**Article:**

Alizadeh, B. and Hitchmough, J. orcid.org/0000-0001-7258-5122 (2019) A review of urban landscape adaptation to the challenge of climate change. International Journal of Climate Change Strategies and Management, 11 (2). pp. 178-194. ISSN 1756-8692

https://doi.org/10.1108/IJCCSM-10-2017-0179

**International Journal of Climate Change Strategies and Management**

A review of urban landscape adaptation to the challenge of climate change

Behdad Alizadeh, James Hitchmough,

# A review of urban landscape adaptation to the challenge of climate change

Behdad Alizadeh and James Hitchmough
*Department of Landscape, The University of Sheffield, Sheffield, UK*

Received 2 October 2017
Revised 14 January 2018
9 March 2018
12 May 2018
Accepted 25 May 2018



## Abstract

**Purpose** – Urban landscapes play a significant role in supporting municipal, ecological and social systems. Besides, valuable environmental services and urban green spaces provide social and psychological services, very important for the liveability of modern cities and the well-being of urban residents. It is clear that the area of green space in a city, the method of designing urban landscape and access to urban green space potentially affect the health, happiness, comfort, safety and security of urban dwellers. Urban landscape plays a significant role in providing habitats for wildlife, and an important vegetation type in doing this is species-rich herbaceous vegetation that provides pollen and nectar plus physical habitat for native fauna. Any factor that makes an impression on the urban landscape (such as climate change) will affect people's lives directly or indirectly. There is a universal consensus that the temperature has increased in most of the world over the past century the investigation of climate change impacts on the urban landscape is the purpose of this study.

**Findings** – Understanding the process of climate change adaptation is necessary to design plant communities for use in public landscapes. Increased $CO_2$ and air temperature in conjunction with the changing rainfall conditions, as the three important factors of climate change, potentially alter almost all world ecosystems. Climate change provides new opportunities, and in some cases, an obligate need to use non-native plant species in conjunction with native plant species, not only to reduce the side effects of climate change but also to increase the species diversity and aesthetic value in meadow-like naturalistic planting design.

**Originality/value** – The authors confirm that this work is original and has not been published elsewhere. In this paper, the authors report on the effects of climate change on urban landscape and suggest different kind of solutions to reduce the effects. The paper should be of interest to readers in the areas of landscape architecture, landscape ecologist, landscape planner, landscape managers and environmental designer.

**Keywords** Climate change, Sustainable design, Planting design, Urban landscape

**Paper type** Literature review

## 1. Introduction

Densely populated areas are changing, and more complicated landscapes in which green or open spaces are considered to be of incalculable value for the well-being of people and wildlife (Pickett *et al.*, 2011) are being developed. Urban landscapes play a crucial role in supporting municipal "ecological and social" systems (Barbosa *et al.*, 2007). In urban areas, city parks, private gardens and street green space supply essential ecosystem services (Gill *et al.*, 2007). The availability of green spaces impacts the qualities of the environment, such as air and water purification, wind and noise filtering or microclimate stabilization.



International Journal of Climate Change Strategies and Management
Vol. 11 No. 2, 2019
pp. 178-194
Emerald Publishing Limited
1756-8692
DOI 10.1108/IJCCSM-10-2017-0179

Parks and gardens play a key role in supporting biodiversity and other important ecosystem services (Barbosa *et al.*, 2007). These urban landscapes enhance the migration of fauna to large cities, leading to maintaining or improving urban biodiversity (Angold *et al.*, 2006). As a result, they can bridge the gap between natural environment, biodiversity and the residents of urban areas (Jorgensen *et al.*, 2002). Beside important environmental benefits, the existence of natural ecosystems, such as urban parks and forests, green belts and their components (i.e. trees and water), improve the standards of life in many ways and provide social and psychological services, which are very important for the liveability of modern cities and the well-being of urban residents (Chiesura, 2004). At the neighborhood level, green spaces help provide restoration from stress, improving mental health (Hartig *et al.*, 1991) for adults; they also pave the way for children's physical and mental development. Green space also potentially enhances feelings of social protection and safety (Groenewegen *et al.*, 2006; Maas *et al.*, 2009; Troy and Grove, 2008), increases social communication and the attractiveness of the city and promotes it as a landmark for tourists, increasing property values and tax revenues (Jim and Chen, 2009). People who are living in a greener environment report lower levels of fear, fewer bad manners, less hostile and violent behavior and feelings of insecurity associated with vandalism and less fear of crime in abandoned places (Chiesura, 2004).

It is clear that the area of green space in a city, the method of designing urban landscape and access to urban green space potentially affect the health, happiness, comfort, safety and security of urban residents. As a result, any factor that makes an impression on the urban landscape (such as climate change) will affect people's lifestyles directly or indirectly. Today, it is widely accepted that our climate is warming. Climate change is one of the most significant environmental issues of our time. Most of the environmental challenges in our world, such as water shortages, flooding, rising sea levels, changes in biodiversity, decreasing air quality, increased size and number of forest fires and changes to the extent and location of landscape-scale vegetation, are significantly associated with climatic changes (Bigler *et al.*, 2006).

## 2. The changing nature of climate

There is a universal consensus that the temperature has increased in most of the world over the past century (Alizadeh, 2016). Since the beginning of the twenty-first century, there has been a rise in the world's temperature by an estimated 0.6°C, with an increase of 0.4°C, recognized since the 1970s (Hulme, 2002). Importantly, the Intergovernmental Panel on Climate Change's (IPCC) 2007 Assessment Report suggests that, during the period 1970-2004, there has been a 70 per cent increase in greenhouse gas emissions (IPCC, 2007). Climate change will have a significant effect on physical and biological phenomena and processes on spatial and temporal scales. Negative impacts will be felt regarding biodiversity changes, air quality, the distribution and resilience of wild-occurring vegetation, water, flooding, sea levels and the proliferation and scale of forest fires (Bigler *et al.*, 2006).

Climate change is already having a marked effect on Western Europe's climate (Bakkenes *et al.*, 2002), as well as that of Britain specifically (Broadmeadow *et al.*, 2005; Wilby and Perry, 2006). By 2050, models suggest that London will have experienced a near Mediterranean climate, similar to that currently experienced by Bordeaux in south-west France (Broadmeadow *et al.*, 2005; Hitchmough, 2011). In addition to background climate changes, the urban heat island effect is expected to be intensified as a direct result of ever-increasing temperatures, especially during the summer, resulting in threats to human health and well-being in the environment, particularly in southern England (Hulme, 2002).

## 3. Climate change and natural ecosystem

The effects of droughts will initially be mostly evident on mown grass growth because of the shallow root depth of this vegetation. When the water supply is without restriction, almost 99 per cent of all the water taken from the plants' roots is lost as a direct result of transpiration through air (Raven *et al.*, 2005). Furthermore, the potential for grass fires to occur, as witnessed in the July 2006 heat wave experienced in Greater Manchester, is far more likely (Greater Manchester Fire and Rescue Service, 2006; Gill, 2006). Accordingly, it is essential for the spatial occurrence of drought conditions to be well examined and considered in direct relation to grass within climate change and baseline settings.

