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A COMPARATIVE ANALYSIS OF CURRENT BIOCLIMATIC LANDSCAPE DESIGN APPROACHES

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Abstract

In the contemporary landscape architecture, the development of bioclimatic design approaches in projects and studies appeared and evolved in the last 20-30 years, yet although some principles date back to the ancient gardens of the Middle East. Bioclimatic landscape design has been developed in order to improve the relationship between human habitats and the natural environment as well as to ameliorate the microclimate influence on human health and comfort. The approach is focused on analyzing and comparing five recent bioclimatic landscape analysis and design projects from several cities located in different climatic zones of the world, including hot arid areas (New Cairo, Egypt; Phoenix, Arizona, USA; Be'er Sheva, Israel), hot humid areas (Guangzhou, China) and temperate humid zones (Utrecht, the Netherlands). The research aims to identify, evaluate and compare methods of analysis, design and implementation used in each case study. The results of the study indicate the main factors involved in the development and implementation of projects in bioclimatic landscape architecture, presenting the impact of the proposed interventions on the bioclimatic variables. The conclusions set out the major principles and methods used in bioclimatic landscape design, underlying the benefits of woody vegetation, the most significant controlling factor of the microclimate in most geographical areas.

Key words: *Bioclimatic landscape planning and design, green infrastructure, urban microclimate, urban vegetation*

INTRODUCTION

Nowadays, bioclimatic planning and design are well known concepts in the field of architecture and urban planning which have been deeply researched in the last half century. In the case of landscape architecture, the modern bioclimatic approach have appeared in the 1980s (Robinette, 1983), but has been theorised, developed and applied mostly in the last 15-20 years (Brown and Gillespie, 1995; Attia and Duchhard, 2011). The main objective of bioclimatic landscape design is to ensure a more comfortable and safer microclimate for the human habitats, especially the urban ones. Thus, the green spaces should be planned in order to mitigate bioclimatic challenges such as urban heat island, wind and dust storms, air pollution, etc. In this context, the study reveals different recent approaches in the field of bioclimatic landscape design.

MATERIALS AND METHODS

The selected case studies are focused on the improvement of urban microclimate conditions through vegetation and water features. Within the research five projects from different climatic zones of the world are analysed through a comparative study (Tables 1, 2). The projects are located in: hot-arid areas – the case of New Cairo, Egypt (Attia and Duchhard, 2011), Phoenix, Arizona, USA (Declet-Barreto et al., 2013) and Be'er Sheva, Israel (Segal, 2015); hot-humid zones - Guangzhou, China (Chen et al., 2009) and temperate-humid areas – Utrecht, the Netherlands (Lensink, 2015). In most of the cases, the projects are approached at the neighbourhood scale, including residential areas and a university campus. The exception is the landscape planning and design strategy for Be'er Sheva, which refers also to the green spaces system at city scale (Figure 1). Regarding the implementation stage, the projects located in Be'er Sheva, Utrecht and Phoenix are approached only at conceptual level, while the bioclimatic landscape design proposal for the American University of Cairo has been already implemented (Figure 2). The proposed analysis criteria include the specific bioclimatic challenges for each type of climate, vision and objectives (Table 1), conceptual principles, specific methods, results and findings (Table 2). The conclusions reflect the most significant findings in the case of each criterion as well as a general overview of the current approaches in bioclimatic landscape design and future perspectives.

