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International Journal of Environment and Sustainability [IJES]
ISSN 1927-9566
Vol. 6 No. 1, pp. 15-36
(2017)

A Comprehensive Review of Blue-Green Infrastructure Concepts

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Abstract. Climate change is expected to result in more intense and longer-lasting droughts and increase in the frequency and intensity of heavy rainfall events. The combination of drought followed by intense rainfall increases the risk of severe flooding, with impacts on a range of natural and anthropogenic systems, including infrastructure (road washouts, damage to houses) and impacts on agriculture (soil erosion and loss of crops and livestock). Blue-Green Infrastructure (BGI) is an interconnected network of natural and designed landscape components, including water bodies and green and open spaces, which provide multiple functions such as: (i) water storage for irrigation and industry use, (ii) flood control, (iii) wetland areas for wildlife habitat or water purification, and many others. This paper provides a review of information on the impact of BGI on environments, particularly on water resources and vegetation. Efforts have been made to review the BGI development situation in different countries. Based on the research reviewed, the authors suggest the following as priorities for future research into the environmental impacts of BGI: determining the feasibility of BGI and determining the impacts of applying the BGI for major regions where there have been considerable nature-based recreation and tourism resources.

Keywords. *climate change, extreme events, sustainability, resilience, Blue-Green Infrastructure*

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1. Introduction

Weather extremes (droughts and floods) are an accepted component of coupled human-environment systems (IPCC, 2014). However, it is unlikely that we are prepared for the possible step change in their intensity and frequency in a changed climate. Impacts associated with recent climate-related extremes, such as droughts, floods, wildfires, and heat waves, reveal the considerable exposure and vulnerability of many natural ecosystems as well as human systems to current climate variability and change. Disruption of food production and water supply, alterations to ecosystems, consequences for human health and well-being, and damage to infrastructure and settlements are some effects of climate-related extremes. These impacts are exacerbated by the lack of awareness and preparedness for existing climate variability in countries at all levels of development (Faggian and Sposito, 2009).

We can either adapt to climate change and reduce its impacts, or we can fail to adapt and expect much more serious consequences. The future will be shaped according to our response to this challenge (Leary, 2012).

Reducing vulnerability and exposure to present climate variability is the first step towards adaptation to future climate change. Flooding and extreme events will become more prevalent under climate change, and only sustainable approaches such as Blue-Green Infrastructure (BGI) will save us from ourselves. Strategies such as BGI that include actions with co-benefits for other objectives can increase resilience across a range of

possible future climates while helping to improve human health, social and economic well-being, environmental quality, and livelihoods (Gentle et al., 2001; IPCC, 2014; Middlemann and Middlemann, 2007).

There is a strong need for an anthropogenic modification of the environment in response to climate and weather over time and development of "sustainable" engineering solutions. BGI, as one of those solutions, provides a proven, sustainable, underpinning of development that protects against floods and offers a range of other benefits with no down sides. The driver of climate change and increased extreme weather means we need to implement systems like BGI if we wish to have sustainable and resilient settlements. There is no comprehensive synthesis of BGI, and given its growing importance, there is need for a review.

The rest of the paper is organized as follows: The literature on sustainable development is briefly covered in Section 2. After reviewing the BGI concepts as a solution for sustainable development in Section 3, Section 4 describes several case studies of development scenarios based on BGI in different countries, namely the Netherlands, Belgium, Japan, the United States, and India. Section 5 describes the feasibility of the BGI implementation. Finally, our conclusions are drawn in Section 6.

2. Literature Review of Sustainable Development

In the last three decades, several alternative approaches have suggested different ways to address sustainability and sustainable development (Sposito, 2012). The more traditional approaches are anthropocentric (also referred to as "weak" approaches to sustainability). These consider nature as something external to humans, a resource to be consumed and exploited, but with moderation to make it last (Baker, 2007). Instead, an eco-centric approach (or "strong" approach to sustainability) presents social systems and nature as co-evolving in mutual, complicated interaction and, therefore, takes into consideration a balance of social requirements, ecological restrictions, and quality of life (Baker, 2007).

An important eco-centric approach is encompassed by reliance thinking and resilience theory that was developed primary by ecologists. Walker and Salt (2006) (Walker and Salt, 2006) use the phrase "resilience thinking" to capture a coherent set of notions that together create a framework for conceptualizing and explaining how systems of humans and nature interact and behave. Resilience theory is an alternative approach to equilibrium-center theories and models that guide management actions in many natural resource systems. The resultant "resilience framework" is based on observations of thresholds, abrupt or non-linear shifts of key system variables, and multiple (possible) states that characterize complex system behavior (Chapin III et al., 2009; Gunderson et al., 2012).

The notion of ecological resilience was first elaborated by Holling in a seminal article published in 1973 (Holling, 1973). This perspective developed from population and landscape ecology and applied resource management. Holling's insight incorporates three concepts of changes that occur in an ecosystem over time. The first described the "persistence of relationships within a system" and the "ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist" (Holling, 1973). The second concept recognized the occurrence of alternative and multiple states in a system as opposed to the assumption of a single equilibrium and global stability; therefore, resilience is "the size of stability domain or the amount of disturbance a system could take before it shifted to an alternative configuration" (Holling, 1973). The third notion was the surprise and discontinuous nature of change. Holling's insights modified the way in which theorists perceived (ecological) systems and how practitioners have attempted to manage them. It is interesting to note that ecological resilience is similar to the cybernetic concept of a "viable system" as advanced by Ashby and Stafford (Ashby, 1957; Stafford, 1981).

