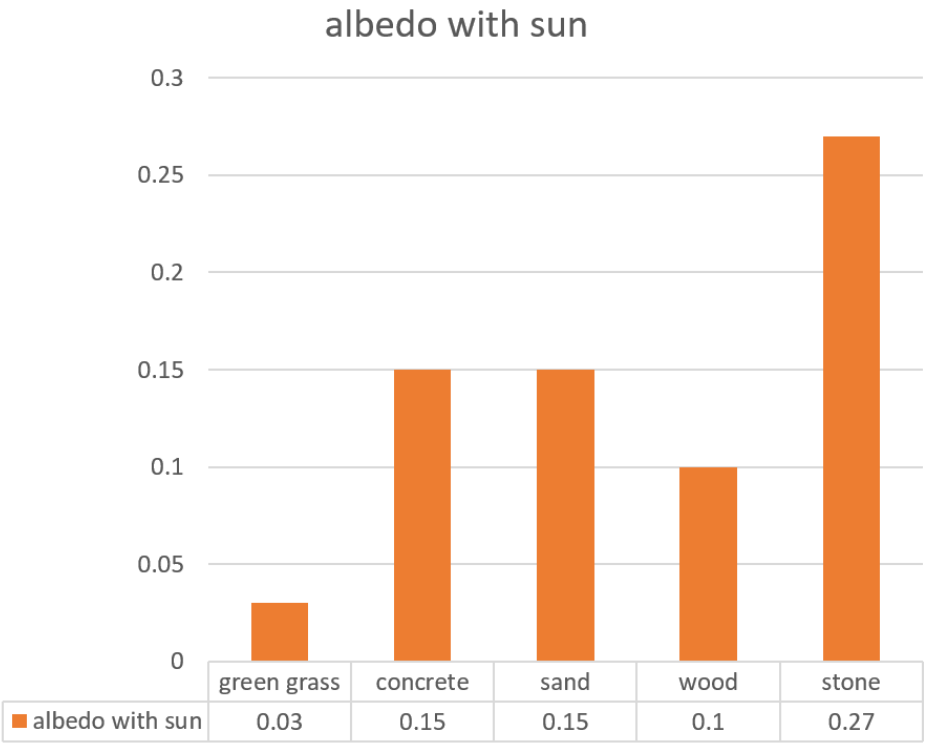

Fig.1: show the albedo value of playgrounds finishing materials in sun

Finishing materials of outdoor playgrounds have different solar reflections amount (albedos) (Cambridge dictionary, 2021). For example, grass results in average respective albedos of 0.25 and 0.03 in the sun, while concrete presents albedos of ~0.34 and 0.15 (table 1), respectively (Vanos, 2015). Outdoor playgrounds finishing material that is not shaded by trees or shading elements gain and expose a large amount of heat during hot and warm seasons. This situation will affect dangerously air and surfaces temperature, and create unsafe thermal environment for any type of playing or relaxing (J.K. Vanos, 2016). In addition, there has been an increase in thermal burns at playground locations (Commission, 2018), primarily believed to be related to the introduction of new materials and artificial surfaces which have reached dangerously high temperatures and burn a child's skin in as little as three seconds. Exposed playground slides, rubber, and artificial turf are the leading culprits of burns (C. Asquith, 2015).

1.2.2. Role of chinaberry trees

In Tripoli, Lebanon, chinaberry trees are the most used type of trees as shading element in outdoor spaces because it is a deciduous tree that grows rapidly and can get as large as 30 to 50 feet (9.14 to 15.24 m) tall with a canopy diameter of approximately 20 feet (6.10 m). It is composed of several smaller trunks that are produced from multiple roots that sprout outwards and can survive in many different climactic and soil conditions (azedarach, 2020).

Tree elements play an important role by reducing temperature through insuring shaded spaces and enhancing transpiration by vegetative process (Bowler et al. 2010). Many studies suggest that using vegetation's and trees would decrease the impact of urban heat island (UHI) (Loughner et al. 2012), while others promote vegetation as a way of modifying urban microclimates and human thermal comfort (HTC) (Shashua-Bar et al. 2010). The key positive effects of tree elements in outdoor spaces onto thermal comfort are lowering air and radiative temperature via evaporative cooling and shading (Norton, et al., 2015).

1.3. Climate

Lebanon has a subtropical climate characterized by hot, humid summers and generally mild to cool winters (Britannica, 2018). In Tripoli, the summers are warm, muggy, arid, and clear and the winters are cool, wet, windy, and mostly clear. The hot season lasts for 3.6 months, from June 19 to October 8, with an average daily high temperature above 27°C. The hottest month of the year in Tripoli is August, with an average high of 30°C and low of 25°C (weatherspark, 2021).

