USING MICROCLIMATIC LANDSCAPE DESIGN TO CREATE THERMAL COMFORT AND ENERGY EFFICIENCY

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***Abstract**: Microclimatic design requires knowledge of the climate conditions, understanding of the ways that landscape elements affect microclimate and methods of applying this knowledge through landscape design to create microclimates that are comfortable for people and minimize the energy use of buildings. In this article it will be introduced the most important components and characteristics of microclimatic landscape design. Green roof ecosystem services in urban areas will be also introduced and future research needs will be mentioned.*

1. Introduction

Some microclimatologists have studied the use of vegetation as a form of microclimatic control in urban spaces (Wilmers, 1990; Alvarez et al., 1991, Picot, 2004). Vegetation can be planted in four different green structures: covering vegetation, isolated trees, groves and lines of trees. Microclimate is the condition of the solar and terrestrial radiation, wind, air temperature, humidity and precipitation in a small outdoor space (Brown and Gillespie, 1995). Urban green structures can cool hot air by evapotranspiration; shade the ground and walls, reduce the radiant temperature and control of wind velocity and direction; regenerate air; absorb the dust that falls as temperatures decrease in the evening; and filter dust and noise (Bernatzky, 1978).

There is strong public interest in the quality of open urban spaces that they can contribute to the quality of life within cities. However, there is a significant lack of information on comfort conditions in outdoor spaces, which in effect will assist the design and planning of such spaces (Nikolopoulou and Lykoudis, 2006). In this context, microclimatic conditions have begun being viewed as integral to the success of an open space. Responses to microclimate are unconscious, but they often result in a different use of open space in different climatic conditions.

Theoretical thermoregulatory models developed for the indoor environment are not viewed as adequate for describing the thermal comfort conditions outdoors, due to the great complexity of the outdoor environment, and variability temporally and spatially (Nikolopoulou and Lykoudis, 2006). In this article it will be introduced the most important components and characteristics of microclimatic landscape design and green roofs while future research needs will be mentioned.

2. Urban design and outdoor spaces

There is adequate understanding of the influence of climate on cities. For example Nikolopoulou et al. (2001) acknowledged the way self-shading streets protect the buildings and the surrounding spaces from the hot sun, in hot arid climates; or dispersed buildings to allow for easy flow of wind through the spaces in hot humid climates (Figure 1); as well as problems created by importing architectural design without adapting it for the local climate.

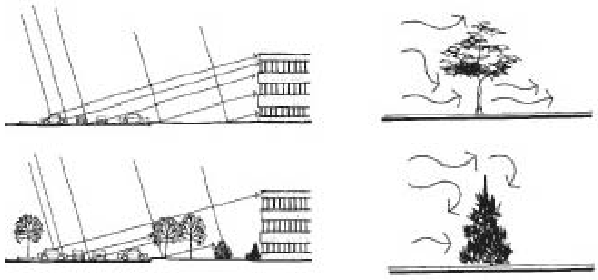

Figure 1 –Solar radiation and wind can be significantly affected by design (US Army, 1988).

Microclimatic design requires a conceptual understanding on how microclimatic components such as wind and solar radiation, can be significantly affected from landscape elements (Brown and Gillespie, 1995). Plants

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have a strong effect on microclimate. Trees and green spaces can help to cool our cities and save energy. Trees can provide solar protection to individual houses during summer and evapotranspiration from trees can reduce urban temperatures. Trees also help mitigate the greenhouse effect, filter pollutants, mask noise, prevent soil erosion, and calm their human observers. Shading from trees is an effective way to significantly reduce energy for cooling purposes.

According to Brown and Gillespie (1995) and Torre (1999) microclimatic design involves a precise analysis of all the elements present on the studied site like:

• Location: Geographic position, topography, position related to water masses, urban form.

• Shape: Orientation, volume, dimension, proportion.

• Limits: Vertical and horizontal limits.

• Material characteristics.

• Vegetation: Species, age, soil, oxygen, water and mineral resources available, foliage form, colour, type (evergreen or seasonal).

• Field measures of a typical day of the period studied (air and radiant temperature, wind speed and direction, solar radiation and relative humidity).

• Growth hypothesis based on site parameters.

Akbari et al. (1997) found that by adding three trees per house in one storey buildings in US cities can reduce the cooling load between 17% and 57%. The direct effects of shading account for 10–35% of the total cooling energy savings and the remaining savings result from temperatures lowered by evapotranspiration. Conventional comfort theory relies on a steady state model where the production of heat is equal to the heat losses to the environment, aiming to keep a constant core body temperature of 37^{o}C. In the 1980s a team of researchers at Berkeley (Bosselmann et al., 1984) worked on thermal comfort outdoors, particularly on implications of design solutions for city microclimate, which led to the San Francisco legislation for solar access and wind protection.