Today, the use of the term stability in describing ecological systems is inappropriate. These systems are best described as occupying a trajectory characterized by non-linear dynamics. Indeed, attempts at "command-and-control" are doomed to failure because by the time the required measurements are put into place, the system would be in a different state. In this view, stability is a system property that should be avoided because stable systems are unlikely to be adaptive and are more likely to experience catastrophic failure (Allison and Hobbs 2004).

Resilience theory explicitly recognizes the role of humans in shaping ecosystem processes. Thus, the term social-ecological systems emphasizes the integrated concept of humans in nature and to stress that the delineation between social and ecological systems is artificial and arbitrary. It is argued that addressing the social dimension of resource management without an understanding of resource ecosystem dynamics is not sufficient to guide society towards sustainable outcomes. The capacity to adapt to, and shape, change is an important component of resilience in a socio-ecological system because the stakeholders (or actors) generally have the capacity to reorganize the system within desirable states in response to disturbance events and changing conditions (Berkes et al., 2008). In this context, adaptive management was developed from theories of resilience as an integrated approach for tackling complexity and uncertainty in natural resource issues. Using a system perspective, adaptive management acknowledges that: (i) managed resources will change as a result of human intervention, (ii) surprises are inevitable, and (iii) new uncertainties will emerge in the future (Chapin III et al., 2009; Gunderson et al., 2012).

Important insights from resilience theory/ thinking that can inform strategic thinking and planning, and their relationship to cybernetics, have been discussed elsewhere (Faggian and Sposito, 2009). The development of BGI is an adaptation action directed at creating resilient regions to internal and external stressors, particularly, but not limited to, climate change.

3. Blue-Green Infrastructure as a Solution Underpinning Sustainable Development

BGI, as an umbrella notion, is closely related to the concept of "Green Infrastructure" - a landscape planning concept that is allied to other planning concepts such as green-ways (Ahern, 1995; Fábos and Ryan, 2006) and ecological networks (Jongman and Pungetti, 2004). Since 2000, Green Infrastructure has primarily been introduced to design and promote urban green bodies as a coherent environmental planning system (Sandström, 2002; Thomas and Littlewood, 2010). It can be considered to include all artificial, natural, and semi-natural components of multifunctional environmental systems around, within, and between urban areas. The increasing popularity of Green Infrastructure applications in various regions of the world underscores its multitude of benefits (Benedict and McMahon, 2006; Gill et al., 2007; Mell, 2008; Tzoulas et al., 2007). Green Infrastructure highlights the quantity and quality of regional, peri-urban, and urban green bodies; their multifunctional impact; and the significance of connections between habitats (Ryn and Cowan, 2013). It has also been argued that the ecosystem services offered by Green Infrastructure can secure healthy environments and health improvements, including physical and mental health, to the people residing within or in close proximity to it (Tzoulas et al., 2007). Encompassing all these aspects, the comprehensive definition put forward by Benedict and McMahon (Benedict and McMahon, 2002) is:

"Green Infrastructure is an interconnected network of waterways, wetlands, wildlife habitats, and other natural areas; greenways, parks, and other conservation lands; working farms, ranches, and forests; and wilderness and other open spaces that support species, maintain natural ecological processes, sustain air and water resources, and contribute to the health and quality of life for (American) communities and people" (Mell, 2008).

Furthermore, the contribution of (Blue-) Green Infrastructure to climate change adaptation has begun to be documented (Gill et al., 2007; Kazmierczak and Carter, 2010), yet there are few

studies that have so far systematically focused on this aspect.

BGI can exist at various geographic levels (e.g. region, city-region, urban, river basin/ catchment/watershed, and site) and functions across jurisdictional boundaries. Therefore, BGI is not limited to urban spaces, and its planning can be considered at multiple levels and in various planning contexts such as urban, peri-urban, regional, and rural planning. BGI is significantly different from conventional "hard" built infrastructures such as roads, sewerage and drainage systems, and utility lines. Connectivity is a key concept for BGI, since many of the benefits of BGI can only be truly realized by an interconnected network of its constituting components (Faggian and Sposito, 2009; Faggian et al., 2012).

BGI is an important means of dealing with flooding/extreme weather since it can consist of a network of interconnected water reservoirs, wetlands, and their associated (natural) open spaces developed along rivers, which serve several interrelated purposes including: (i) water storage, especially for agriculture's irrigation and industry use; (ii) regulators of the river system, particularly the prevention of floods during extreme rainfall events; (iii) habitat for plants and animal wild life (nature conservation); (iv) a cleaning system of polluted water, particularly absorbing fertilizers that are often washed away from farmland and which tend to cause algae blooms in rivers and lakes; (v) areas for the growth of wetland crops, such as reed, for second generation biofuel production; and (vi) zones for the pursuit of suitable recreational activities (Benedict and McMahon, 2006; Kazmierczak and Carter, 2010; Koomen et al., 2012; Mell, 2008).

The number of BGI projects that have been successfully carried out or are still under development is relatively small, but this number will increase in the future. Despite its great promise, there are a number of obstacles preventing the wide-scale uptake of the BGI concept. While it is costly to implement BGI, the expense is quickly recovered through avoided damage at the first flood and easily justified through the multiple benefits that accrue. In some parts of the world, such as in The Netherlands, BGI is well accepted; but the concept has not been as widely implemented elsewhere due to a general lack of awareness (Thorne et al., 2015).

