Sustainability of Green Infrastructure and Ecosystem Services towards quality of life

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Abstract: Integration of urban green space with the built environment that surrounds it is crucially important if benefits are to be maximized. Green space, whether connected or not, must be seen as providing facilities or services for the people who live amongst it. Its real potential will only be realized if activities or operations undertaken in or on the green space are supported by the whole local community. Benefits will be achieved most successfully if green space creation and management are integrated with more traditional land development and built infrastructure planning. An important consideration is the spatial positioning of the component parts of the green infrastructure. Some goods and services depend on a strong connectivity between location and user.

Keywords: Green Infrastructure, Ecosystem Services, Quality of life

1. INTRODUTION

One of the most pressing social challenges is the ongoing global process of urbanization, resulting in the degradation of urban ecosystem services and the loss of certain benefits to residents generated by urban nature [1,2]. Urban sprawl is undermining the "ecology in the city" [3], including natural and semi-natural areas, e.g., forests or wetlands [4,5]. For instance, urban sprawl can fragment natural habitats such as of forest cover [6], thereby negatively impacting on wildlife. The food supply is also threatened by urban sprawl when ex-urban growth destroys high quality soils [7]. To reduce such negative ecological and environmental impacts as well as social (e.g., over-reliance on cars) and economic repercussions (e.g., higher per capita infrastructural costs) of urban sprawl, policymakers and scientists are calling for the promotion of a more sustainable urban form, namely compact cities [4,5,8]. Although policies favoring the compact city include multi-dimensional objectives to secure sustainable development, the main aim of compact cities is to protect the environment from further degradation by urban sprawl [5].

To succeed, the concept of the compact city requires an integrative approach to ecological and environmental sustainable development, one that reflects trade-offs between densification and the quantitative/qualitative supply of green spaces within urban developed areas [9]. Such an integrative view is vital since ecosystem services (and thus urban green spaces as the most important supplier of ecosystem services) are most effective when located close to areas which require them [10]. Clearly, the ecosystem benefits for the mental and physical health of residents are maximized when urban green areas are located at short distances from local housing [11,12]. However, a case study in Barcelona (Spain) showed that the

demand for ecosystem services such as cleaner air and outdoor recreation sites is largely unsatisfied in core urban areas because these services are mainly supplied by peri-urban green areas [13]. This imbalance between the supply of ecosystem functions and demand for ecosystem services is intensified when compact cities are fostered and urban green spaces are lost due to infill development and densification processes. In general, greater effort is required to establish integrative urban monitoring concepts which reflect the ecology of the city. These must take into account built and (semi-)natural structures as well city stewardship by urban actors while considering the interactions between biophysical, social as well as governance structures and processes [3,14]. Such monitoring concepts are vital to determine how a qualified urban infill development can be implemented to create compact and green cities [8]. To this end, landscape ecological approaches for green structures (e.g., connectivity, patch structure), governance processes (e.g., consideration of multiple functions of urban green spaces and its benefit for human well-being) as well as public participation (e.g., adaption of green spaces to demands of residents) are required for the integrative urban green space planning of compact and green cities. A recent review of green spaces and densification has highlighted the need to identify such successful policies, which aim at preventing green space degradation during compaction and enable development of multi-functional urban green spaces [9].

2. WHAT IS GREEN INFRASTRUCTURE?

Infrastructure can be defined as the basic structures and facilities necessary for the efficient functioning of a given geographical area. Green infrastructure refers to the combined structure, position, connectivity and types of green spaces which together enable delivery of multiple benefits as goods and services. It is important to consider green infrastructure holistically and at landscape as well as individual site scale. Integration of urban green space with the built environment that surrounds it is crucially important if benefits are to be maximized. Green space, whether connected or not, must be seen as providing facilities or services for the people who live amongst it. Its real potential will only be realized if activities or operations undertaken in or on the green space are supported by the whole local community. Benefits will be achieved most successfully if green space creation and management are integrated with more traditional land development and built infrastructure planning. An important consideration is the spatial positioning of the component parts of the green infrastructure. Some goods and services depend on a strong connectivity between location and user. Others, such as wildlife habitat, may depend on the interconnectedness of the component parts of the green space ‘jigsaw’.

3. CLIMATE CHANGE

The importance of green infrastructure in urban policy matters has risen up the agenda in recent years as a response to climate change and the need to move towards a low carbon economy. Urban green infrastructure is likely to play an increasingly important role within ‘climate proofing’ of towns and cities. It also directly supports carbon capture, for example in building soil carbon reserves over time. Larger woodlands can