According to weather stations of Lebanon, the average temperature of outdoor spaces increases with two degrees from 2013 till 2021 in august (figure 1), which is the hottest month in summer (weatherspark, 2021).

In a way to improve thermal comfort in outdoor playground, microclimate components like temperature, wind speed, humidity, sun condition will be collected through Lebanon weather stations based on historical analysis from January 1/1980 to December 31/2016.

Many researchers studied the impact of urban greenery on the albedo of surfaces in different locations (PirMohammad, 2021) as mentioned in (table 2). From the literature review mentioned above, some research gaps can be noticed. It's rare to find a paper that focus on playground surfaces albedo and how to enhance its performance during hot seasons in subtropical climate by providing chinaberry tree element.

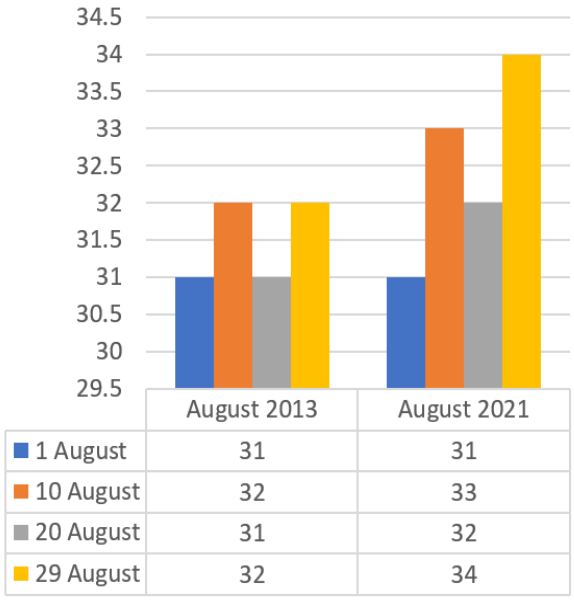

Fig.2: show a comparison in the temperature history in august between 2013 and 2021 (weatherspark, 2021)

Table 1 show the field of studies on finishing materials (PirMohammad, 2021)

Strategy	City	Method	Suggestion	Reference
Cool material	Athens	Field measurements	Mean air temperature decreases by an average of 2.3 K at low wind speeds	(Karlessi et al., 2013)
	Athens	Field measurements	all the samples of colored thin layer asphalt show lower surface temperature than conventional asphalt	(Synnefa et al., 2011)
	Toronto	Simulation	increasing 0.1 albedos from the surface increases MRT by 1.2 °C and, consequently, 0.8 °C higher PET	(Taleghani, 2018)
Urban greenery	Urmia	Field measurements and simulation	Concrete with a high-albedo, trees of Platanus and Pine, and the use of sufficient water in summer were considered as the optimal solution for summer.	(Gachkar et al., 2021)
	Lisbon	Field measurements	Maximum Ta reduction up to 6.9 °C	(Oliveira et al., 2011)

2. METHODOLOGY

The study will be conducted through a quantitative approach that start by observing the selected study zones, then collecting needed data related to playground finishing materials, microclimate conditions. The collected data will be simulated using Envi-met software. The results will be compared using excel software.

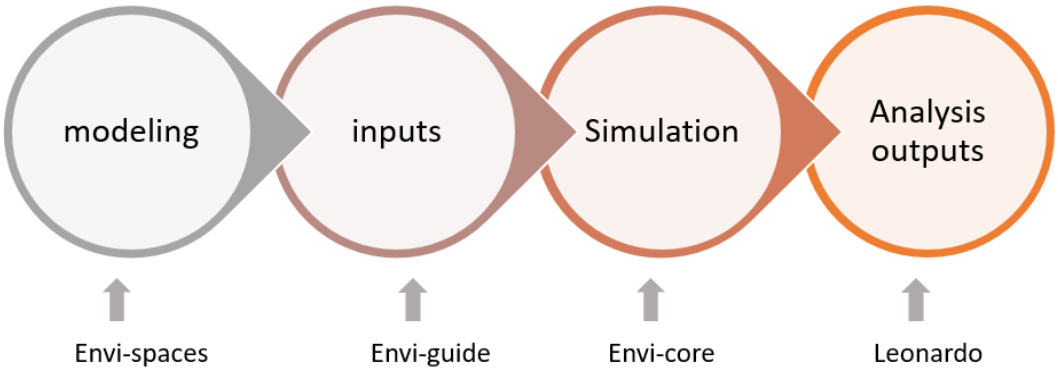

Fig.3: show the simulation sequence using Envi-Met software

ENVI-met software allows designers to create sustainable living conditions in a constantly changing environment. With the support of its interactive modules, it is possible to specify surface types and building materials, as well as vegetation on walls and roofs, to scientifically analyze the impact of design measures on the local environment and help mitigate factors such as urban heat stress. The software model is used worldwide for environmental analysis and urban planning – from the tropics to Polar Regions (figure 3). The software's potential has been validated and its calculations verified in over 3,000 scientific publications and independent studies. It calculates the microclimate of a city with ENVI-met down to the square meter (Envi-Met, 2021).