The most important antecedent to BGI is the extensive spatial planning work and research undertaken in The Netherlands over many decades. In particular, climate change impacts on flooding are especially relevant in the Netherlands where about 25% of the land is below mean sea level and over 50% of the country is being protected from flooding by embankments (Koomen et al., 2012; Snepvangers et al., 2011; Sposito et al., 2014; Verburg et al., 2012). More broadly, it has been argued that:

"Drastic changes are expected in land-use patterns as a result of socioeconomic developments and climate change. Biodiversity and other land-use functions require larger areas for adaptation to changes in climatic conditions and thus increase competition for available space. This requires a different, more multi-functional type of land-use planning and more efficient management of resources" (Koomen et al., 2012).

Practical examples from The Netherlands of various possible components of BGI that promote functional synergies are illustrated in Figure 1 (Snepvangers et al., 2011). In this figure, Figure 1(a) shows a long and flat reservoir, which allows for a highly flexible system to store water at different levels. This BGI component can be ecologically managed to develop a large natural area along the watercourse, so improvements in water quality can be secured. The larger area has the capacity to soak up much more of the nutrient and sediment load than the animals and plants in the stream channel, which can be overwhelmed at the time of heavy rainfalls. Therefore, it can improve the water quality. Moreover, wetlands take a while to fill and empty during a flood, so they help decrease the size of floods for downstream areas (Snepvangers et al., 2011).

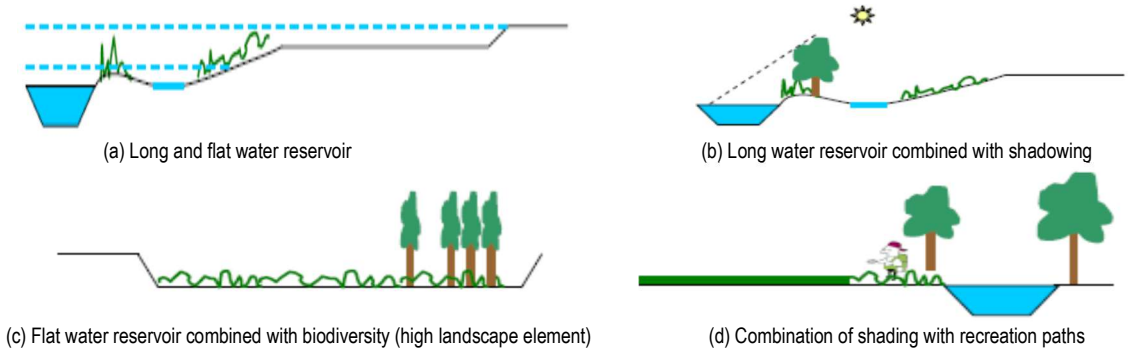


Figure 1: Practical examples from The Netherlands of various possible components of BGI (Snepvangers et al., 2011)

Table 1

Classification of BGI components based on their contribution to flooding mitigation and their position (Cruijsen, 2015)

	Surface	Sub-surface	Aboveground
Infiltration retention	parks and forests, permeable pavement, storm water flow-through planters, storm water trees, bio retention garden, bio retention swales, regional agriculture	subsurface storage with retention capacity	green facades, green roofs, trees
Storage retention	regional wetland, retention storage basins, seasonal storage and rainwater harvesting		rainwater tanks
Detention	surface detention ponds, water square	subsurface storage tanks	blue roofs

Figure 1(b) shows a long water reservoir combined with shadowing along the river banks. If the banks are designed with attention to dynamic changes, water quality improvements can be secured. For instance, dynamic changes can be obtained by planting suitable trees (river trees) that project shadows to the watercourse. Shadows aid significantly in keeping watercourse temperature cool. Catchment organisms desire their watercourse to be shaded. Warmer water can't carry as much dissolved oxygen, and this will lead to water quality decline and death for some organisms that can't survive in these situations. Tree planting also helps to stabilize the bank and reduce erosion and reinstate the natural habitat. It also prevents excess soil and nutrients from getting into the watershed and will improve the quality of the water. Figure 1(c) shows the combination of a flat water reservoir that can be enhanced by marshy forests (wetlands) and a rich plant growth at a low level to attract birds and animal species. Figure 1(d) shows shading that has been secured through high landscape elements (trees) along a watercourse, which adds variety as well as interesting resting places for people pursuing recreational activities (Snepvangers et al., 2011).

3.1 Classification of BGI Components

A wide variety of BGI components have been classified for designing resilient areas in the past several years. BGI components can be broadly categorized according to function, position, and scale (Cruijsen, 2015; Pötz and Bleuze, 2012).

3.1.1 Function

The first categorization of BGI components is based on their contribution to reducing storm water runoff. That is, detention and retention components. Detention components can store water during and after extreme precipitation and gradually discharge it to the sewer system. On the other hand, retention components can store water and gradually infiltrate it to the

ground without any connection to the sewer system. Storage retention components are natural storage basins with low infiltration capacity that are always filled with water. Infiltration retention components infiltrate water directly without containing it (Cruijsen, 2015; Pötz and Bleuze, 2012).

3.1.2 Position

The second categorization of components is based on their position: above ground, on the ground, or subsurface components. Above the ground, BGI components such as green roofs, blue roofs, and green facades can gather the storm water to reduce precipitation overflows. On the ground components include vegetated areas and usually have a significant impact on a site's livability. Finally, subsurface components include measures below the ground surface, which typically are constructed below public spaces or existing constructions. Storage below farms, gardens, and playing fields are some examples (Cruijsen, 2015; Pötz and Bleuze, 2012).