3. The urban heat island

The urban heat island has negative impact on people. People in cities often feel too hot in the summer due to the higher than average temperatures. This is intensified when the air temperature is higher than 17^{o}C, the relative humidity is greater than 85%, the air pressure is more than 18.8 hPa and the windspeed is close to zero. This oppressiveness causes worse thermoregulation in our bodies as it slows down evaporation of sweat.

To reduce the negative impact of the urban climate on people, we need to increase the amounts of green spaces in cities. Green space has significant ecosystem services, which are defined as “the benefits human population derives, directly or indirectly, from ecosystem functions” (Costanza, 1997). Green areas "filter" the air and air pollution can be lower in a park by as much as 20 to 40% in comparison with the rest of the city (Jo, 2002). They can produce oxygen, purify air and water, regulate microclimate, reduce noise, protect soil and water, maintain biodiversity, increase air humidity, reduce thermal stress, enhance local air circulation, and have recreational, cultural and social values and improve our quality of life. (Loures et al., 2007).

In summer, green areas decrease air temperature by shading the ground (less solar energy reaches the ground, so less is absorbed by the surface and radiated back to the air as heat). According to Panagopoulos (2007) studying different colour soils in mine areas, surface soil temperature under shadow was on average 19.5^{o}C lower than bare soil temperature of the same area, same time and type of spoil. Also studying the effect of olive trees shadow on soil temperature it was found that during summer period soil can be 11^{o}C cooler under olive shadow and during winter 4^{o}C warmer (Figure 2). As a result of shading, soil surface temperatures in a park may be 12^{o}C lower than the temperature of a street surface and according to Akbari (2002) urban tree planting can account for a 25% reduction in net cooling and heating energy usage in urban landscapes. Urban shade trees offer significant benefits in reducing building air-conditioning demand and improving urban air quality with associated savings up to $200 per tree. He estimates that a tree planted in Los Angeles avoids the combustion of 18 kg of carbon annually and it sequesters 11 kg.

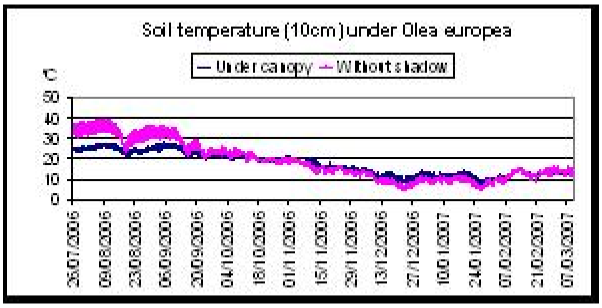

Figure 2 - the effect of olive trees shadow on soil temperature during summer and winter.

4. Green roofs

Adopting strategies of reroofing and repaving in lighter colours and planting shade trees can effect substantial energy savings directly and indirectly (Rosenfeld et al., 2001). Green roofs (roofs with a vegetated surface and substrate) provide ecosystem services in urban areas, including improved storm-water management, better regulation of building temperatures, reduced urban heat-island effects, and increased urban wildlife habitat. Green roofs are becoming increasingly popular in hot countries to combat the urban heat island effect and in cold countries to filter and store some of storm water on site, thus, to not overload the sewer-wastewater system (Figure 3).

Roof gardens, the precursors of contemporary green roofs, have ancient roots. The earliest documented roof gardens were the hanging gardens of Mesopotamia, considered one of the seven wonders of the ancient world (Oberndorfer et al., 2007). Green-roof habitats contribute to local biodiversity conservation and provide aesthetic and psychological benefits for people in urban areas. Even when green roofs are only accessible as visual relief, they contribute to stress relief (Hartig et al., 1991). Other services of green roofs include urban agriculture (food production can provide economic and educational benefits) and sound pollution reduction (Dunnett and Kingsbury 2004).

Figure 3 – The City Hall rooftop garden sits atop Chicago's City Hall.

5. Conclusions

Improved microclimatic conditions have major implications for the development of cities. The energy use of the surrounding buildings is affected. By controlling sources of discomfort, sedentary activities, as well as the use of public transport cycling and walking, will be promoted. Successful areas will attract people, which in turn will attract businesses, workers, residents, and the area becomes economically profitable. The strong relationship between microclimatic and comfort conditions demonstrate that careful design can allow for the use of open spaces, balancing exposure and protection to the different climatic elements (Nikolopoulou et al., 2001).