2.1. Selected Study Zones

This paper will focus on different playgrounds in two different locations in Tripoli, Lebanon. First case is King Fahed playgrounds which is situated in Al Maarad with area of an 18411square meter and has a low dense of surrounded building cover. The second case is al Biaa playgrounds which is located in Dam and Farez with area of 18153 square meter and has a high dense of surrounded building cover (figure 4). The selected gardens have a similarity with area but differ in its surrounding built area. Many similar finishing materials is used in king Fahed and al Biaa garden, and other differ.

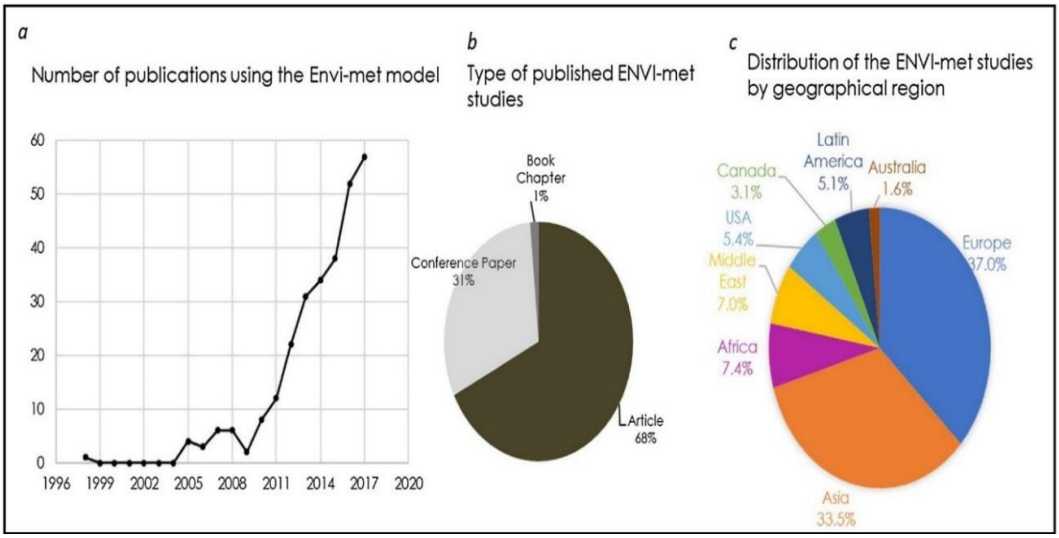

Fig.4: show the distribution of studies using Envi-met software around world (S.Tsoka, 2018)

2.2. Observation Method

To collect the needed data about king Fahed garden and al Biaa garden, it's important to start with an observation for the selected zones as a method to define the types of playgrounds finishing materials and types of trees used.

2.2.1. King Fahed garden

King Fahed Park consists of 10 thematic gardens, and planted with various Mediterranean trees and shrubs (El-Kholei, 2009). King Fahed is the most reachable park since it's connected with important nodes like Al Maarad road and Al Noor square (MOHAREB, 2018). The playground finishing materials used in park are: grass, concrete tiles and sand (figure 5).

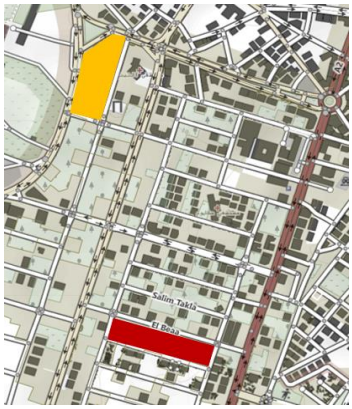

Fig.5: show the building cover around king Fahed park in yellow and al Biaa park in red

2.2.2. Al Biaa garden

Al Biaa garden is located in the middle of Dam and Farez neighborhood and consist of a large grass area for playing and relaxing, playing area covered with sand and free zone covered with natural stone ground (figure 6). Around 75% of al Biaa garden surrounding is built as residential buildings with stable height of around 40 meters (Google maps, 2021).

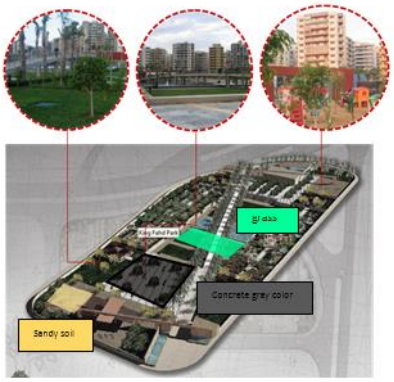

Fig.6: show the different type of playground finishing materials in king Fahed Park

3. RESULTS AND DISCUSSIONS

3.1. Virtual modeling

The modeling of king Fahed and al Biaa garden surfaces starts by importing the bitmap map of two gardens and applying locations coordinates using google maps (Google maps, 2021). Then importing the gardens bitmap maps into spaces script using Envi-met software. The second step consist of defining the actual surfaces finishing materials of playgrounds and placing the existing trees and palms and extruding the surrounding context like roads and buildings (figure 7).