3.1.3 Scale

The third categorization of the components is based on the scale in which the components can be implemented: regional/urban, private, or block scale. On the regional/urban scale, efficient components include regional/urban agriculture, parks, protected areas, public spaces, wetlands, and retention and detention ponds. In this situation, the connectivity between the blue and green districts will improve the impacts of BGI components individually. Private scale components such as blue and green roofs, private gardens, and rain water containers can reduce storm water overflow on private segments. Block scale components such as planters, permeable pavement, water squares, and subsurface storage, contain collections of public or private segments (Cruijsen, 2015; Pötz and Bleuze, 2012).

A sample of the first two classifications of BGI components is summarized in Table 1 (Cruijsen, 2015).

3.2 Performance of BGI Components

As previously discussed, BGI has a number of tangible and intangible benefits. BGI provides many physical advantages, such as flood volume reduction, aquatic ecosystem protection, healthy ecosystem provision, the creation of biodiversity-rich zones, species diversity protection, water quality improvement, air pollution reduction, noise reduction, and drought amelioration. It also strongly supports social interaction by improving physical and mental well-being connection between different groups in society via social activities in public spaces as well as areas for recreational activities and places for spending time with family members and friends. Moreover, the added value of BGI in economic terms is direct and indirect. It contributes directly through the supply of services (flood protection, recreational space) and goods (farm produce). There are also many indirect advantages that are hard to calculate, such as improving property values, amenity, and the quality of services and goods.

The contribution of different BGI components such as parks/forests, farms, planters, permeable pavements, green/blue roofs, seasonal storage, rainwater harvest, detention ponds/tanks, green facades, retention ponds, hollow roads, storm water trees, open channel water, bio retention swales, and rain gardens in addition to the physical, social, and economic advantages can be weighted according to their estimated adaptation performance.

4. Case Studies of Development Scenarios Based on BGI

This section covers the implementation of BGI in different countries.

4.1 The Netherlands

Different BGI schemes have been applied in different parts of The Netherlands. These approaches combine employing natural and water resources to provide multi-functional climate corridors, which in turn result in efficient nature adaptation, agrobiodiversity, and sustainable farming (Steingrover et al., 2010).

4.1.1 Hoeksche Waard

In 2010, the Dutch Government conducted a study aiming to design a blue-green network for pest control in Hoeksche Waard - an agricultural

area in the southwest of the Netherlands identified by cultivable fields and a widespread network of creeks, dikes, ditches, and field margin (Steingröver et al., 2010). The goal was to discover how logical knowledge about the relevance between the spatial structure of blue-green networks and improvement of natural pest control could be applied by local stakeholders. Blue-green landscape elements have the potential to improve natural pest control by supplying several resources (e.g. food, shelter, favorable microclimate) for the survival of beneficial insects that suppress crop pests. Workshops were organized together with local stakeholders to develop spatial norms (i.e., minimum spatial dimension of the network elements needed to achieve the desired targets) and design rules (i.e., guidelines for stakeholders to apply spatial norms in concrete situations) for the design of a blue-green network supporting natural pest control. The stakeholders represented various interests in the area, including ecologists, farmers, hydrologists, and local policy makers. Although all stakeholders had a mutual interest in protecting the agronomic character of the area, each group also had particular interests. Hydrologists were mostly interested in securing water quality improvement and the ecologists in improving biodiversity. For farmers, natural pest control must be not only useful (i.e., crop yields must not be affected by pest damage) but also cost efficient by saving on the costs of chemical pesticides and of water purification. The ultimate goal was thus the development of sustainable farming systems that do not depend on chemical pesticides and are economically viable (Sposito et al., 2014; Steingröver et al., 2010; Alterra, 2007).

In general, three different BGI-inspired scenarios were considered for Hoeksche Waard development, as follows:

- Achieving optimal agrobiodiversity by using public and private spaces to create the BGI standards,
- Achieving effective agrobiodiversity and biological control by investment in public spaces only to create the minimum BGI standards, and
- Achieving optimal agrobiodiversity, agriculture, and recreation by using public and private spaces to create BGI standards along with focusing on recreational opportunities.

In order to measure the impacts of BGI in the Hoeksche Waard region, the Social Cost-Benefit Analysis (SCBA) method was used. This method compares the return to the society versus the costs of the required actions. The analysis showed that in all three scenarios, the benefits obtained from the solution exceeded the costs. However, according to the estimates, Scenario 3 offered a better net value. Comparatively, Scenario 2 had the least costs and benefits, and Scenario 3 had the most. In other words, Scenario 2 was the least expensive solution, and Scenario 3 was the most expensive. The net present value of Scenario 3 was nearly €30 million more and twice as much as Scenario 2 and €8 million more than Scenario 1 (Table 2) (Steingröver et al., 2010; Alterra, 2007).

Table 2

Expenses, advantages, and balance per project alternative (net present values in millions of €) (Alterra, 2007)

	Alternative 1	Alternative 2	Alternative3
Cost	64,8	25,6	89,2
Benefits (network)	102,4	50,8	133,1
Benefits (individual)	8,9	0,5	10,2
Balance	46,5	25,7	54,2

The SCBA showed any advantages as results of three scenarios dependent on an adequate system of robust and fine components. In addition to boosting agrobiodiversity, applying the blue-green concepts had other benefits for Hoeksche Waard too. For instance, it allowed for the design of a network of bike and foot paths in the area that can potentially attract more people and contribute to tourism. This example truly proved that collaboration between parties is a compulsory condition for establishing an appropriately intense system (Alterra, 2007).