Cost-benefit models are necessary for evaluating whether green areas and green roofs are in fact the most effective technology for mitigating common urban environmental problems. Further research is needed to identify suitable plant species for living roofs in different climatic regions. The role of biodiversity and native versus exotic diversity in living-roof performance has been little investigated. The potential benefits of roof greening for air quality have not studied yet.

The design of open spaces is very important for the urban environment and an understanding of the effects influencing thermal comfort in these spaces will assist in designing spaces that encourage public use all times of the year. However, this can only be feasible if great care is taken to include microclimatic concerns at the design phase. This would assist the design of cities and eventually the use of open spaces, by allowing for different activities to be carried out and social interaction to take place, giving life back to the cities. Ultimately, such systematic knowledge can contribute to the sustainable development of cities of the future.

6. References

Akbari, H., 2002. Shade trees reduce building energy use and CO_2 emissions from power plants. Environmental Pollution, Vol. 116, pp.119–126.

Akbari, H., Kurn, D.M., Bretz, S.E., Hanford, J.W., 1997. Peak power and cooling energy savings of shade trees. Energy and Buildings, Vol. 25, pp. 139-148.

Alvarez, J., Lopez, S. Yannas, E. and De Oliveira F., 1991. Architecture and Urban Space, Dordrecht, Kluwer Academic Publishers.

Bernatzsky, A. 1978. Atmospheric Ecology and Preservation, Amsterdam Elsevier.

Bosselmann, P., Flores, J., Gray, W., Priestley, T., Anderson, R., Arens, E., Dowty, P., So, S. and Kim, J.J., 1984. Sun, wind and comfort: a study of open spaces and sidewalks in four downtown areas. Institute of Urban and Regional Development, University of California, Berkeley.

Brown, R.D. and Gillespie, T.J. 1995. Microclimatic Landscape Design—Creating Thermal Comfort and Energy Efficiency, Wiley, New York.

Costanza, R., d’Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Laskin, R., Sutton, P., van den Belt, M. 1997. The value of the world’s ecosystem services and natural capital. Nature, Vol.387, pp. 253–260.

Dunnett, N.P., Kingsbury, N., 2004. Planting Green Roofs and Living Walls. Portland, Timber Press.

Hartig, T., Mang, M., Evans, G.W., 1991. Restorative effects of natural environment experience. Environment and Behavior, Vol. 23, pp.3–26.

Jo, H.K. 2002. Impacts of urban greenspace on offsetting carbon emissions for middle Korea. Journal of Environmental Management, Vol.64, pp. 115–126.

Loures, L., Santos, R., Panagopoulos, T., 2007. Urban parks and sustainable development – the case study of Portimao City, Portugal. Proceedings of the 3rd Int. Conf. on Energy, Environment, Ecosystems & Sustainable Development, Agios Nikolaos, Greece, pp: 127-131.

Nikolopoulou, M. and Lykoudis S. 2006. Thermal comfort in outdoor urban spaces: Analysis across different European countries. Building and Environment, Vol. 41 pp. 1455-1470.

Nikolopoulou, M., Baker N. and Steemers, K. 2001. Thermal comfort in outdoor urban spaces: understanding the human parameter. Solar Energy, Vol. 70, pp. 227–235.

Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R.R Doshi, H., Dunnett, N. Gaffin, S., Köhler, M., Liu, K.K.Y and Rowe B., 2007. Green roofs as urban ecosystems: ecological structures, functions, and services. BioScience, Vol. 57, pp.823-833.

Panagopoulos, T., 2007. Assessment of reclamation potentiality in the lignite mines of northern Greece. In Barnhisel, R.I. (Ed.) Thirty Years of Surface Mine Control and Reclamation Act and Beyond. American Society of Mining and Reclamation, Lexington, KY, pp. 602-610.

Picot, X. 2004. Thermal comfort in urban spaces: impact of vegetation growth. Case study: Piazza della Scienza, Milan, Italy. Energy and Buildings, Vol. 36, pp. 329–334.

Rosenfeld, A.H., Akbari, H., Romm, J.J., Pomerantz, M., 2001. Cool communities: strategies for heat island mitigation and smog reduction. Energy and Buildings, Vol. 28, pp. 51-62.

Torre, J.M.O, 1999. La vegetacion como instrumento para el control microclimatico, Tesis Doctoral, U.P.C., Barcelona.

US Army and Air Force, 1988. Landscape Design and Planting, TM5-803-13/AFM1268.

Wilmers, F. 1990. Effect of vegetation on urban climate & buildings, Energy and Buildings, Vol. 22, pp. 15–16.