When seeking greater understanding of global change responses concerning natural ecosystems (Zavaleta *et al.*, 2003), there is a wealth of data derived through laboratory experiments on plants' reactions to $CO_2$, moisture and temperature (Larcher, 2003). The temperature changes, and the response to such, all depend on the characteristics of the plant species and thus may be negative or positive, depending on the overall health of the environment. Importantly, the effects of some factors could be counterbalanced by others: as an example, biomass production will increase through higher $CO_2$, while biomass production will be lessened as a result of lower precipitation (Gifford *et al.*, 1984; Cannell, 1985). Should there be no change in precipitation or temperature, the root to shoot ratio could increase through an increase in $CO_2$ as the plant adapts and responds to decreasing carbon (C) limitation in line with the deficiency of nutrients (Troughton, 1977). Should there be an increase in precipitation along with $CO_2$, there could be water stress reductions ultimately counterbalanced by the decreased C limitation, where the net effect on the root to shoot ratio would not be simple to estimate. Plant response effects following climate change cannot be established through the assessment of photosynthesis only, and the impact of climate change on ecosystems will not be found just as a result of plant responses. The decomposition response, as a result of moisture- and temperature-related modifications, probably will be as notable as those experienced during photosynthesis. However, decomposition should not have a direct impact stemming from $CO_2$ (Bachelet and Gay, 1993).

When considering the long-term effects associated with global climate changes on the operation of the ecosystem, one of the critical approaches is to model a micro ecosystem that is subject to factorial manipulations and that can produce a quick response (Shaw *et al.*, 2002). The annual grasslands containing a diversity of small, short-lived plants are regarded as an appealing model system for global change experiments (Shaw *et al.*, 2002). When aiming at establishing a viable global change manipulation of an entire ecosystem, complete with animal, microbial, plant and soil processes, an area of approximately 1 $m^2$ is adequate (Shaw *et al.*, 2002). Importantly, the yearly lifecycle of the dominant plant enables brief experiments to be carried out across some whole generations (Reich *et al.*, 2001).

The majority of experimental studies under natural field conditions, specifically those geared toward the responses of the ecosystem to global change, have addressed only single global changes. Few studies have examined two or more interacting treatments and system responses. Using the experimental manipulations, such as changes in $CO_2$concentration, precipitation and temperature in relation to ecosystem studies, is not accepted by all the researchers (Grime, 1973; Mittelbach *et al.*, 2001) despite the fact that the elevated $CO_2$ is regarded as being a key driving force behind the phenomenon of climate change (Vitousek *et al.*, 1997). Some modeling investigations have been centered on addressing ecosystem responses to global multifactorial changes (Tilman, 1988; Goldberg and Miller, 1990). However, the theoretical foundation underpinning the estimation of ecosystem responses to multiple factors is incomplete. Accordingly, in an effort to establish and identify the impacts concerning climate change on the ecosystem, a number of different experimental manipulation projects need to be carried out in the context of terrestrial ecosystems, on a global scale, ensuring the inclusion of increased temperature, elevated $CO_2$levels and changes in precipitation volumes and trends (Wright, 1998; Knapp *et al.*, 2002; Beier *et al.*, 2004).

It is challenging to bring together experimental manipulations that involve $CO_2$ increases alongside changes in precipitation and temperature in ways that do not confound the results (Beier *et al.*, 2004, 1998). Thus far, no experimental research has been undertaken on the effects of climate change in the specific area of designed plant communities in urban settings.

## 4. Climate change effects on urban landscape

Research publications concerned with the impact of climate change on urban greenspace are relatively few (Wilby and Perry, 2006; Gill, 2006). Nonetheless, some of the effects of climate change on urban greenspace have been considered (Gill, 2006).

In spite of all maintenance and management in urban landscape, including urban parks and gardens, the climate remains the most important factor, which controls the range of species and their "behavior," "physiology" and "phenology" in the urban landscape (Bisgrove and Hadley, 2002).

Extremes of soil and water, storms and temperatures will have significant effects on fungal diseases and insect pests and hence the growth of trees (Broadmeadow, 2002). Moreover, climate change can increase the utilization of urban greenspace by citizens seeking to take advantage of the cooler microclimate in urban greenspace during times of high temperatures. These increases in use will place additional pressures on the growth of vegetation and particularly in historically essential elements such as mown turf in such areas (The London Climate Change Partnership, 2018).

The more extended frost-free winter periods and other changes in temperature are beginning to affect the growing season in most of the world and UK as well (Bisgrove and Hadley, 2002), with every degree of annual warming meaning the growing season is extended by as many as three weeks in the south and 1.5 weeks in more northern regions (Alizadeh, 2016).

Accordingly, the expectation is that, by the 2050s, threshold spring temperatures could be witnessed 1-3 weeks earlier than at present, with a corresponding delay of winter temperatures by 1-3 weeks (Hulme, 2002). A growing season that is longer would have an effect on the phenology of plants, as highlighted by various scholars (Sparks *et al.*, 2002). This, in turn, would encourage a number of subsequent phenomena including earlier flowering, leaf appearance and plant maturity in addition to delayed leaf fall, prolonged flowering into winter time, "unseasonal" spring bulb flowering and continuous growth of lawns, thereby increasing maintenance costs for grass cutting (Bisgrove and Hadley, 2002). Of course, these differences have already occurred across the UK, with south-west England and Wales experiencing almost frost-free wet winters in stark contrast to winter conditions in central and northern England. In this sense, we are already familiar with the nature of future climate change. The gradients will, however, be stretched further. These differentials will be maximal within urban areas where plant phenology is already hugely affected by the urban heat island (White *et al.*, 2002; Roetzer *et al.*, 2000). Moreover, higher $CO_2$levels in combination with higher temperatures enhance the speed of plant species growth, development and their growth rate. As a result, the herbaceous plant will die or go into the dormant situation before they use the full growing season (Bisgrove and Hadley, 2002).

These changing climatic gradients will affect the types of plant that can be grown, with those plants better able at adapting being most favored. In south-east England, beech trees are at a decline because of more regular summer moisture stress (Bisgrove and Hadley, 2002), with the London region, in contrast, more able to adapt to climate change owing to its green space being dominated by hybrid and oriental plants that naturally grow in hotter climates, such as the Mediterranean (White, 1994). In addition, it is well known that dry and hot climates facilitate the growth of sweet chestnuts and further support a larger number of species (The London Climate Change Partnership, 2018). While most of the climate change discourse is on the negatives of climate change, within urban areas, species that grow less well will be counterbalanced by species that grow better in a climate change world; there will be opportunities as well as threats. Throughout the twentieth century, there have been a large number of new trees introduced (Grimshaw and Bayton, 2009) in response to the changing climatic conditions.

Trees experiencing drought-related stress are identified as being particularly susceptible to various pathogens. The capacity to withstand summer droughts could also be weakened as a direct result of winter rainfall, causing anoxia in the root and thus impacting the rooting depth (Broadmeadow, 2002). In turn, this further increases trees' vulnerability to wind throw (Bisgrove and Hadley, 2002; Broadmeadow, 2002).

## 5. Climate change, invertebrates and pests in urban landscape

Green spaces are one of the most important wildlife habitats in the metropolitan area. The urban green space plays a significant role in providing habitats for wildlife, and a significant vegetation type in doing this is species-rich herbaceous vegetation, which provides pollen and nectar plus physical habitat for native fauna (Dunnett and Hitchmough, 2004). These habitats also support large populations of invertebrates and herbivores such as slugs, snails and insects; they have a reciprocal impact on the vegetation itself (Hitchmough and Wagner, 2011). Green space is part of urban ecosystems, and biodiversity has a critical role in a dynamic ecosystem. It is a fact that climate change can affect all parts of an ecosystem. At present, ecosystem services are being affected and influenced by climate change regarding primary production (Melillo *et al.*, 1993) and water flux and quality (Vörösmarty and Sahagian, 2000). The ecosystem services are recognized as the supply of advantages from ecosystems to society, being fundamental in supporting human life (Chan *et al.*, 2006). Research investigating relationships between climate-change-related responses by invertebrates to ecosystem services-related consequences are somewhat limited, but the majority of ecosystem services are, however, affected by invertebrates in some ways (Prather *et al.*, 2013).