Table 1. Comparative analysis of recent bioclimatic landscape design projects; challenges, visions and objectives

City	**New Cairo, Egypt**	**Phoenix, Arizona, USA**	**Guangzhou, China**	**Utrecht, the Netherlands**	**Be'er-Sheva, Israel**
Project title (author, year)	***Bioclimatic landscape design strategy for the American University of Cairo (AUC) Campus (Shaddy Attia, 2006)***	***Creating the park cool island in an inner-city neighbourhood: heat mitigation strategy for Phoenix (J. Declet-Barreto, A. J. Brazel, C. A. Martin, W. T. L. Chow, S. L. Harlan 2012)***	***Field measurements on microclimate in residential community in Guangzhou (Z. Chen, L. Zhao, Q. Meng, C. Wang, Y. Zhai, F. Wang, 2009)***	***Climate-Responsive Maarschalkerw-eerd (Rick Lensink, 2014)***	***Street garden – Trees and vegetation as generators of urbanism in the desert city (Lotem Segal, 2014)***
Type of project	Conceptual landscape design, Implemented	Landscape planning scenario	Analysis of an implemented landscape design project	Conceptual landscape planning and design project	Conceptual landscape planning and design project
Scale of project	University campus	Inner city neighbourhood	Residential community	Suburban area	Neighbourhood scale and city scale
Climate	Hot arid	Hot arid	Hot humid	Temperate humid	Hot arid
Bioclimatic challenges	- Solar radiation (Heat) control - Wind and dust storm control - Evaporation control	- Urban heat island - Heat wave - Wind and dust storm - Evaporation control	- Urban heat island - Wind speed - Air humidity	- Urbanization effects - Wind control - Air quality - Urban heat island in summer	- Poor quality of urban open spaces, lack of green spaces - Solar radiation (Heat) control - Wind and dust storm control
Vision and objectives	- Improvement of microclimate, thermal comfort and energy conservation through landscape elements (vegetation, water, structural elements)	- Assessment of the impact of vegetation in lowering temperature during extreme heat periods in an urban neighbourhood park	- Development of an analysis method to improve the microclimate of a residential community by changing the bioclimatic factors	- Planning a climate-responsive suburban neighbourhood by optimizing the thermal comfort - Minimizing the negative impact of urban development	- Creating an oasis for the desert city - "The Street Garden" concept proposes an alternative circulation channel connecting residential, commercial and public centres

RESULTS AND DISCUSSIONS

Bioclimatic challenges. In hot arid areas, the main bioclimatic challenges are the heat and solar radiation control, protection against wind and dust storms and evaporation control. In hot humid climate, the challenges include wind speed control, urban heat island and air humidity control. In the case of the temperate humid climate, the main bioclimatic challenge during winter is wind control, while during summer the prevalent is the urban heat island phenomenon. Beside these bioclimatic issues, the air quality level is a common factor independently to the type of climate. Thus, it can be observed that mitigating urban heat island effect and reducing the impact of wind speed and dust storms are the main goals of bioclimatic landscape design (Table 1).

Vision and objectives. All the analysed projects are concerned on improving the microclimate and human thermal comfort through landscape elements, especially woody vegetation and watersheds. Nevertheless, several projects include specific and complementary objectives such as energy conservation, in the case of New Cairo (Attia and Duchhard, 2011), minimizing the negative impact of urban development, in Utrecht (Lensink, 2015) or creating an alternative circulation network through green infrastructure, in Be'er Sheva (Figure 1) (Segal, 2015). The differences between the projects in terms of visions and objectives depend also on the analysis and planning approaches, on the main principles and the specific methods used in each project (Table 1).

Conceptual principles and measures. It should be mentioned that part of the projects are focused mostly on analysis (Guangzhou and Phoenix), while the others combine analysis and planning principles and methods (Table 2). In Guangzhou and Phoenix, two residential neighbourhoods are assessed in order to identify and quantify the impact of vegetation on the microclimate. The difference between the two approaches is that in the first case, the effect of vegetation and watersheds on the microclimatic conditions is analysed on site (an already developed residential area), while in the second case the impact of a bioclimatic landscape planning scenario is evaluated through simulation methods. The projects focused on planning involve distinct approaches, based on specific principles. Thus, the bioclimatic strategy for the university campus located in New Cairo proposes a bioclimatic zoning concept with specific vegetation and microclimatic impact (Attia and Duchhard, 2011). Besides this, the walled-garden concept (used to protect from desert storms and heat waves) and intensive/extensive landscaping (used as an adaptation to water scarcity) are proposed (Figure 2). Even Utrecht and Be'er Sheva are characterized by different bioclimatic challenges the planning solutions for both urban areas are concerned on creating green infrastructure networks (Segal, 2015; Lensink, 2015). The main measures consist of preserving, expanding and connecting the green areas in order to improve the thermal comfort using vegetation. In Utrecht the planning proposal refers only to Maarschalkerweerd suburban area, while in the case of Be'er Sheva the green infrastructure strategy is proposed at the whole city scale (Table 2).