Fig.7: show the playground finishing materials of Al Biaa garden in Dam and Farez

3.2. Microclimate inputs

After modeling king Fahed and al Biaa gardens, the microclimate of sites is applied in the 8th of august which is the hottest day of the year (weatherspark, 2021). The meteorological boundary conditions needed in simulations is air temperature, humidity, wind speed and wind directions (figure 8). The microclimate conditions of king Fahed and al Biaa garden is derived from "waetherspark" website based on Tripoli weather stations history from 2013 till 2021.

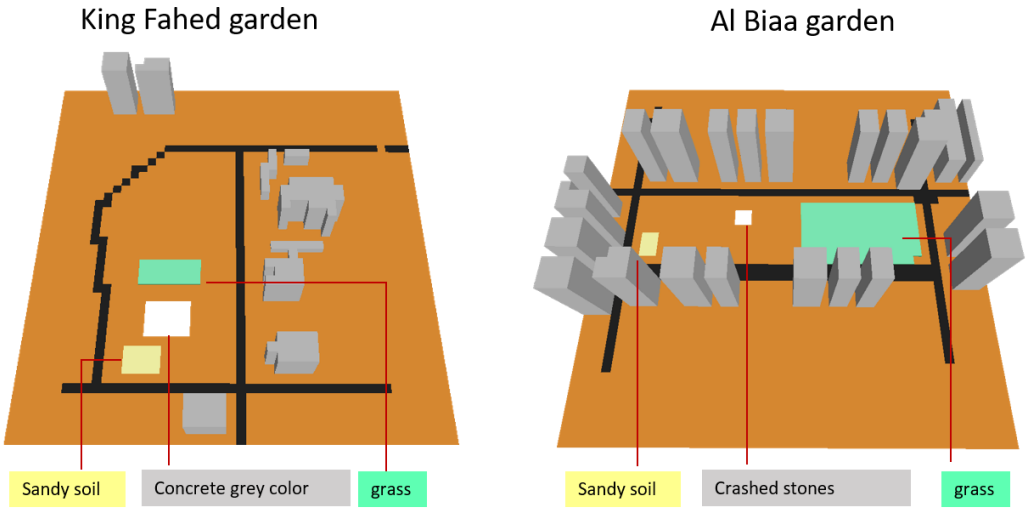

Fig.8: show the modeling stage in Envi-met of king Fahed and al Biaa gardens with selected finishing materials

According to waetherspark website, in 8th august 2021, the meteorological boundary conditions was:

1. Temperature: 29C is minimum air temperature, and 30C is the maximum air temperature.
2. Humidity: 80% is the minimum relative humidity, and 99% is the maximum relative humidity.
3. Wind speed: 5.1 m/s.
4. Wind direction: west.

3.3. Models Simulation

The simulation stage is done using Envi-Core script in Envi-Met software. It's divided into two steps, first, the finishing materials of king Fahed and al Biaa gardens is simulated without adding chinaberry tree. Then, the second step consist of simulating the finishing materials of two gardens after adding the chinaberry tree.

3.3.1. Before adding chinaberry tree

The finishing materials of king Fahed and al Biaa gardens were firstly simulated in Envi-Core without adding chinaberry trees. The results derived from simulations is analyzed as surface temperature map in Leonardo script in Envi-Met software (figure 9).