Much of the discourse on urban greenspace has focused on the balance between pests, their hosts and their enemies and how this balance is likely to be affected by climate change, making it difficult to be conclusive on possible patterns of damage (Broadmeadow, 2002). Insect distributions and their life cycles are significantly weather-dependent (Burt, 2002), with population sizes increasing with temperature increases (Broadmeadow, 2002). The range of some native insects will progress northward in direct response to warmer temperatures and longer growing seasons (Bisgrove and Hadley, 2002; Parmesan *et al.*, 1999). Some species will expand their range, others will show contraction. Insect pests currently common in continental Europe are highly likely to develop their territories in the UK (Bisgrove and Hadley, 2002). However, there will also be a possible increase in the diversity of flying insects, for example, in butterfly diversity and abundance (Gill, 2006).

The studies that do exist focus on insect-mediated changes to ecosystem services in response to climate change (Volney and Fleming, 2000; Ladanyi and Horvath, 2010; Rojas *et al.*, 2010; Moraal and op Akkerhuis, 2011; Rafferty and Ives, 2011). These tend to be centered on only the direct services (and disservices) provided by invertebrates, with no mention of the indirect effects through food web interactions (Traill *et al.*, 2010). The climate change effects on these organisms at the ecosystem level need to be assessed because they are recognized as being highly sensitive to climate change (Prather *et al.*, 2013).

Herbivory is essential because when combined with competition between plant species, it acts to exaggerate rivalry. Slow growing, shade-intolerant species that are palatable are likely to be eliminated much more quickly from vegetation than species of similar competitiveness but unpalatable. Mollusc herbivory is an important element for limiting plant species distribution as has been shown, for instance, by *Arnica montana*. In the UK, molluscs have significant effects on their environment within these ecosystems (Alizadeh, 2016).

It is possible to make some general conclusions on the effects of climate change on slug herbivory based on past studies (Briner and Frank, 1998; Fenner *et al.*, 1999; Frank, 2003; Hulme, 1994; Keller *et al.*, 1999; Scheidel and Bruelheide, 1999; Hitchmough and Wagner, 2011). As soft-bodied animals, slugs are highly sensitive to desiccation and are most active regarding feeding under moist conditions. Nystrand and Granström (1997) found that damage from slugs was directly correlated to the duration for which the soil surface stayed wet. Climate change scenarios that involved longer drier summers suggest that slug grazing declines during these times of the year, whereas it is likely to be extended in warmer wetter winters. What is ultimately unknown is what the net effect of these changes will be for both naturally occurring and designed urban plant communities.

There is much evidence that in moist temperate climates slugs and snails affect the development and composition of herbaceous vegetation significantly (Bruelheide and Scheidel 1999; Hitchmough and Wagner, 2011; Wilby and Brown, 2001; Holland *et al.*, 2007; Alizadeh, 2016).

Alizadeh (2016) indicated that mollusc herbivory interacts with climate change affected the stability of both individual species and the plant community. He confirms the results of pervious researchers such as Melillo *et al.* (1993) and Vörösmarty and Sahagian(2000). Slugs, in particular, are very sensitive to reductions in rainfall because they are entirely soft-bodied, and the need to avoid desiccation restricts feeding to times when humidity is high and temperatures low. Plant species in different stages of their life have different shapes and structures. The chemical compounds within plant species also differ from one stage of their life to another (Alizadeh, 2016). Shape, structure and chemical compounds are very important for mollusc palatability. They are affected by climate change as well. They showed that increasing the temperature reduced mollusc activity. On the other hand, increasing precipitation enhanced the slugs' activity. All environmental factors have important effects on mollusc behavior, but the interaction of them is more critical (Alizadeh, 2016). Increasing temperature and decreasing the humidity are two reasons for growing small and tiny hair (regarding size and number) on the leaves of plant species. This is one of the plant species' reactions to drought situations, which can usually, but not always, make the species unpalatable to molluscs. Because snails have a shell through which they can better manage water loss, they can feed under drier conditions than slugs can. This knowledge of mollusc behavior allows us to keep our valuable species within a plant community by adding some species, which are more palatable to molluscs. Mollusc grazing affected the flowering development and flowering period of the species by reducing the competition between species in the plant community. They cut some species, allowing the other species to receive more space to grow and develop along with more light and nutrition (Alizadeh, 2016).

### 6. Climate change and creative opportunities associated with planting design

Urban planners, urban designers, architects, landscape architecture and professionals are interested in sustainability by climate change challenges. However, climate change also helps to free up conventional thinking by making people come to terms with the idea that the future will not be the same as the past.

The climate change literature suggests that, in the years to come, a number of the species incorporated into public planting programs will no longer be sustainable. In the specific context of North America, for example, there has been a wide implementation of naturalistic design with the use of predominantly native species, whereas, in the context of Europe, both non-native and native species have been used, depending on various cultural and ecological factors (Hitchmough and Dunnett, 2004a, 2004b). Importantly, some species utilized in the planting design initiatives of the UK, at present, are not well aligned to their current locations from a climatic point of view. To ensure that sustainable urban landscapes can be achieved, it is likely to be essential to incorporate a broader range of native and non-native species that are increasingly well fitted to the changing climate. In Europe, there is a diversity of views surrounding the incorporation of exotic plant species in urban-designed landscapes, although the debate is less skewed to a natives-only policy than is the case in the USA (Hitchmough, 2011). These arguments are based on concerns about potential invasiveness and the advantages of using native rather than non-native species, to support animal biodiversity to the highest possible degree. Nativeness is a concept first outlined by John Henslow in 1783. Henslow was a botanist who had considered the idea in line with the terms "native" and "alien," as applied in the common law in the late 1840s, to define plants that were British rather than artefacts from elsewhere. His interests were mainly practical rather than philosophical. In the 100 years that followed, some different professionals, including zoologists and botanists, have detailed and examined the various species introduced with and without awareness. British ecologist Charles Elton wrote the *Ecology of Invasions by Animals and Plants* in 1958 at a time when there was a general lack of agreement about the overall appropriateness of intervention upon the introduction of alien species. It was sometime later – notably in the 1990s – that the concept of invasion biology became recognized as its distinctive discipline and non-native species began to be seen as doing harm. In more recent years, there have been signs of more thoughtful standpoints on non-native species starting to emerge in the ecological research literature, although not in the USA, as the evidence begins to accrue for non-native species also playing valuable roles regarding delivering ecosystem services. In many countries, exotic species and their introduction have notably increased the number of species in a region, both those that are now established parts of the biota and the much more extensive range or species which are transient and are on the brink of extinction. This is not to say that there are not some evil aliens, but preferably that the balance sheet is more complicated than initially thought.

In this vein, it is clear that utilizing a combination of both non-native and native species in urban public environments enables a more significant impact regarding color (Hitchmough and Woudstra, 1999). The native species tend to be accepted as the most suitable plants for use when aiming at achieving the most sustainable planting, as they are often highly pre-adapted to local climates with the assumption that they have been sourced from comparable biomass as in urban settings. They are particularly useful because of their high capacity in many cases for self-reproduction, without this being regarded (as it is with non-native species) as a biological invasion. Nonetheless, exotic plants have also been recognized as part of many civilizations and designed landscapes for long period of time, particularly in Europe and Asia, meaning it is essential to consider the views of people regarding what they perceive to be suitable (Kendle and Rose, 2000). Accordingly, there are some valuable opportunities centered on improving the aesthetic character of urban landscapes through ensuring the careful selection of non-native plant communities. It is typical for plant fitness, in an urban setting, to be significantly influenced by the habitat in which the species have evolved, where the species will be seen to be a better fit when the habitat is well aligned with the environmental conditions apparent at the location of cultivation. Such plants will be the most sustainable (Hitchmough, 2011). With this in mind, the view might be taken that local native species typically will be more fitted to many planting sites than species from further afield (Schmitz and Simberloff, 1997; Gilbert and Anderson, 1998; Parker *et al.*, 1999). Although the view seems to be relatively accurate when taking into account climatic factors (Davis, 1989; Hitchmough, 2011), some species prove to be well fitted even when those environments are comparatively different to their present habitats. Sometimes, this is because of their past biogeographical distribution and history. In other cases, species that are well fitted are those that occur in habitats for a long time, which because of local factors such as altitude and soil moisture, etc., closely resemble the conditions at the planting site. Importantly, although fitness is acknowledged to be an important factor, it remains that there has been little attention directed toward herbaceous species.