support some timber products, and by-products from street tree management can be usefully converted into renewable energy or mulches and composts. Executive summary Green infrastructures has an important role in supporting the adaptation of people who live in towns and cities to a changing climate. Depending on location, type and extent, it provides shade, cooling and wind interception and an insulation role in the winter. Green infrastructure can also potentially mitigate risks from climate change-induced reductions in air and water quality; and it can provide a buffer for habitats and species, whilst contributing to attainment of sustainable urban drainage and controlling upstream water flows to reduce flood risk. Effectively harnessed, green infrastructure has real potential for informing people about climate change. Green spaces can also be used to promote an appreciation of the impacts of climate change and lifestyle changes needed to reduce further effects and/or to adapt to them. Climate change will certainly affect the performance and delivery of green infrastructure in urban areas. At a technical level, choice of vegetation and species, provision of adequate contamination management, and soil and form of land management will all need to be factored into the planning of new green infrastructure. A changing climate and a need to reduce carbon footprints also provide an opportunity to reconsider green infrastructure, and the outcomes expected from it in the years to come. An informed position, based on a synthesis of the evidence for a range of important potential benefits, should allow policy makers, planners and land owners to make complex decisions about green infrastructure more effectively.

4. HEALTH AND WELL-BEING

Good quality, accessible green space and infrastructure can provide many potential health and wellbeing benefits. The most significant of these can be grouped into three broad categories: (1) increased life expectancy and reduced health inequality; (2) improvements in levels of physical activity and health; (3) promotion of psychological health and mental well-being. Associations have been found between access to green space and raised levels of physical activity, which in turn improves individuals' health. Green space can also have a beneficial impact on mental well-being and cognitive function. The evidence strongly suggests that, at their best, green spaces can help reduce health inequalities and that both the improvement of existing, and creation of new, green infrastructure should be prioritized, especially in areas of greatest need.

5. ECONOMIC GROWTH AND INVESTMENT

Placing accurate economic values on green infrastructure or its green space components is vital to support the case for sustained investment. Examples of case studies where economic valuation has taken place are outlined to demonstrate the net economic value of initiatives to create or improve green infrastructure. There is good evidence that green space can make positive impacts on local economic regeneration, especially for job creation, business start up, increased land values and inward investment. However, the quality and quantity of this evidence is comparatively poor and further case studies are needed to improve it.

6. LAND REGENERATION

Previously developed, derelict, underused, neglected (brownfield) land in and around urban centers can deliver social, environmental and economic benefits via conversion to green infrastructure. By delivering improved local environment and quality of place this conversion can be very cost-effective as a result of reduced environmental health risks. Nevertheless, regeneration requires both land regeneration project resources and revenue funds for long-term management and maintenance, and these can be substantial. The evidence highlights the need to improve delivery through effective sustainability evaluation for land regeneration and green infrastructure creation programs and the impacts of climate change.

7. WILDLIFE AND HABITATS

Ecological benefits of urban green infrastructure are largely related to the provision of habitat. Species from the very common to the very rare make use of all types of green infrastructure. Increased opportunities for movement are considered a key adaptation activity for many species' response to climate change, and resilient ecological networks are advocated to support this. However, while they are based on sound theory and good evidence of the effectiveness for some individual components, the overall value of ecological green networks in climate change adaptation remains to be demonstrated.

8. STRONGER COMMUNITIES: SOCIAL INCLUSION AND COMMUNITY COHESION

Green infrastructure is, in the main, a public resource, available for use by the 80 per cent of the population who live in towns and cities. Such a latent demand, set against the comparatively small resource that green space still is, requires careful planning in order to maximize its cost effectiveness and its ability to deliver the most desirable goods and services in a sustainable way. It is thus vital that proposed, and existing, green infrastructure is considered in the context of the communities that it will serve. There is now considerable evidence that the most successful elements of this infrastructure are those where effort has been made to consult and, more importantly, to engage with these communities. Committed individuals, societies and business enterprises can make all the difference to its success, and can attract additional funding to maintain or improve the facilities, whilst acting as superintendents or care managers too. Understanding the range of benefits that green space can offer can help identify the parts of the community which might particularly support its management, and exploit its potential. Green space has potential for enhancing social cohesion; it can bring people together, and can create community cohesion as different social groups engage with each other.

9. IMPORTANCE OF GREEN INFRASTRUCTURE

Heat amelioration

Towns and cities are usually a degree or two warmer than surrounding rural areas, as a result of the urban heat island (UHI) effect mentioned in the introduction. The UHI is caused by two main factors: the

absorption of direct solar radiation by buildings and other man-made surfaces, and the lack of vegetation in urban areas (Heidt and Neif, 2008). Green infrastructure in urban areas has an important role to play in ameliorating the warming effects of climate change and the UHI. Provision of green infrastructure can reduce higher urban temperatures through evapotranspiration, direct shading and conversion of solar radiation to latent heat (Dimoudi and Nikolopoulou, 2003). The research outlined below shows how green infrastructure can facilitate heat amelioration:

Reducing flood risk

Alterations to the natural environment can affect the movement of water through the hydrological cycle and alter its composition. Urban development retains very little of the original vegetation and landscape, replacing it with buildings, roads, gardens and parks (Whitford et al., 2001), and these changes have a significant impact on the hydrology and also on freshwater ecology and the terrestrial ecosystems that river systems support. Green infrastructure provides a means through which to restore natural environmental features to the urban environment and can provide hydrological benefits in two key areas: flood alleviation and water quality. A number of serious flood events in recent years have focused attention on flood prevention and mitigation. Urban development and engineered flood defences have profoundly changed the natural shape of river beds, banks and shores of estuaries; and these alterations can exacerbate the nature and seriousness of flood and drought events by changing volume, velocity and direction of water flow (Defra, 2008).

