"POWER" PLANTS

The importance of trees in a challenging urban environment

ABSTRACT

Our cities are a challenging environment for plants due to urban specific environmental stresses like urban heat island effects altering the radiative regime. Ecosystem service provision by urban trees qualifies the uptake of urban greening as an engineering solution to climate change. Further interdisciplinary research and wider community engagement is needed to utilize the full potential of vegetative cooling benefits.

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"Power" plants: The importance of trees in a challenging urban environment

'*Sol omnibus lucet*' – The sun shines on everyone. Proclaimed in the context of social inequality in the Satyricon, this quote by Petronius sums up one of the challenges and opportunities that urban populations are facing today. The change of surface energy balance in our cities creates a warmer environment and subsequently a range of knock on effects.

Presumably, Petronius quote was formulated with only the visible light spectrum in mind. Would he have been familiar with the dynamic theory of the electromagnetic field (Maxwell, 1865) introduced by James Clarke Maxwell 150 years ago, his statement would surely have been rephrased to '*the whole electromagnetic spectrum shines on everyone*' since the majority of the energy received on terrestrial surfaces stems from wavelengths outside of the visible light region.

Sunlight is essential to life as we know it, being indeed an important driver behind the environmental factors that shape our world. Weather processes, food production or more recently utilising wind, water or solar power as a source of renewable energy are unthinkable without the presence of the Sun's energy. We take daylight for granted in the eternal diurnal terrestrial cycle and socially associate light with many positives such as warmth and security as an antagonist to darkness and disorder. But specifically the association with warmth and security could be a fallacy. Today, we are facing climate change related challenges especially in regards to global warming and the projected negative impacts this brings about. An increase in extreme weather events, the rise of sea water levels or drought induced food shortages just to name a few (IPCC, 2014; Abrams and Nowacki, 2015). It is evident from these, that with the shift in the earth's energy balance due to anthropogenic activities and the resulting greenhouse effect, the never ending influx of energy from the Sun needs to be mitigated somehow.

This problem become particularly obvious and tangible in built up areas. Urban spaces are dominated by non-natural surfaces that constitute the fabric of modern city life (Compagnon, 2004). Transport links, work and living quarters constructed with concrete, metal and glass dominate the visible skin of the urban metabolism (Kennedy et al., 2011). Though essential to the functional flow of contemporary society and modern life, this has subtle yet increasingly significant consequences. Cities are considerably warmer than their rural surroundings, due to a change of surface albedo and emissivities, radiative trapping in urban street canyons and the high heat storage and release potential of construction materials (Oke, 1982; Heinl et al., 2015). Paired with a loss of natural surface due to land use change and active anthropogenic heat input this leads to a change of the environmental radiative regime. Though not named as such but first described in 19th century London by Luke Howard this ‘Urban Heat Island’ effect has pronounced consequences on the urban climate and subsequently on local and global communities (Howard, 1820).

Due to warmer cities, heat waves have more severe impacts on urban populations causing an increase in high temperature related injuries and deaths (Clarke, 1972; McMichael et al., 2008). Energy usage for air conditioning is elevated and effects on cloud formation and precipitation as well as wind patterns can be observed. With a continuous increase of urban population and subsequently the growth of built up areas, these problems are destined to exacerbate and impact the lives of more and more metropolitan dwellers around the world (Grimmond, 2007; U.N., 2014). It is evident that effective measures must be researched and implemented to ensure sustainable development and future resilience for urban futures.

Concepts for such resilient futures often focus on behavioural change and technological solutions. Whilst these approaches are without a doubt an important corner stone of sustainable development they often overlook the full contribution potential of life forms that are older than human society: plants. Vegetation can provide a natural cooling system not only through evapotranspiration or physically shading a sidewalk or building envelope but also by interacting directly with the radiation regime (Gill et al., 2007).

We share our living environment with a wide range of vegetation and the provision of ecosystem services by urban green space is an essential contribution to a healthy city. Parks for example provide stress reduction and health improvement by offering recreational space and animating us to physical activity (Shanahan et al., 2014) Green corridors and habitats are essential to maintaining biodiversity. Physical ecosystem services provided by vegetation, especially trees, include air and water purification, noise reduction and oxygen generation but most importantly in the context of urban heat islands, the potential for natural cooling. Depending on study location, research has shown that parks reduce ambient temperature by 2 ℃ to 15 ℃. Permanent Tree shading in a UK context has been found to reduce local temperature between 5 ℃ to 7 ℃ (Armson et al., 2012). Similar effects can be observed during night time (Doick et al., 2014). In economic terms, these effects have been estimated to realize savings in excess of $ 5 billion in the wider Los Angeles metropolitan area due to a decreased energy demands for air conditioning (Akbari, 2005).