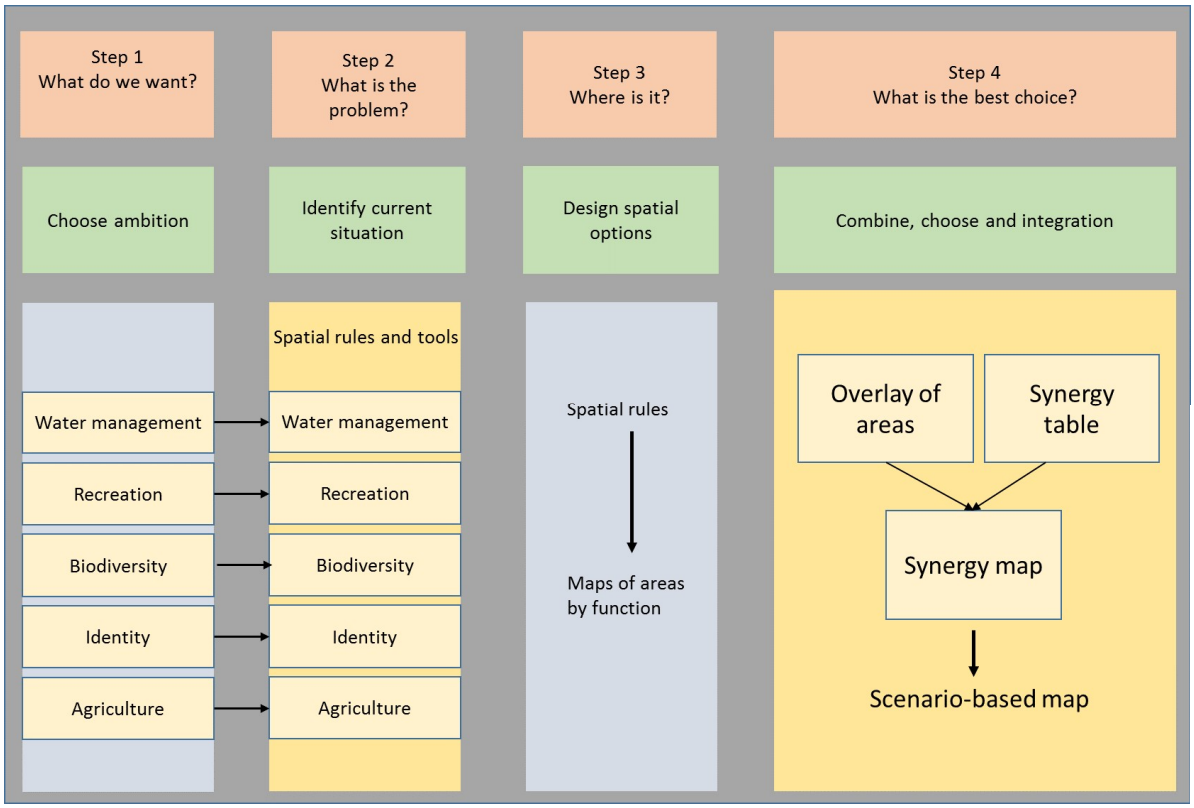


Figure 2: Four Steps of PLAN-IT Method in Salland (Snepvangers et al., 2011)

4.1.2 Salland

In the Salland Region of the Overijssel Province, Snepvangers et al. applied the PLAN-IT method (Snepvangers et al., 2011) on the design of a collaborative spatial planning strategy aiming to achieve optimal multifunctional agricultural land use. The aim of this study was to explore the spatial opportunities and potential synergies for multifunctional adaptation in order to realize how and where to invest effectively and efficiently in the regional blue-green network. The following landscape functions were considered: agriculture, water management, recreation, landscape identity, and biodiversity. Ambitions (i.e. goals) for the different functions were defined in consultation with local and regional stakeholders. The contribution of different landscape elements to the defined goals per function was then assessed in a spatially-explicit way.

The PLAN-IT method consists of four steps, which are shown in Figure 2. In the Salland example, five functions (water management, recreation, biodiversity, identity, and agriculture) were considered. Other functions can be added in other areas (Snepvangers et al., 2011).

In step 1, the ambitions (goals) by function are mapped together with stakeholders. Preferably, such ambitions should be formulated as quantitatively as possible (i.e. in the form of "objectives"). The ambitions follow partly from existing policies and partly from broader goals based on expected social and biophysical trends. In this step, it is of great importance that the time horizon is set properly. In step 2, the current situation is mapped for each function in relation to the established goals from step 1. The intent here is to determine the extent to which the desired goals are already (partly) fulfilled by existing infrastructure, what are the current developments in the area, and what is still missing to achieve the desired goals. In step 3, spatial rules are formulated per function, describing the positive or negative contribution of landscape elements for the respective goals. Based on these spatial rules,

the contribution of different landscape elements for a particular function according to their location can be determined and represented in maps showing the guidelines for the effective planning of landscape elements for specific functions. Finally, the integration of the steps 1 to 3 is carried out in step 4. Workshops with regional and local stakeholders are carried out in order to explore opportunities for the development of a spatially efficient and multifunctional BGI network. The use of quantitative planning rules creates involvement and understanding among stakeholders, and choices are based on objective goals rather than personal perceptions. The final result of step 4 is a synergy map and associated tables, displaying the areas where potential synergies and negative impacts among the considered functions occur.

The resulting map (Figure 3) depicts the areas where investing in the BGI most efficiently associates nature adaptation with other land use purposes (Snepvangers et al., 2011). The most efficient collaboration of BGI with natural landscape components is achieved in the dark blue areas on the western side and central part of the region.