## 7. Naturalistic design of a plant community: a solution to climate change effects in urban landscape

All planting styles have some different sustainability-related outcomes about dynamism and diversity. Naturalistic and ecologically inspired designs are typically viewed as being more sustainable than traditional styles (Dunnett and Hitchmough, 1996). Throughout the past 20 years, there has been much attention directed toward the design of structurally diverse and species-rich naturalistic vegetation for utilization in urban areas (Kingsbury, 2004). This attention has centered on semi-natural stereotypes, including North American prairie and Eurasian meadow, as a substitution for species-poor monocultural plantings (Kingsbury, 2004).

In the mid-1990s, Dunnett and Hitchmough (1996) focused their research on selecting native and non-native species to cultivate sown, naturalistic, urban planting. Cost-effective management and creating new visual forms can be achieved through cultivation based on ecological concepts using the plant species well fitted to the local environment.

Planting based on ecological concepts using species well fitted to the local environment to create semi-natural vegetation can not only reduce management costs but also create new visual forms in urban landscapes. In particular, it can change our traditional planting design from being dominated by the mono-colored mass planting of evergreen shrubs to more vibrant, more diverse and long-flowering herbaceous planting. However, these changes are not without loss as meadow landscapes involve trade-offs between drama and attractive winter effects (Alizadeh, 2016). Achieving the desired aesthetic impression over a long season can only be attained if a combination of native and exotic species is used, in particular, when a country has a very limited native flora. When the mixture of species is designed/planned, this combination needs to be functional and to address the aesthetic needs of a landscape. Typical features that need to be considered are the color of the flowers, the leaf textures and inflorescence. Low maintenance requirements, while producing dramatic flowering displays, are only feasible if the initial plant density is controlled and their growth requirements, adaptability and phenology are appropriately evaluated (Alizadeh, 2016).

In the majority of situations, naturalistic planting is further recognized as encouraging the natural regeneration of spontaneous vegetation on site and further enables distinctive urban vegetation to be developed (Dunnett and Hitchmough, 1996). Community involvement in the design process not only reduces labor requirements but often increases final-use flexibility and the adoption of local materials when designing a natural setting (Dunnett and Clayden, 2000).

Such developments, to some degree, have encouraged the view that such vegetation, especially when involving native species established by sowing (Luscombe and Scott, 2004), necessitates a lower degree of resource input in the establishment and longer-term management when compared with more conventional plantings (Oudolf and Kingsbury, 2005). These perceptions have run in parallel with the view that such vegetation might also be considered more attractive, not only to those people living in urban settings (Dunnett and Hitchmough, 2004) but also to native invertebrate species (Hitchmough and Wagner, 2011). Moreover, even when species that are non-native to the area are used, naturalistic vegetation that is complex in terms of species diversity, species phenology (Crisp *et al.*, 1998; Asteraki *et al.*, 2004) and spatial form is likely to be a more valuable habitat for fauna that are native to the setting than monocultural plantings (Hitchmough and Wagner, 2011).

Their particular advantages are to be garnered from interacting with nature in urban places. Much of the research in this area has dealt with nature in a very vague, generalized sense. More specific work, for example, Özgüner and Kendle (2006), has shown that flower-rich, nature-like vegetation is particularly attractive to urban people.

Among professionals in the field, one common idea is that naturalistic landscapes are seen to be far less expensive to manage when compared with more formal landscapes. Some ecologists have suggested that costs could be decreased through adopting a vegetation pattern that is more natural and that will require a lesser degree of intervention for it to be maintained (Bradshaw and Handley, 1982; Brooker and Corder, 1986). This is probably true in some situations, such as woodlands, but in many situations, these ideas are not realistic. Kendle and Forbes (1997) argue that the costs associated with naturalistic landscape management might prove to be greater when compared with some ornamental and formal plantings, especially when management operations are unfamiliar, and there are many intricacies in the patterning.

When vegetation is viewed as an educational resource, traditional formal open space is less able to provide for environmental education compared to more naturalistic landscapes comprising essential ecosystem elements, such as grassland, woodland, water and scrub. Historically, it has been argued that various types of habitat act as a better stimulant to the imagination and can provide a valuable means of drawing contrasts between different kinds of habitat (Cole, 1983). Ensuring the presence of the most valuable habitats for wildlife is a fundamental consideration when adopting an urban landscape design. Potentially, one of the most useful assumptions about the naturalistic management and design of urban landscapes centers on the view that they are better at encouraging wildlife than urban landscapes based on conventional ornamental designs. Thus, they are better able to meet wildlife conservation objectives. Increasing the overall diversity of plant species and habitats for birds, insects and small mammals can be achieved through various methods, such as creating softer edges when lining ponds and changing the mowing regimes to allow for more extended grass growth. The significant change that has taken place over the past ten years is that these approaches seem to be successful whether pursued with native or non-native species (Salisbury *et al.*, 2015). This recent evolution of ecological understanding is significant in urban places, as it enables a diverse fauna to be supported while providing a wide range of physical structures or seasonal color effects that are not always possible with native species alone in small countries with a low native flora (Hitchmough and Dunnett, 2004a, 2004b). These aesthetics-based strategies are critical to ensuring public support for naturalistic vegetation in cities (Hands and Brown, 2002; Todorova, 2004; Özgüner *et al.*, 2007).

There are many factors that affect the secure feeling in the urban landscape and the form of design is one of them (Özgüner and Kendle, 2006). In spite of all the advantages of the naturalistic design of an urban landscape, there are some issues, such as increasing the cover available for potential attackers (Özgüner *et al.*, 2007), which give rise to real concerns.

Schroeder and Anderson (1984) showed that the perceived security of the parks and urban landscapes was significantly enhanced by high visibility. Involving local people in the management of public landscape increases their sense of responsibility and, as a result, enhances the feeling of security while decreasing vandalism (Hollick, 1982; Johnston, 1990).

These aesthetic preferences run in parallel with the attention given during the past two decades to the design of species-rich and structurally diverse naturalistic vegetation for use in urban green spaces to benefit biodiversity. In actuality, during recent years, there has been a wealth of landscape development in urban areas involving the application of ecological or naturalistic styles. In other words, designs centered on semi-natural stereotypes, including prairie and meadow, as mentioned previously, provide a substitute for species' poor monoculture plantings (Hitchmough, 2011; Kingsbury, 2004). In response to the separation of people from nature during the industrial revolution, new perspectives have been adopted in many rich Western countries toward the creation of more natural landscapes as a means of ensuring that contact with more natural settings is preserved (Kendle and Forbes, 1997).

The naturalistic landscape style in the UK has a long history and was a significant factor in the eighteenth century, when the English Landscape Garden first appeared. In the nineteenth century, landscape naturalism coexisted with far more architectural styles, sometimes on a smaller urban scale, notably by William Robinson in the "Wild Garden" (Robinson, 2009). Naturalistic landscapes reappeared as a major force in the UK in the 1970s as "nature in cities" or "ecological design" (Ruff, 1979; Ruff and Tregay, 1982), and these ideas were adopted in various park systems and new towns to varying degrees. McHarg (1969); and Hough (1995) were influential thinkers in the application of different principles and theories surrounding the design of ecological landscapes in urban areas, but their ideas were mostly associated with planning rather than design scales.