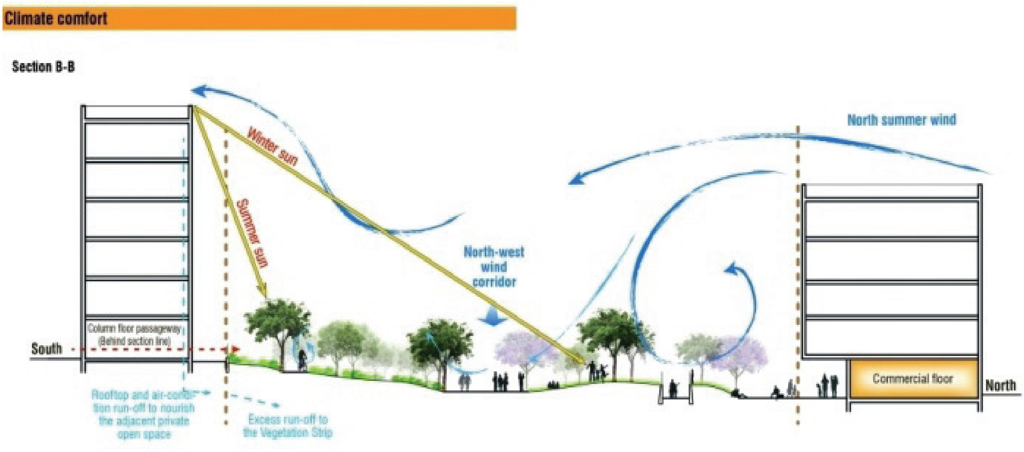

Figure 1 – An urban bioclimatic green corridor proposal for Be'er Sheva, Israel
(Source: Segal, 2015)

Table 2. Comparative analysis of recent bioclimatic landscape design projects; principles, methods and findings

City	New Cairo, Egypt	Phoenix, Arizona, USA	Guangzhou, China	Utrecht, the Netherlands	Be'er-Sheva, Israel
Project title (year)	***Bioclimatic landscape design strategy for the American University of Cairo (AUC)* Campus *(2006)***	***Creating the park cool island in an inner-city neighbourhood: heat mitigation strategy for Phoenix (2012)***	***Field measurements on microclimate in residential community in Guangzhou (2009)***	***Climate-Responsive Maarschalkerw-eerd (2014)***	***Street garden – Trees and vegetation as generators of urbanism in the desert city (2014)***
Conceptual principles	Bioclimatic zones concept: 1. Shelterbelt, 2. Oasis, 3. Desert landscape, 4. Greenways, 5. Parking and roads, 6. Building / landscape interface, 7. Inner garden - Walled gardens (shelterbelt) - Extensive/intensive landscaping	- Comparing the current situation of a residential area with a landscape planning scenario in order to quantify the benefits of vegetation	- Researching the impacts of different surface materials with various thermal properties on the outdoor thermal environment, including large areas of water, tree shadows and pavement materials.	- Preserving, expanding and connecting the current green areas in order to prevent the urban sprawl and to ensure a thermal comfort for the local community - Principles: greenery, urban geometry, wind control, watersheds.	- Climate comfort (using vegetation) - A tool system for the Street Garden layout (determined by existing trees, watersheds, valuable open spaces) - Urban backbone Master plan (a green infrastructure network for the whole city)
Specific methods	- ENVI-MET simulations - ECOTECT shading analysis - PET index to calibrate and validate the simulation	- ENVI-MET simulations - Object-Based Image Analysis (OBIA)	- Field measurements in order to determine the microclimatic parameters (air temperature, black bulb globe temperature, humidity, wind speed): 9 spots placed in different conditions (trees, watersheds, pavements)	- A microclimate specific analysis shows the most suitable areas that can be developed as climate-responsive elements	- Behavioural, well-being and perceived quality analyses - Green infrastructure density analysis
Results and findings	- Vegetation plays the most effective role in surface and air temperature modification - The outdoor environment is moderated most efficiently by combining trees, ground cover vegetation and water surfaces	- Significant air and surface temperature reduction in the landscape plan scenario - A "Park cool island" effect, extended to the close non-vegetated areas - A net cooling of air in the planted areas, ranging from 0.9°C to 1.9°C during the warmest period of the day - Reduction of the surface temperature from 0.8°C to 8.4°C in planted areas	- Air temperature was 1.3°C lower near the lake and 25% less in high temperature (>35°C) compared to other areas - Spots placed in vegetation shaded spaces are 0.6-0.8°C lower and 20% less in high temperature - Humidity – the lake doesn't have a significant impact on the community - A safe wind environment	- Vegetation is presented as the main influencing factor: it provides shade, controls wind, cools the air temperature by water evaporation. - The green areas are preserved and made accessible for the inhabitants	- Trees and vegetation are the most significant factors in microclimate improvement, having also a positive social and psychological impact