4.2 Belgium

The second case study of BGI implementation is in Belgium. During the past few decades, Turnhout City has experienced considerable damage from the flooding of River Aa (De Vleeschauwer et al., 2014). Several factors, such as increased urbanization, increased amount of spilling water into the rivers, straightening of the river in the 1970s, and natural valley characteristics of the city have contributed to this problem.

To reduce the damages caused by the frequently inundated catchment, three different adaptation strategies were examined (De Vleeschauwer et al., 2014):

- Source control as a result of blue-green water integration
- Retention basins located downstream of the storm water sewers
- End-of-pipe solutions based on river flood control reservoirs

A long-term simulation (100 years rainfall) was used to quantify the efficiency of each strategy. The efficiency scores were calculated based on factors such as the sewer overflow volumes and the reduction in the frequency and volume of river floods and sewer. The simulation identified optimum locations for adaptation strategies 1 and 2. For the BGI solution, these locations were found to be the open green areas in the city centre, which can infiltrate as well as retain the storm-water (Figure 4) (De Vleeschauwer et al., 2014). Also, the third strategy was implemented as storage reservoirs, which are filled by the overflowing of a weir.

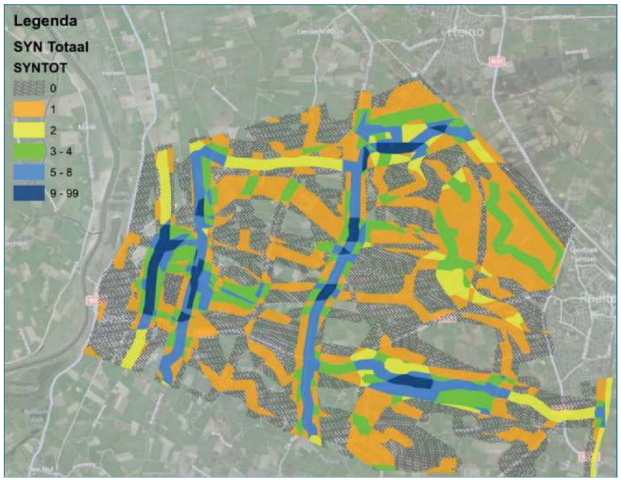


Figure 3: Synergy Amount between Different BGI Planning Objectives in Salland (Snepvangers et al., 2011)

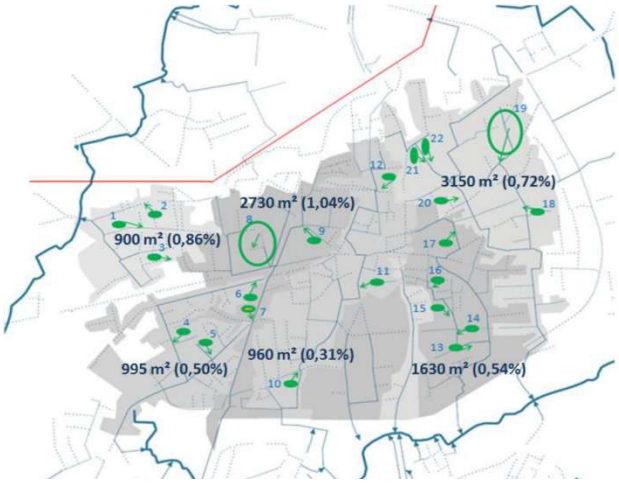


Figure 4: Locations of the 22 Open Green Bodies Recognized for BGI Components (Adaptation Option 1) (De Vleeschauwer et al., 2014)

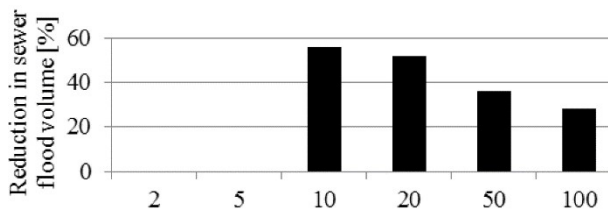


Figure 5: Reduction in Sewer Flood Volume Obtained by Implementing the BGI Strategy (Adaptation Option 1) (De Vleeschauwer et al., 2014)

As mentioned earlier, one factor in measuring the efficiency of the adaptation strategies was the reduction in flood volumes. Figure 5 (De Vleeschauwer et al., 2014) shows the reduction in sewer flood volume obtained by implementing the BGI strategy. It is considerably high and close to 55% for the return periods of 10-20 years. This is due to the non-linearity of the flood variable response to the run-off changes. The storm sewer system was designed to cope with return periods of less than 5 years. Therefore, there is no reduction in the sewer flood volumes for those periods. Note that the selected open-green locations are proportionally very small and do not exceed more than 1% of the catchment area; but their effect shows that even a very limited amount of surface, if selected properly, can reduce the sewer flood volumes significantly.

The Turnhout City experience showed that assigning open areas blue-green integration locations for water storage and infiltration demands extensive collaboration between urban planning and management. Nevertheless, it results in more sustainability and biodiversity.

Figure 6 (De Vleeschauwer et al., 2014) shows the effect of applying strategies 1 and 2 on the storm sewer overflow. While the impact of blue-green water integration on the reduction of sewer flood volumes was considerable (Figure 5), its impact on the storm sewer overflow was limited (Figure 6). However, the retention basins show significant performance in peak overflow discharge. Since these retention basins were designed for return periods of less than 20 years, they have the best efficiency for those periods. For larger return periods, their effect is smaller but still more than 50% in comparison to no adaptation (De Vleeschauwer et al., 2014).