At the design scale, natural planting design is the concept of taking species and combining them in ways that reflect the character they display in the wild (Oudolf and Kingsbury, 2005). This approach embraces ecology as a dynamic concept, with change within the planting time being a vital part of the design process. Thoughtful plant selection is the preliminary stage. The collection of a species that is appropriate for the new environment and which can compete and persist is not a simple task. Preferably, there is a fundamental need to examine the natural setting and to investigate how such species can grow naturally in their environment and subsequently achieve stable species combinations. Accordingly, when implementing the design of a naturalistic vegetation that is species-diverse in nature and thereby potentially positioned well to support a wide variety of fauna, it is essential to utilize species that are capable of living for long period of time as adults while achieving recruitment from self-sown seed (Hitchmough and de la Fleur, 2006; Hitchmough and Wagner, 2011). Naturalistic planting involves a diversity of approaches which are necessary to deal with a variety of contexts, for example, aesthetics, community involvement, costs, environmental education, safety, sustainability and wildlife conservation (Hitchmough, 1994; Kendle and Forbes, 1997; Dunnett and Hitchmough, 2004).

As design ideas based on naturalistic planting have developed, there has been an equivalent increase in asking questions about what people think about the appearance of these designed plant communities. Studies conducted within environmental psychology typically found that people tend to consider natural environments more attractive from an aesthetic perspective because of their continuity, intricacy, their symbolic and cultural significance and their overall sensory stimulation (Kaplan and Kaplan, 1989). The objectives of studies are landscape preference and research concerning the conservation of aesthetically valuable landscape (Godlovitch, 1998), which attempts to find a way to describe and evaluate the public's preference regarding the aesthetic values of urban landscapes. Research studies in the field of landscape preferences and perceptions surrounding urban natural areas is growing (Chiesura, 2004; Jorgensen, 2004; Özgüner and Kendle, 2006), most recently driven by the increasing importance of biodiversity policy in urban areas. The difficulties in this literature are that it often deals with notions being so vague or sometimes meaningless. Just because someone implies that they prefer natural environments does not mean they favor environments which are, at the human scale, relatively disordered. Hence, there is a need for vegetation to be designed with attention to aesthetic principles if it is to achieve the aim of being well understood and appreciated by the public as a whole (Dunnett and Hitchmough, 2004).

## 8. Conclusion

Improving the quality of life, human well-being and biodiversity are currently important policy drivers in metropolitan areas and megacities through urban green space. Green spaces are one of the most important wildlife habitats in the urban area. Herbaceous vegetation is an increasingly essential element of the urban landscape. Currently, public and professional urban designers increasingly accept naturalistic planting design, semi-natural grassland and meadow in the urban landscape. Both native and exotic species have an essential role in naturalistic planting design. Understanding the process of climate change adaptation is necessary to designing plant communities for use in public landscapes. Increased $CO_2$and air temperature in conjunction with the changing rainfall conditions, as the three critical factors of climate change, potentially alter almost all world ecosystems. Climate change provides new opportunities, and in some cases, an obligate need to use non-native plant species in conjunction with native plant species, not only to reduce the side effects of climate change but also to increase the species diversity and aesthetic value in meadow-like naturalistic planting design.

## References

Alizadeh, B. (2016), "The impacts of climate change on designing sustainable urban landscapes", Doctoral dissertation, University of Sheffield, Sheffield.

Angold, P.G., Sadler, J.P., Hill, M.O., Pullin, A., Rushton, S., Austin, K., Small, E., Wood, B., Wadsworth, R., Sanderson, R. and Thompson, K. (2006), "Biodiversity in urban habitat patches", *Science of the Total Environment*, Vol. 360 Nos 1/3, pp. 196-204.

Asteraki, E.J., Hart, B.J., Ings, T.C. and Manley, W.J. (2004), "Factors influencing the plant and invertebrate diversity of arable field margins", *Agriculture, Ecosystems & Environment*, Vol. 102 No. 2, pp. 219-231.

Bachelet, D. and Gay, C.A. (1993), "The impacts of climate change on rice yield: a comparison of four model performances", *Ecological Modelling*, Vol. 65 Nos 1/2, pp. 71-93.

Bakkenes, M., Alkemade, J.R.M., Ihle, F., Leemans, R. and Latour, J.B. (2002), "Assessing effects of forecasted climate change on the diversity and distribution of European higher plants for 2050", *Global Change Biology*, Vol. 8 No. 4, pp. 390-407.

Barbosa, O., Tratalos, J.A., Armsworth, P.R., Davies, R.G., Fuller, R.A., Johnson, P. and Gaston, K.J. (2007), "Who benefits from access to green space? a case study from Sheffield, UK", *Landscape and Urban Planning*, Vol. 83 Nos. 2/3, pp. 187-195.

Beier, C., Gundersen, P., and Rasmussen, L. (1998), "European experience of manipulation of forest ecosystems by roof cover: possibilities and limitations", *Experimental Reversal of Acid Rain Effects: The Gårdsjön Roof Project*, John Wiley and Sons, New York, pp. 397-410.

Beier, C., Emmett, B., Gundersen, P., Tietema, A., Penuelas, J., Estiarte, M., Gordon, C., Gorissen, A., Llorens, L., Roda, F. and Williams, D. (2004), "Novel approaches to study climate change effects on terrestrial ecosystems in the field: drought and passive nighttime warming", *Ecosystems*, Vol. 7 No. 6, pp. 583-597.

Bigler, C., Bräker, O.U., Bugmann, H., Dobbertin, M. and Rigling, A. (2006), "Drought as an inciting mortality factor in scots pine stands of the Valais, Switzerland", *Ecosystems*, Vol. 9 No. 3, pp. 330-343.

Bisgrove, R. and Hadley, P. (2002), *Gardening in the Global Greenhouse: The Impacts of Climate Change on Gardens in the UK*, The UK Climate Impacts Programme, Reading.

Bradshaw, A.D. and Handley, J. (1982), "An ecological approach to landscape design: principles and problems", *Landscape Design*, Vol. 138, pp. 30-34.

Briner, T. and Frank, T. (1998), "The palatability of 78 wildflower strip plants to the slug *Arion lusitanicus*", *Annals of Applied Biology*, Vol. 133 No. 1, pp. 123-133.

Broadmeadow, M.S. (Ed.) (2002), *Climate Change: Impacts on UK Forests (Vol. 125)*, Forestry Commission, Scotland.

Broadmeadow, M.S.J., Ray, D. and Samuel, C.J.A. (2005), "Climate change and the future for broadleaved tree species in Britain", *Forestry: An International Journal of Forest Research*, Vol. 78 No. 2, pp. 145-161.

Brooker, R. and Corder, M. (Eds) (1986), *Environmental Economy*, E. & FN Spon, London.

Bruelheide, H. and Scheidel, U. (1999), "Slug herbivory as a limiting factor for the geographical range of Arnica Montana", *Journal of Ecology*, Vol. 87 No. 5, pp. 839-848.

Burt, P.J.A. (2002), "Weather and pests", *Weather*, Vol. 57 No. 5, pp. 180-184.

Cannell, M.G.R., 1985. "Dry matter partitioning in tree crops", Huntingdon, pp. 160-193.

Chan, K.M., Shaw, M.R., Cameron, D.R., Underwood, E.C. and Daily, G.C. (2006), "Conservation planning for ecosystem services", *PLoS Biology*, Vol. 4 No. 11, p. e379.