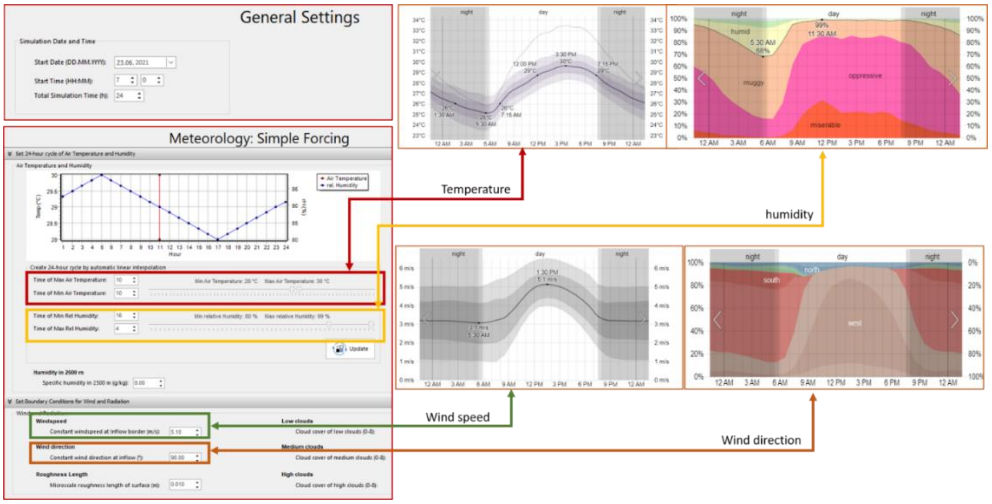

Fig.9: show the microclimate inputs of king Fahed and al Biaa gardens

The results of king Fahed and al Biaa garden simulation in 8th of august 2021 at 15:30 pm shows:

1. The temperature of sand surfaces in king Fahed garden (23.70 to 24.34 C) is more than its temperature in al Biaa garden (20.61 to 22.98 C).
2. Temperature of grass surface in king Fahed garden (23.06 to 23.70 C) is more than the grass finishing material in al Biaa garden (21.79 to 22.59 C).
3. The temperature of grey concrete finishing material in king Fahed garden is from 24.34 to 24.98 C.
4. The temperature of crashed stone finishing material in al Biaa garden is from 20.21 to 20.61 C.

3.3.2. After adding chinaberry tree

The second simulation of king Fahed and al Biaa gardens is done after adding chinaberry trees in playgrounds. Figure 10 show the places of chinaberry trees in red circles.

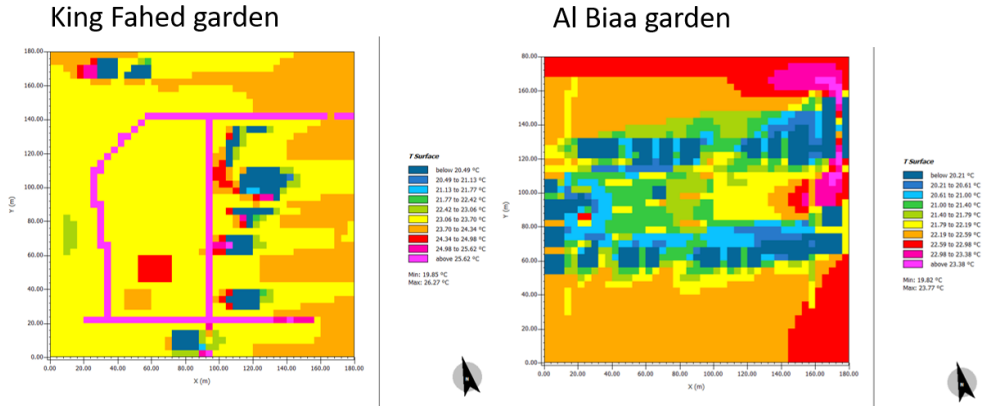

Fig.10: show the surface temperature of king Fahed and al Biaa garden before adding chinaberry tree

The results derived from simulations is analyzed as surface temperature map in Leonardo script in Envi-Met software (figure 11).