4.3 Japan

Another successful example of BGI can be found in Japan. Given the threats of climate change and the loss of green spaces in the city, Nagoya has undertaken various measures to create more sustainable lifestyles. The key initiative that aims to increase green space is the Nagoya Strategy for Biodiversity, which recognizes the links between the green space cover and the urban heat island effect. This strategy also includes the Nagoya Water Cycle Revitalization Plan, which aims to re-establish the natural water cycle that has been disturbed due to continued urban development. In particular, it aims to increase the infiltration of water into the ground from the present level of 24% to 33% and to reduce runoff levels from 62% to 36% by 2050. This is to be achieved through protection and increased provision of green space, green roofs, permeable paving, and other structural measures, allowing the infiltration of rainwater to ensure the effective use of underground water (Figure 7). It provides a multi-functional and cross-sectoral approach to increase the blue-green spaces in the city and, as a result, the sustainability of the city (Kazmierczak and Carter, 2010).

4.4 The United States

An interesting example for the USA is the delta city of Hoboken. It is susceptible to floods caused by extreme storm weather events (Cruijsen, 2015; Showstack, 2014) as well as coastal flooding. To establish a sustainable urban water management system and to decrease the susceptibility of the city to extreme water events, a BGI strategy was developed. Figure 8 (Cruijsen, 2015) illustrates how the retention and infiltration obtained by a BGI-influenced approach affects the water drainage in Hoboken.

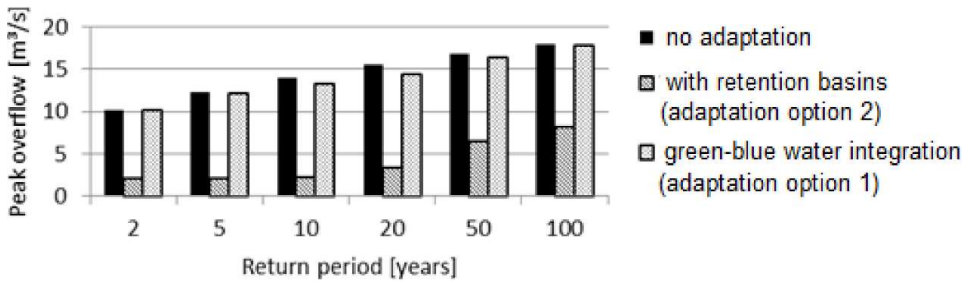


Figure 6: Results of Applying Strategies 1, 2, and No Adaptation on the Storm Sewer Overflow (De Vleeschauwer et al., 2014)

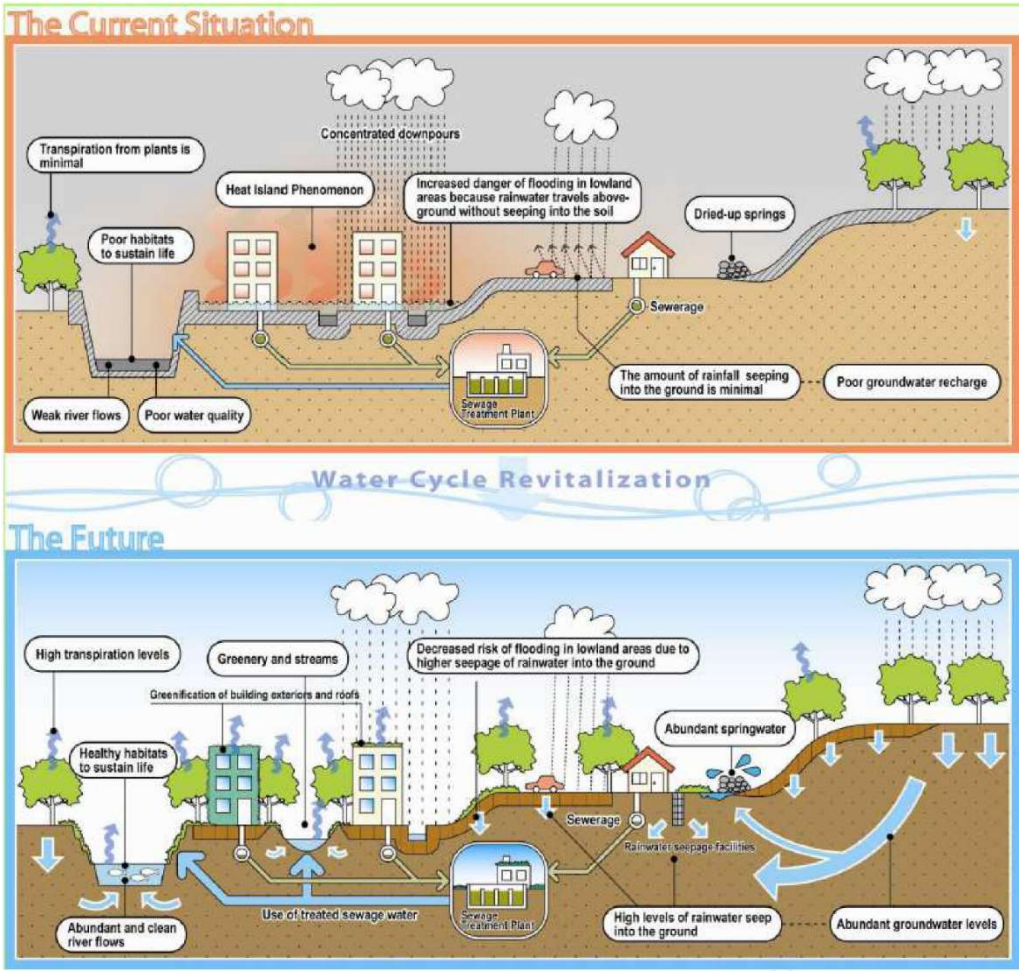


Figure 7: The BGI Plan in Nagoya (Kazmierczak and Carter, 2010)