Chiesura, A. (2004), "The role of urban parks for the sustainable city", *Landscape and Urban Planning*, Vol. 68 No. 1, pp. 129-138.

Cole, D.N. (1983), "Monitoring the condition of wilderness campsites (No. 04; USDA, FOLLETO 4.)", US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Utah.

Crisp, T.M., Clegg, E.D., Cooper, R.L., Wood, W.P., Anderson, D.G., Baetcke, K.P., Hoffmann, J.L., Morrow, M.S., Rodier, D.J., Schaeffer, J.E. and Touart, L.W. (1998), "Environmental endocrine disruption: an effects assessment and analysis", *Environmental Health Perspectives*, Vol. 106 No. 1, p. 11.

Davis, M.B. (1989), "Lags in vegetation response to greenhouse warming", *Climatic Change*, Vol. 15 Nos 1/2, pp. 75-82.

Dunnett, N. and Hitchmough, J. (1996), "Excitement and energy", *Landscape Design*, Vol. 251, pp. 43-46.

Dunnett, N. and Clayden, A. (2000), "Resources: The raw materials of landscape", *Landscape and Sustainability*, Architectural Press, London.

Dunnett, N. and Hitchmough, J. (2004), *The Dynamic Landscape: Design, Ecology and Management of Naturalistic Urban Planting*, Taylor & Francis, New York.

Fenner, M., Hanley, M.E. and Lawrence, R. (1999), "Comparison of seedling and adult palatability in annual and perennial plants", *Functional Ecology*, Vol. 13 No. 4, pp. 546-551.

Frank, T. (2003), "Influence of slug herbivory on the vegetation development in an experimental wildflower strip", *Basic and Applied Ecology*, Vol. 4 No. 2, pp. 139-147.

Gifford, R.M., Thorne, J.H., Hitz, W.D. and Giaquinta, R.T. (1984), "Crop productivity and photoassimilate partitioning", *Science (New York, N.Y.)*, Vol. 225 No. 4664, pp. 801-808.

Gilbert, O.L. and Anderson, P. (1998), *Habitat Creation and Repair*, Oxford University Press on Demand, Oxford.

Gill, S. (2006), "Climate change and urban greenspace", Doctoral dissertation, The University of Manchester, Manchester.

Gill, S.E., Handley, J.F., Ennos, A.R. and Pauleit, S. (2007), "Adapting cities for climate change: the role of the green infrastructure", *Built Environment*, Vol. 33 No. 1, pp. 115-133.

Godlovitch, S. (1998), "Valuing nature and the autonomy of natural aesthetics", *The British Journal of Aesthetics*, Vol. 38 No. 2, pp. 180-197.

Goldberg, D.E. and Miller, T.E. (1990), "Effects of different resource additions of species diversity in an annual plant community", *Ecology*, Vol. 71 No. 1, pp. 213-225.

Greater Manchester Fire and Rescue Service (2006), "Firefighters feel heat during warm spell", available at: www.manchesterfire.gov.uk/gen/news_display.asp?id7=&id8=&id9=276 (accessed 4 September 2013).

Grime, J.P. (1973), "Competitive exclusion in herbaceous vegetation", *Nature*, Vol. 242 No. 5396, p. 344.

Grimshaw, J. and Bayton, R. (2009), *New Trees: Recent Introductions to Cultivation*, Royal Botanic Gardens, Sydney.

Groenewegen, P.P., Van den Berg, A.E., De Vries, S. and Verheij, R.A. (2006), "Vitamin G: effects of green space on health, well-being, and social safety", *BMC Public Health*, Vol. 6 No. 1, p. 149.

Hands, D.E. and Brown, R.D. (2002), "Enhancing visual preference of ecological rehabilitation sites", *Landscape and Urban Planning*, Vol. 58 No. 1, pp. 57-70.

Hartig, T., Mang, M. and Evans, G.W. (1991), "Restorative effects of natural environment experiences", *Environment and Behavior*, Vol. 23 No. 1, pp. 3-26.

Hitchmough, J.D. (1994), *Urban Landscape Management*, Inkata Press, Stuttgart.

Hitchmough, J. (2011), "Exotic plants and plantings in the sustainable, designed urban landscape", *Landscape and Urban Planning*, Vol. 100 No. 4, pp. 380-382.

Hitchmough, J. and De la Fleur, M. (2006), "Establishing North American prairie vegetation in urban parks in Northern England: effect of management and soil type on long-term community development", *Landscape and Urban Planning*, Vol. 78 No. 4, pp. 386-397.

Hitchmough, J. and Dunnett, N. (2004a), 'Naturalistic herbaceous vegetation for urban landscapes", *The Dynamic Landscape, Design, Ecology and Management of Naturalistic Urban Planting*, Spon Press, London, pp. 130-183.

Hitchmough, J. and Dunnett, N. (2004b), Introduction to naturalistic planting in urban landscapes. *The Dynamic Landscape*, Taylor & Francis, New York, pp. 1-32.

Hitchmough, J. and Wagner, M. (2011), "Slug grazing effects on seedling and adult life stages of North American prairie plants used in designed urban landscapes", *Urban Ecosystems*, Vol. 14 No. 2, pp. 279-302.

Hitchmough, J. and Woudstra, J. (1999), "The ecology of exotic herbaceous perennials grown in managed, native grassy vegetation in urban landscapes", *Landscape and Urban Planning*, Vol. 45 Nos 2/3, pp. 107-121.

Holland, K.D., Mcdonnell, M.J. and Williams, N.S. (2007), "Abundance, species richness and feeding preferences of introduced molluscs in native grasslands of Victoria, Australia", *Austral Ecology*, Vol. 32 No. 6, pp. 626-634.

Hollick, T. (1982), "Community environment in leeds", *Landscape Journal*, Vol. 15 No. 2, pp. 15-17.

Hough, M. (1995), *Anxiety about Crime: Findings from the 1994 British Crime Survey*, Home Office, London.

Hulme, P.E. (1994), "Seedling herbivory in grassland: relative impact of vertebrate and invertebrate herbivores", *Journal of Ecology*, Vol. 82 No. 4, pp. 873-880.

Hulme, M. (2002), "Climate change scenarios for the United Kingdom: the UKCIP02 scientific report", Tyndall Centre for Climate Mental Sciences University, Cambridge.

Jim, C.Y. and Chen, W.Y. (2009), "Ecosystem services and valuation of urban forests in China", *Cities*, Vol. 26 No. 4, pp. 187-194.

Johnston, J. (1990), "Nature areas for city people", *Nature Areas for City People*, Vol. 14.

Jorgensen, A. (2004), "The social and cultural context of ecological plantings", *The Dynamic Landscape: Design, Ecology and Management of Naturalistic Urban Planting*, Vol. 11 No. 1, pp. 416-459.

Jorgensen, A., Hitchmough, J. and Calvert, T. (2002), "Woodland spaces and edges: their impact on perception of safety and preference", *Landscape and Urban Planning*, Vol. 60 No. 3, pp. 135-150.

Kaplan, R. and Kaplan, S. (1989), *The Experience of Nature: A Psychological Perspective*, CUP Archive, Cambridge.

Keller, M., Kollmann, J. and Edwards, P.J. (1999), "Palatability of weeds from different European origins to the slugs *Deroceras reticulatum* Müller and *Arion lusitanicus* Mabille", *Acta Oecologica*, Vol. 20 No. 2, pp. 109-118.

Kendle, T. and Forbes, S. (1997), *Urban Nature Conservation*, E & FN Spon, London, p. 264.

Kendle, A.D. and Rose, J.E. (2000), "The aliens have landed! What are the justifications for 'native only' policies in landscape plantings?", *Landscape and Urban Planning*, Vol. 47 Nos. 1/2, pp. 19-31.