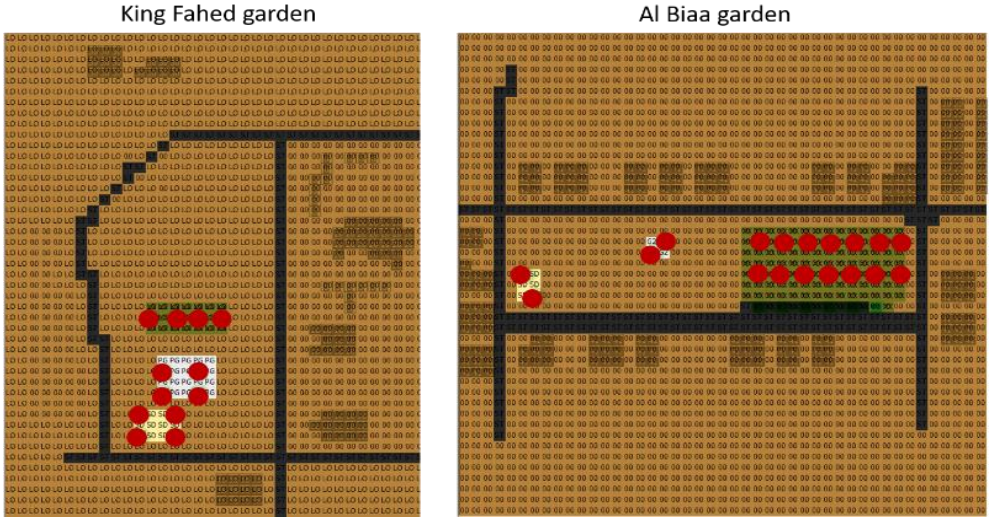

Fig.11: show the places of chinaberry trees in red circles

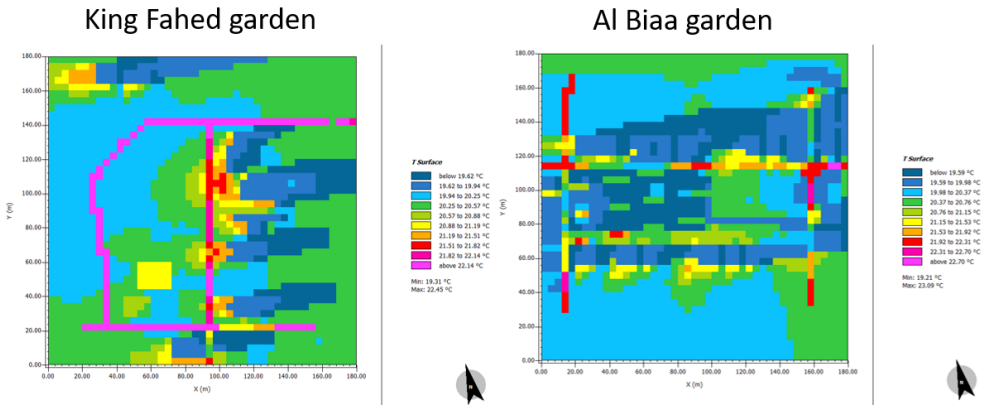

Fig.12: show the temperature of finishing materials of king Fahed and al Biaa gardens after adding chinaberry tree

According to simulations of king Fahed and al Biaa gardens show the results below:

1. The temperature of sand surfaces decreased in king Fahed garden (20.25 to 20.8 C), and in al Biaa garden (19.98 to 21.92 C).
2. Grass surfaces has decreased it temperature in king Fahed garden (19.94 to 20.57 C), and in al Biaa garden (19.98 to 20.76 C).
3. The temperature of grey concrete finishing material in king Fahed garden decreased (20.88 to 21.19 C).
4. The temperature of crashed stone finishing material in al Biaa garden decreased (19.98 to 20.37 C).

3.4. Discussion

Few studies have focused on the effects of tree elements and the albedo of playground finishing materials at the same time. Therefore, the objective of this study is improving kids' thermal comfort of outdoor playgrounds by providing chinaberry tree to decrease finishing materials temperature.

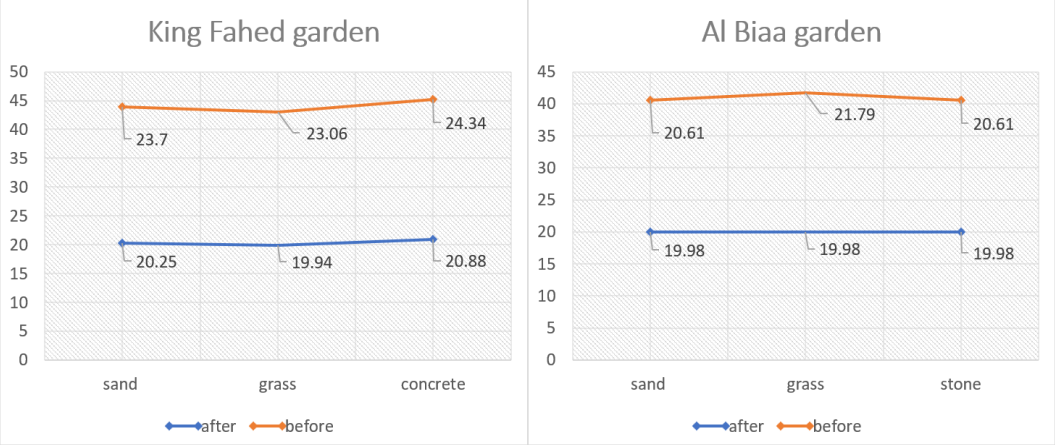

Fig.13: chart that shows the temperature values of surfaces in king Fahed and al Biaa gardens after adding chinaberry trees

The chart below confirms the positive impact of chinaberry tree on the temperature of playground finishing materials in Tripoli, Lebanon. It shows that all tested surface materials (sand, grass, concrete and natural stone) in king Fahed and al Biaa gardens has a decrease in its temperature:

1. Sand surfaces decreased around 3 degrees in king Fahed garden, and one degree in al Biaa garden.
2. Grass surfaces decreased around 3degrees in king Fahed garden and two degrees in al Biaa garden.
3. Concrete finishing material decreased around four degrees in king Fahed garden.
4. Natural stone finishing material decreased around one degree in al Biaa garden.

In addition, results in bar chart shows that after adding chinaberry trees, grass surfaces have the lowest temperature (19.94) in king Fahed garden, then sand surfaces (20.25), and concrete finishing material has the highest degree (20.88). in the other hand, the finishing material in al Biaa garden has the same temperature values which is 19.98 C.