Improving water quality

The provision of high quality water is essential for the health and survival of all forms of life. The quality of water flowing through an urban catchment can be severely impacted due to high speed runoff, pollutants and detritus collected from urban surfaces and reduced infiltration of precipitation (Pompeu and Alves, 2005; Stovin et al., 2008; Jacob and Lopez, 2009). Additionally, many urban areas have combined sewerage and stormwater collection systems from which overflows, due to high rainfall events, adversely affect water quality (Stovin et al., 2008).

Sustainable urban drainage

Sustainable urban drainage systems (SUDS) have been developed to improve urban drainage and reduce the volume of urban runoff. SUDS encourage green space in urban areas by controlling the water at the source through trees and vegetation, green roofs, infiltration trenches and filter drains, swales and basins and ponds and wetlands. Drainage is a continual problem in highly urbanized areas and with space at a premium green roofs especially can be implemented as an alternative measure to reduce rainwater runoff and prevent flooding.

Improving air quality

The role of vegetation in mitigating the effects of air pollution has been highlighted as one of the potential benefits of urban green space (Tiwary et al., 2009). Trees in urban green space can influence air quality in a number of ways; for example through direct absorption of gaseous pollutants and interception of particles onto leaf surfaces, by lowering air temperatures through transpiration which can reduce the formation of ozone, and through the direct production of oxygen during photosynthesis.

Increasing life expectancy and reducing health inequality

The Sustainable Development Commission (2010) has reported that access to green spaces is unequally distributed across socio-economic groups, with poorer social groups having, in general, lower access. It is also considered that green space could have positive influence on health conditions such as obesity, mental health, circulatory disease and asthma, which are significant factors in relation to health inequality. The commission considered that more equal access to green space could be key to reducing health inequalities between socio-economic groups, and provide a preventative and synergistic approach that has social, environmental and economic benefits.

Improving levels of physical activity and health

Strong associations have been found between access to green space and higher levels of physical activity, which can dramatically improve individuals' health. Green spaces have been shown to independently promote physical activity, thereby enhancing the health profile of the people who use those spaces.

Improving psychological health and mental well-being

People have a well-developed awareness of the stress reducing benefits of nature, and green spaces have been shown to provide a restorative environment which helps alleviate stress and mental fatigue. Studies suggest that the evidence on the restorative effects of green spaces, and contact with nature, is more compelling than the evidence on the potential benefits for physical health (Croucher et al., 2007). There is also strong evidence which suggests that green spaces have a beneficial impact on mental well-being and cognitive function through both physical access and usage (Whitelaw et al., 2008), as well as through access to views (Ulrich, 1984). Furthermore, the restorative benefits of green space generally come at no direct cost to the user whereas other forms of relaxation (such as yoga) or medical treatment usually do. Green spaces can also help improve mental well-being by encouraging social activity and interaction.

10. CONCLUSION

The perceptions of respondents revealed that the socio-economic status of the respondents influenced their perceptions regarding the benefits of green spaces. The more affluent the respondents are, the less emphasis they put on the importance of provisioning services of green spaces. Green infrastructure is an approach to

managing urban wet weather impacts that mimics, restores, or maintains natural hydrology. Green infrastructure includes a wide array of practices, including infiltrating, evapotranspiring, or harvesting and using stormwater. On a regional scale, green infrastructure is the preservation or restoration of natural landscape features, such as forests, floodplains and wetlands. On the local scale, green infrastructure consists of site and neighborhood-specific practices, such as bioretention, trees, green roofs, permeable pavements and cisterns. Regional and local practices are coupled with policies such as infill and redevelopment that reduce overall imperviousness in a watershed. Green infrastructure is an important component of sustainable urban communities. Green infrastructure helps maintain ecosystem services in the following ways:

Air quality regulation: Potential of ecosystems to capture and remove air pollutants in the lower atmosphere.

Erosion protection: Potential of ecosystems to retain soil and to prevent erosion and landslides.

Water flow regulation: Influence ecosystems have on the timing and magnitude of water runoff and aquifer recharge, particularly in terms of water storage potential.

Pollination: Potential of animal vectors (bees being the dominant taxon) to transport pollen between flower parts

Maintenance of soil structure and quality: The role ecosystems play in sustaining the soil's biological activity, physical structure, composition, diversity and productivity.

Water purification: The role of biota in biochemical and physicochemical processes involved in the removal of wastes and pollutants from the aquatic environment

Climate regulation: The influence ecosystems have on global climate by regulating greenhouse and climate active gases (notably carbon dioxide) from the atmosphere.

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