Kingsbury, N. (2004), "Contemporary overview of naturalistic planting design", *The Dynamic Landscape: Design, Ecology and Management of Naturalistic Urban Planting*, Taylor & Francis, New York, pp. 81-127.

Knapp, A.K., Fay, P.A., Blair, J.M., Collins, S.L., Smith, M.D., Carlisle, J.D., Harper, C.W., Danner, B.T., Lett, M.S. and McCarron, J.K. (2002), "Rainfall variability, carbon cycling, and plant species diversity in a mesic grassland", *Science*, Vol. 298 No. 5601, pp. 2202-2205.

Ladanyi, M. and Horvath, L. (2010), "A review of the potential climate change impact on insect populations- general and agricultural aspects", *Applied Ecology and Environmental Research*, Vol. 8 No. 2, pp. 143-152.

Larcher, W. (2003), *Physiological Plant Ecology: Ecophysiology and Stress Physiology of Functional Groups*, Springer Science & Business Media, New York.

Luscombe, G. and Scott, R. (2004), *Wildflowers Work: A Guide to Creating and Managing New Wildflower Landscapes*, Landlife, Amsterdam.

Maas, J., Spreeuwenberg, P., Van Winsum-Westra, M., Verheij, R.A., Vries, S. and Groenewegen, P.P. (2009), "Is green space in the living environment associated with people's feelings of social safety?", *Environment and Planning A*, Vol. 41 No. 7, pp. 1763-1777.

Melillo, J.M., McGuire, A.D., Kicklighter, D.W., Moore, B., Vorosmarty, C.J. and Schloss, A.L. (1993), "Global climate change and terrestrial net primary production", *Nature*, Vol. 363 No. 6426, p. 234.

Mittelbach, G.G., Steiner, C.F., Scheiner, S.M., Gross, K.L., Reynolds, H.L., Waide, R.B., Willig, M.R., Dodson, S.I. and Gough, L. (2001), "What is the observed relationship between species richness and productivity?", *Ecology*, Vol. 82 No. 9, pp. 2381-2396.

Moraal, L.G. and op Akkerhuis, G.A.J. (2011), "Changing patterns in insect pests on trees in The Netherlands since 1946 in relation to human induced habitat changes and climate factors – an analysis of historical data", *Forest Ecology and Management*, Vol. 261 No. 1, pp. 50-61.

Nystrand, O. and Granström, A. (1997), "Forest floor moisture controls predator activity on juvenile seedlings of *Pinus sylvestris*", *Canadian Journal of Forest Research*, Vol. 27 No. 11, pp. 1746-1752.

Oudolf, P. and Kingsbury, N. (2005), *Planting Design: Gardens in Time and Space*, Timber Press, Portland.

Özgüner, H. and Kendle, A.D. (2006), "Public attitudes towards naturalistic versus designed landscapes in the city of Sheffield (UK)", *Landscape and Urban Planning*, Vol. 74 No. 2, pp. 139-157.

Özgüner, H., Kendle, A.D. and Bisgrove, R.J. (2007), "Attitudes of landscape professionals towards naturalistic versus formal urban landscapes in the UK", *Landscape and Urban Planning*, Vol. 81 Nos 1/2, pp. 34-45.

Parker, I.M., Simberloff, D., Lonsdale, W.M., Goodell, K., Wonham, M., Kareiva, P.M., Williamson, M.H., Von Holle, B.M.P.B., Moyle, P.B., Byers, J.E. and Goldwasser, L. (1999), "Impact: toward a framework for understanding the ecological effects of invaders", *Biological Invasions*, Vol. 1 No. 1, pp. 3-19.

Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J.K., Thomas, C.D., Descimon, H., Huntley, B., Kaila, L., Kullberg, J., Tammaru, T. and Tennent, W.J. (1999), "Poleward shifts in geographical ranges of butterfly species associated with regional warming", *Nature*, Vol. 399 No. 6736, p. 579.

Pickett, S.T., Cadenasso, M.L., Grove, J.M., Boone, C.G., Groffman, P.M., Irwin, E., Kaushal, S.S., Marshall, V., McGrath, B.P., Nilon, C.H. and Pouyat, R.V. (2011), "Urban ecological systems: Scientific foundations and a decade of progress", *Journal of Environmental Management*, Vol. 92 No. 3, pp. 331-362.

Prather, C.M., Pelini, S.L., Laws, A., Rivest, E., Woltz, M., Bloch, C.P., Del Toro, I., Ho, C.K., Kominoski, J., Newbold, T.A. and Parsons, S. (2013), "Invertebrates, ecosystem services and climate change", *Biological Reviews*, Vol. 88 No. 2, pp. 327-348.

Rafferty, N.E. and Ives, A.R. (2011), "Effects of experimental shifts in flowering phenology on plant–pollinator interactions", *Ecology Letters*, Vol. 14 No. 1, pp. 69-74.

Raven, P.H., Evert, R.F., and Eichhorn, S.E. (2005), *Biology of Plants*, Macmillan, New York.

Reich, P.B., Tilman, D., Craine, J., Ellsworth, D., Tjoelker, M.G., Knops, J., Wedin, D., Naeem, S., Bahauddin, D., Goth, J. and Bengtson, W. (2001), "Do species and functional groups differ in acquisition and use of C, N and water under varying atmospheric CO2 and N availability regimes? a field test with 16 grassland species", *New Phytologist*, Vol. 150 No. 2, pp. 435-448.

Robinson, W. (2009), *The Wild Garden: Expanded Edition*, Timber Press, Portland.

Roetzer, T., Wittenzeller, M., Haeckel, H. and Nekovar, J. (2000), "Phenology in Central Europe – differences and trends of spring phenophases in urban and rural areas", *International Journal of Biometeorology*, Vol. 44 No. 2, pp. 60-66.

Rojas, M.R., Locatelli, B. and Billings, R. (2010), "Climate change and outbreaks of Southern pine beetle in Honduras", *Forest Systems*, Vol. 19 No. 1, pp. 70-76.

Ruff, A.R. (1979), *Holland & the Ecological Landscape*, Department of Town and Country Planning, the University of Manchester, Manchester.

Ruff, A.R. and Tregay, R. (Eds) (1982), *An Ecological Approach to Urban Landscape Design (Vol. 8)*, Department of Town and Country Planning, University of Manchester, Manchester.

Salisbury, A., Armitage, J., Bostock, H., Perry, J., Tatchell, M. and Thompson, K. (2015), "EDITOR'S CHOICE: enhancing gardens as habitats for flower-visiting aerial insects (pollinators): should we plant native or exotic species?", *Journal of Applied Ecology*, Vol. 52 No. 5, pp. 1156-1164.

Scheidel, U. and Bruelheide, H. (1999), "Selective slug grazing on Montane meadow plants", *Journal of Ecology*, Vol. 87 No. 5, pp. 828-838.

Schmitz, D.C. and Simberloff, D. (1997), "Biological invasions: a growing threat", *Issues in Science and Technology*, Vol. 13 No. 4, pp. 33-40.

Schroeder, H.W. and Anderson, L.M. (1984), "Perception of personal safety in urban recreation sites", *Journal of Leisure Research*, Vol. 16 No. 2, p. 178.

Shaw, M.R., Zavaleta, E.S., Chiariello, N.R., Cleland, E.E., Mooney, H.A. and Field, C.B. (2002), "Grassland responses to global environmental changes suppressed by elevated CO2", *Science (New York, N.Y.)*, Vol. 298 No. 5600, pp. 1987-1990.