As it shown in bar chart below, the temperature of finishing material (19.98 C) in al Biaa garden which is surrounded by residential building cover is less than the temperature of finishing materials (20.88 C) in king Fahed garden that have a low surrounded building cover.

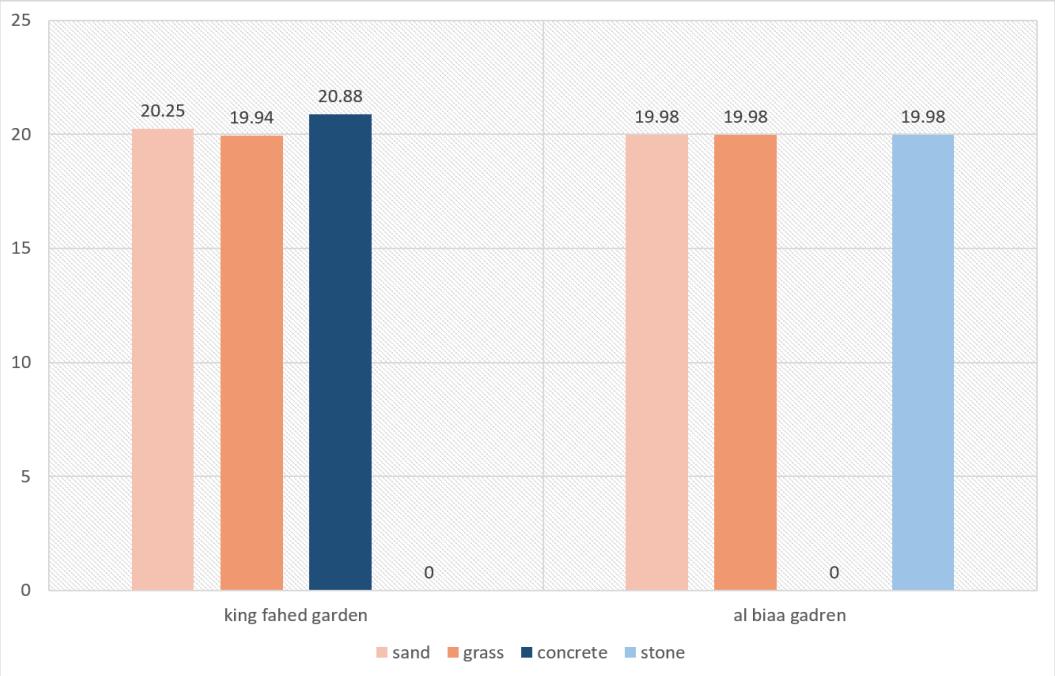

Fig.14: bar chart that compare surfaces temperature in both gardens after adding chinaberry trees

4. CONCLUSION

Research findings shows that type of playgrounds finishing materials affect kids' thermal comfort in different levels according to its types and shading situation. The use of chinaberry trees in playgrounds enhance the performance of finishing materials during summer days. Natural finishing materials such as grass cover is the most type that decrease surfaces temperature after adding chinaberry shading, and artificial finishing materials like concrete has the highest temperature comparing with selected surfaces.

Building cover around playgrounds plays an important role to enhance surfaces finishing materials during summer days by providing building shade. Playgrounds that are surrounded by buildings scored a decrease in the temperature of finishing materials more than surfaces that is surrounded building cover. Many factors of building cover need to be studied in further simulations such as building height, length, width and building-playground distance to enhance kid's thermal comfort.

This contextual analysis gives basic understanding, conversation, and novel inquiries relating finishing materials of outdoor playground, which can commonly uphold social and biological qualities while giving kids thermal comfort. Not exclusively are significant kids' infections, like sun related burns, temperature limits, and concealing overlooked in current outdoor playgrounds security rules.

The study outcomes spur future huge scope studies surveying the impact of finishing materials and tree types for enhancing kids' thermal comfort in playgrounds. Understanding the expected advantages and co-benefits requires reevaluating the most useful type of trees that improve kids' thermal comfort and all kinds of playing activities during summer day, to guarantee both physical and natural security and availability through scene plans, which might upgrade the experience.

To further develop local area reasonableness, kids' prosperity, and reinforce the general outdoor playground security condition, there is a huge need to bring issues to light concerning playgrounds microclimates associated with finishing materials and accessible natural shade, and illuminating the people who settle on choices in plan of outdoor playgrounds spaces or buy materials.