The interaction of plants with photosynthetically active radiation and the underlying biophysical and biochemical processes are well studied and understood (Jones, 2013). Due to the importance for food production, particularly agricultural and horticultural research has produced large amounts of written contributions to the field. Trees have evolved to be dependent upon radiant energy as a driving force for their metabolic processes. Being sessile organism, these plants have also developed mechanisms to influence their microclimate, including strategies to cool down to prevent heat damage. Basically, any heat and mass transfer of leaves relies on non-physiological (radiation, conduction and convection) and physiological (respiration, evapotranspiration and photosynthesis) processes which are interdependent. Since radiometric surface temperature is influenced by vegetation, the height and number as well as the structure of plants will play an important role in the resulting provision of ecosystem services (Bolund and Hunhammar, 1999). As a cooling method, Evapotranspiration has proven an especially effective method for decreasing the ecosystem surface temperature by withdrawing comparatively large amounts of energy required to break hydrogen bonds for the phase transition of water into vapour (Sirmak, 2003; Maes and Steppe, 2012).

Besides evapotranspiration, trees like every terrestrial object, also dissipate heat through (re)radiation. Given the variety of species and genera that can be found in any given park or street it is no surprise that plant tissues have different biological, chemical and physical properties and will thus differ in their radiative energy exchange (Henrion and Tributsch, 2009). This energetic exchange is furthermore dependent on air temperature, incoming radiation, wind speed and relative humidity as well as plant metabolic relevant factors like soil quality and water availability. Outside of dedicated green areas trees thus face a challenging growth environment in cities (Jim, 1998). This is of special significance as urban conditions vary distinctly from rural or forest settings. Besides genetic predisposition i.e. species variability, growth conditions lead to a high variation in cooling performance (Rahman et al., 2014).

Urban soil differs substantially from productive soils and is often compacted. Furthermore, high levels of contaminants from construction rubble or polluted rainfall can be identified (Kelly et al., 1996). Water and nutrient availability can be poor thus effecting the evapotranspiration potential in an already warmer built up environment (Mullaney et al., 2015). Nighttime light pollution from street lights, traffic or ad boards also contributes to the problem since species show a difference in artificial light tolerance. All of this leads to dynamic reaction of urban trees, altering leaf structures and stomatal response which in turn influences the emissive properties of tree tissues. This in turn has an impact on heat dissipation capacity of the plant and as a result leads to decreased tree functionality. This in turn promotes or obstructs the delivery of ecosystem services.

In order to utilize the full potential of cooling benefits from urban greenspace, further cross disciplinary research is needed. Despite our long standing history with trees we do not fully understand their properties and energetic exchange beyond the photosynthetically active and near infrared radiation spectrum. A better knowledge will help improve urban radiation models for example that in turn could lead to improved tool for urban planners (Lemonsu et al., 2012). With the ever increasing need to find adaptation and mitigation strategies for our heated cities it is important to reevaluate the role of vegetation in urban design.

Technical greening solutions like green roofs or walls find increasing attention in building design and domestic energy policies. If these could be extended to a strategic implementation of the ‘*right tree in the right place*’ another stepping stone towards an environmentally resilient urban future could be achieved.

In conclusion, trees truly are power plants given their cooling potential despite the adverse growing conditions faced in the urban environment. And as long as the sun shines on all of us we mustn’t overlook the services that trees can provide in making our cities cooler and more livable spaces. The provision of multiple ecosystem services by vegetation makes a strong case for the uptake of urban greening as an engineering solution for climate conscious urban planning ideas. Utilizing vegetation in sustainable urban planning concepts is a viable option to purely technocratic solutions. We cannot afford an ever increasing environmental rift with the dire prospects of climate change looming ahead. Cities as the condensed depiction of our global civilization will feel the impacts more severely. And as such offer the ideal setting to engage the wider society in reconnecting with our natural roots. As such, environmental sciences hold the key to an even better understanding of how to maximize benefits from urban trees.

After all, "*A society grows great when men plant trees whose shade they know they shall never sit in*." - Greek proverb.

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