Sparks, T., Gill, R. and Broadmeadow, M.S.J. (2002), "Climate change and the seasonality of woodland flora and fauna", *Forestry Commission Bulletin*, Vol. 125, pp. p69-p82.

The London Climate Change Partnership (2018), *London's Warming – The Impacts of Climate Change on London*, available at: https://ukcip.ouce.ox.ac.uk/wp-content/PDFs/London_tech.pdf (accessed 3 July 2018).

Tilman, D. (1988), *Plant Strategies and the Dynamics and Structure of Plant Communities (No. 26)*, Princeton University Press, Princeton.

Todorova, M. (2004), "What is or is there a Balkan culture, and do or should the Balkans have a regional identity?", *Southeast European and Black Sea Studies*, Vol. 4 No. 1, pp. 175-185.

Traill, L.W., Lim, M.L., Sodhi, N.S. and Bradshaw, C.J. (2010), "Mechanisms driving change: altered species interactions and ecosystem function through global warming", *Journal of Animal Ecology*, Vol. 79 No. 5, pp. 937-947.

Troughton, A. (1977), "Relationship between the root and shoot systems of grasses", in Marshall, J.K. (Ed.), *The Belowground Ecosystem: A Synthesis of Primary Production Associated Processes, Science Series, No. 26*, Range Science Department, Colorado State University, Fort Collins, CO, pp. 39-51.

Troy, A. and Grove, J.M. (2008), "Property values, parks, and crime: a hedonic analysis in Baltimore, MD", *Landscape and Urban Planning*, Vol. 87 No. 3, pp. 233-245.

Vitousek, P.M., D'antonio, C.M., Loope, L.L., Rejmanek, M. and Westbrooks, R. (1997), "Introduced species: a significant component of human-caused global change", *New Zealand Journal of Ecology*, Vol. 21 No. 1, pp. 1-16.

Volney, W.J.A. and Fleming, R.A. (2000), "Climate change and impacts of boreal Forest insects", *Agriculture, Ecosystems & Environment*, Vol. 82 Nos 1/3, pp. 283-294.

Vörösmarty, C.J. and Sahagian, D. (2000), "Anthropogenic disturbance of the terrestrial water cycle", *AIBS Bulletin*, Vol. 50 No. 9, pp. 753-765.

White, J.E.J. (1994), "New tree species in a changing world", *Arboricultural Journal*, Vol. 18 No. 2, pp. 99-112.

White, M.A., Nemani, R.R., Thornton, P.E. and Running, S.W. (2002), "Satellite evidence of phenological differences between urbanized and rural areas of the Eastern United States deciduous broadleaf Forest", *Ecosystems*, Vol. 5 No. 3, pp. 260-273.

Wilby, A. and Brown, V.K. (2001), "Herbivory, litter and soil disturbance as determinants of vegetation dynamics during early old-field succession under set-aside", *Oecologia*, Vol. 127 No. 2, pp. 259-265.

Wilby, R.L. and Perry, G.L. (2006), "Climate change, biodiversity and the urban environment: a critical review based on London, UK", *Progress in Physical Geography*, Vol. 30 No. 1, pp. 73-98.

Wright, R.F. (1998), "Effect of increased carbon dioxide and temperature on runoff chemistry at a forested catchment in Southern Norway (CLIMEX project)", *Ecosystems*, Vol. 1 No. 2, pp. 216-225.

Zavaleta, E.S., Shaw, M.R., Chiariello, N.R., Thomas, B.D., Cleland, E.E., Field, C.B. and Mooney, H.A. (2003), "Grassland responses to three years of elevated temperature, CO2, precipitation, and N deposition", *Ecological Monographs*, Vol. 73 No. 4, pp. 585-604.

## Further reading

Authority, G.L., 2002. "London's warming: the impacts of climate change on London", London.

Cameron, R. and Hitchmough, J. (2016), *Environmental Horticulture: science and Management of Green Landscapes*, Cabi, Wallingford.

Cannell, M.G., Palutikof, J.P. and Sparks, T.H. (Eds) (1999), *Indicators of Climate Change in the UK*, Department of the Environment, Transport and the Regions, London.

Dunnett, N. (2011), "Urban meadows: an ecological discussion", *Aspects of Applied Biology*, Vol. 108, pp. 11-17.

Evered, E. (2016), "The role of the urban landscape in restoring mental health in Sheffield, UK: service user perspectives", *Landscape Research*, Vol. 41 No. 6, pp. 678-694.

Farbod, S., Kamal, M. and Maulan, S. (2017), "Safety perception and concerns in naturalistic landscapes of urban parks in Malaysia", *Security Journal*, Vol. 30 No. 1, pp. 106-122.

Gao, F. (2010), "Role of hemi-parasites in the development of designed naturalistic herbaceous vegetation", Doctoral dissertation, The University of Sheffield, Sheffield.

Götzenberger, L., de Bello, F., Bråthen, K.A., Davison, J., Dubuis, A., Guisan, A., Lepš, J., Lindborg, R., Moora, M., Pärtel, M. and Pellissier, L. (2012), "Ecological assembly rules in plant communities – approaches, patterns and prospects", *Biological Reviews*, Vol. 87 No. 1, pp. 111-127.

Hitchmough, J. and Wagner, M. (2013), "The dynamics of designed plant communities of rosette forming forbs for use in supra-urban drainage swales", *Landscape and Urban Planning*, Vol. 117, pp. 122-134.

Hitchmough, J., Wagner, M. and Ahmad, H. (2017), "Extended flowering and high weed resistance within two layer designed perennial "prairie-meadow" vegetation", *Urban Forestry & Urban Greening*, Vol. 27, pp. 117-126.

Hoyle, H., Hitchmough, J. and Jorgensen, A. (2017), "Attractive, climate-adapted and sustainable? Public perception of non-native planting in the designed urban landscape", *Landscape and Urban Planning*, Vol. 164, pp. 49-63.

Hunter, M. (2011), "Using ecological theory to guide urban planting design an adaptation strategy for climate change", *Landscape Journal*, Vol. 30 No. 2, pp. 173-193.

Ignatieva, M. (2010), Design and future of urban biodiversity. *Urban Biodiversity and Design*, 1.

IPCC (2014), "Climate Change 2014", Synthesis Report: Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds)], IPCC, Geneva, p. 151.

Köppler, M.R. and Hitchmough, J.D. (2015), "Ecology good, aut-ecology better; improving the sustainability of designed plantings", *Journal of Landscape Architecture*, Vol. 10 No. 2, pp. 82-91.

Lemon, E.R. (1983), "CO2 and Plants", AAAS Selected Symposium No. 84.

McHarg, I.L. and Mumford, L. (1969), *Design with Nature*, American Museum of Natural History, New York.

PeccoL, E., Bird, A.C., and Brewer, T.R. (2012), "Developing new multi-layered, long flowering mediterranean plant communities for use in the warming cities of maritime western Europe", *Research Symposium*, 26 January, Vol. 34, pp. 1-10.

Sjöman, H., Bellan, P., Hitchmough, J. and Oprea, A. (2015), "Herbaceous plants for climate adaptation and intensely developed urban sites in Northern Europe: a case study from the Eastern Romanian Steppe", *Ekologia*, Vol. 34 No. 1, pp. 39-53.

Southon, G.E., Jorgensen, A., Dunnett, N., Hoyle, H. and Evans, K.L. (2017), "Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space", *Landscape and Urban Planning*, Vol. 158, pp. 105-118.

Wang, J., Wang, Y. and Yu, S. (2010), "Relationships between diversity and compositional stability in experimental grassland communities exposed to drought stress", *Community Ecology*, Vol. 11 No. 1, pp. 105-112.

**Corresponding author**
Behdad Alizadeh can be contacted at: behdadalizade@gmail.com