Figure 2. The implemented landscape design project for the American University of Cairo, New Cairo, Egypt (Source: The American University of Cairo – Aviation Academy, 2013)

Specific methods. The specific methods used in bioclimatic planning projects include a wide range of analyses such as: ENVI-MET simulations; ECOTECT shading analysis; object-based image analysis, microclimatic field measurements; green infrastructure suitability analysis; behavioural, well-being and perceived quality analysis; density of green infrastructure.

ENVI-MET simulations were used both in analysis and design projects (Phoenix and New Cairo) in order to determine the impact of the vegetation on air temperature (Attia and Duchhard, 2011; Declet-Barreto et al., 2013).

The ECOTECT shading analysis was used within the bioclimatic landscape strategy for the American University of Cairo (Figure 2) to find out the percentage of the tree shaded area (Attia and Duchhard, 2011).

Microclimatic parameters have been measured on site in order to assess the impact of trees and water features in a residential community in Guangzhou (Chen et al., 2009).

The suitability analysis for the development of climate-responsive elements has been used within the planning strategy for Maarschalkerweerd suburban area (Utrecht) to identify the potential open spaces to be integrated into the green infrastructure network (Lensink, 2009).

Behavioural and green space quality analyses have been utilized in Be'er Sheva in order to assess the social and psychological impact of vegetation (Segal, 2015).

CONCLUSIONS

All the analysed projects illustrate the significant impact of vegetation (especially the trees) and water features in air temperature regulation and wind control. Beside this, a "cool island" effect, extended to the close non-vegetated environment, has been identified in the case of Phoenix landscape planning scenario (Declet-Barreto et al., 2013). The improvement of microclimate through vegetation has also had a positive psychological and social impact on the inhabitants (Segal, 2015).

Despite the fact that each project proposes a distinct approach, all the authors highlight the significant benefits of the woody vegetation on the microclimate conditions. It may be concluded that bioclimatic landscape planning projects are focused on the improvement of microclimate conditions through modelling vegetation and water features in order to minimize the negative impact of the built environment and to increase the thermal and psychological comfort.

Each project uses different analysis methods, which could be combined to develop more complex assessment tools in bioclimatic landscape architecture. Even if a there is a common aim in the field of bioclimatic landscape planning and design, the methodological approaches are still heterogeneous. Thus, the current comparative study reveals the necessity to develop further integrated analysis and design instruments in order to optimize the bioclimatic impact of green infrastructure and its associated benefits.

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