REFERENCES

- azedarach, M. (2020). *Chinaberry Tree*. Retrieved from https://www.anniesannuals.com/plants/view/?id=673
- Baldinelli. (2015). Analysis of albedo influence on surface urban heat island by spaceborne detection and airborne thermography.
- BehnamNabavizadeh. (2021). Playground Equipment-related Genital Injuries in Children: An Analysis of United States Emergency Departments Visits, 2010-2019.
- *Britannica*. (2018). Retrieved from https://www.britannica.com/place/Lebanon/Climate
- C. Asquith, R. K. (2015). Too hot to trot (barefoot)… A study of burns in children caused by sun heated surfaces in Queensland, Australia.
- *Cambridge dictionary*. (2021). Retrieved from https://dictionary.cambridge.org/dictionary/english/albedo
- Commission, C. P. (2018). CPSC Fact Sheet: Burn Safety Awareness on Playgrounds.
- D, A. (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area.
- Dee, C. (2007). Form and fabric in landscape architecture.
- El-dinKamel, D. K. (2013). A strategy for selecting safe and low maintenance floorings in early childhood centers outdoors.
- El-Kholei, A. O. (2009). Rapid Environmental Assessment of The Urban Community of Al-Fayha', Lebanon.
- Envi-Met. (2021). Retrieved from https://www.envi-met.com/
- Erell, E. (2014). Effect of high-albedo materials on pedestrian heat stress in urban street canyons.
- Farhadi. (2019). Mitigating the urban heat island in a residential area in Tehran: Investigating the role of vegetation, materials, and orientation of buildings.
- *Google maps*. (2021). Retrieved from https://www.google.com/maps/@34.4282431,35.8313926,431a,35y,16.87h/data=!3m1!1e3
- J.J, H. (2020). Trade-off between urban heat island mitigation and air quality in urban valleys.
- J.K. Vanos, A. M. (2016). Hot playgrounds and children's heath: A multiscale analysis of surface temperatures in Arizona, USA.
- K.Vanos, J. (2016). Hot playgrounds and children's health: A multiscale analysis of surface temperatures in Arizona, USA.
- Karimi, A. (2020). Evaluation of the thermal indices and thermal comfort improvement by different vegetation species and materials in a medium-sized urban park.
- Keeler, R. (2008). Natural playscapes: Creating outdoor play environments for the soul.
- Mazhar, N. (2015). Thermal comfort of outdoor spaces in Lahore, Pakistan: lessons for bioclimatic Urban Design in the context of global climate change.
- Microsoft. (2021). *Microsoft Excel*. Retrieved from https://www.microsoft.com/en-us/microsoft-365/excel
- Mohammad, P. (2019). The impact of the land cover dynamics on surface urban Heat Island variations in semi-arid cities : a case study in Ahmedabad City, India, using multi-sensor/source data.
- MOHAREB, N. (2018). RECOMMENDATIONS FOR DESIGNING HEALTHIER KIDS'GARDENS: IN TRIPOLI, LEBANON.
- N.G. Cosco, R. M. (2014). Childcare outdoor renovation as a built environment health promotion strategy: Evaluating the preventing obesity by design intervention.
- Naveed Mazhar, R. D. (2015). Thermal comfort of outdoor spaces in Lahore, Pakistan: lessons for bioclimatic Urban Design in the context of global climate change.

- Norton, B., Coutts, A., Livesley, S., Harris, R., Hunter, A., & Williams, N. (2015). *Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes.*
- PirMohammad. (2021). Evaluating the role of the albedo of material and vegetation scenarios along the urban street canyon for improving pedestrian thermal comfort outdoors.
- Pisello, A. L. (2017). *State of the art on the development of cool coatings for buildings and cities.*
- Renterghem, V. (2012). Road traffic noise shielding by vegetation belts of limited depth.
- S.Tsoka. (2018). analyzing the ENVI-met microclimate model's performance and assessing cool materials and urban vegetation applications–A review.
- S.Y. Chan, C. C. (2017). On the study of thermal comfort and perceptions of environmental features in urban parks: a structural equation modeling approach.
- Shi, Y. (2013). Physicochemical properties of dirt-resistant cool white coatings for building energy efficiency.
- Sleiman, M. (2014). *Soiling of building envelope surfaces and its effect on solar reflectance–part II: development of an accelerated aging method for roofing materials.*
- Vanos. (2015). Children's health and vulnerability in outdoor microclimates: A comprehensive review.
- Vanos, J. (2015). Children's health and vulnerability in outdoor microclimates: A comprehensive review.
- Vanos, J. (2015). Children's health and vulnerability in outdoor microclimates: A comprehensive review.
- Wang. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada.
- *weatherspark*. (2021). Retrieved from https://weatherspark.com/h/m/148700/2013/8/Historical-Weather-in-August-2013-at-Beirut-International-Airport-Lebanon#Figures-Temperature
- WoongKim, S. (2021). Urban heat island (UHI) variations within a city boundary: A systematic literature review.
- Z. Xu, C. H. (2013). Extreme temperatures and emergency department admissions for childhood asthma in Brisbane, Australia.