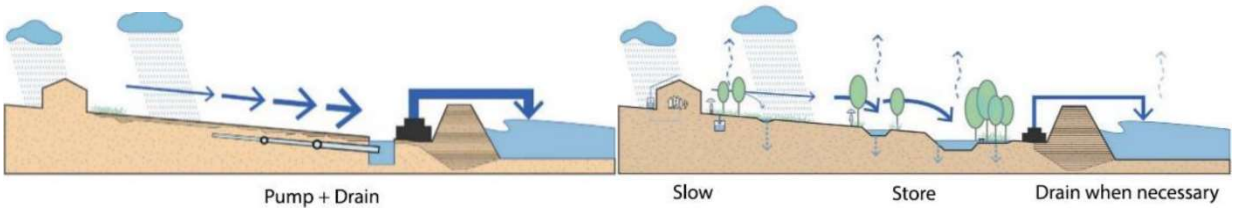


Figure 8: Retention and Infiltration Obtained by a BGI-influenced Approach (Cruijsen, 2015)

Urban planning along with information on the subsoil characteristics identified the best BGI measures for Hoboken. They involved subsurface detention storage in higher elevations, trees and permeable pavements for infiltration, and storm water flow-through planters. Also, other measures, such as urban farming, open water, detention below sport fields, and water/green squares for public spaces were implemented.

To ensure the maximum benefits, five different strategies with combinations of BGI components were studied. These strategies were as follows (Cruijsen, 2015):

- Improving the current situation with subsurface adaptation measures that include using deep and shallow storage basins
- Improving the current situation with infrastructural adaptation measures that include using permeable pavements, storm water infiltration, green streetscapes, and planting trees along the roads
- Applying adaptation methods on the public space, which include transforming undeveloped public areas into rain gardens, water and green squares, detention below sport fields, retention ponds, and more
- Applying adaptation methods on private spaces, which means implementing blue-green roofs
- Combining all previously proposed measures

The performance of five scenarios was measured based on the Storm Water Management Model and used the following parameters to quantify the contribution of proposed strategies in water management: flood volume reduction, combined sewer overflow reduction, city infrastructures vulnerability reduction, and improvement in the quality of life.

Although all strategies had an influence on storm water reduction and improving the quality of the environment, not all of them were as effective as strategy 5. Strategy 1 could collect about 10% of the total flood volume, and since only subsurface storage and no vegetated measures were applied, it had the least contribution on improving the quality of the environment. While strategy 2 contained the greening of three main roads, it had a very extensive impact on the green experience of the area. Among all strategies, strategy 3 had the least influence on total storm water reduction since it used undeveloped areas to construct a green system in the city. In strategy 4, appropriate buildings were developed with green roofs, which resulted in the improvement of storm water reduction, air quality, and mitigation of the heat. Strategy 5 comprehensively joined all strategies into a framework of BGI. It had the most additional green bodies in the framework of vegetated components. The results of modelling revealed that Hoboken would benefit most from strategy 5, specifically in terms of flood reduction. Since it was the combination of all the other measures, it inherited their advantages (Tables 3 and 4) (Cruijsen, 2015).

Table 3

Flood volumes per sub basin for a T10 storm event (Cruijsen, 2015)

Sub basin	Strat.0Volume [MG]	Strat.1Volume [MG]	Strat.2Volume [MG]	Strat.3Volume [MG]	Strat.4Volume [MG]	Strat.5Volume [MG]
H1	11.90	7.80	11.37	11.88	10.42	6.37
H2	0.01	0.0	0.0	0.01	0.0	0.0
H3	3.47	3.00	3.31	3.47	2.98	2.46
H4	4.91	3.08	4.69	4.91	4.09	2.19
H5	2.38	0.91	2.17	2.38	1.76	0.54
H6	2.74	2.19	2.55	2.71	2.42	1.78
H7	4.33	3.21	3.86	4.33	3.26	1.68
Total	29. 7	20.2	27.0	29.7	24.9	15.1

Table 4

Rainfall Runoff (MG per 24 hours) per sub basin for T10 design storm (Cruijsen, 2015)

Sub basin	Total Volume Storm Water [MG]	Strategy 0 [MG]	Strategy 1 [MG]	Strategy 2 [MG]	Strategy 3 [MG]	Strategy 4 [MG]	Strategy 5 [MG]
H1	35.4	22.3	22.3	21.7	22.3	20.7	20.1
H2	4.0	2.4	2.4	2.2	2.4	2.1	2.0
H3	9.2	5.4	5.4	5.2	5.4	5.0	4.8
H4	14.4	9.3	9.3	9.2	9.3	8.4	8.2
H5	21.4	11.0	11.0	10.5	10.3	9.7	9.3
H6	3.8	2.5	2.5	2.3	2.5	2.2	2.0
H7	10.9	7.0	7.0	6.3	6.7	6.1	5.4
Total	99.1	59.9	59.9	57.5	58.9	54.2	51.8
Percent	100	60.4	60.4	58.0	59.4	54.6	52.2

Table 5

The summary of benefit / impact scorecard for future proofing projects of Madurai (Aktins, 2014)

Future proofing projects in Madurai	Benefit / Impact Scorecard			
	Climate change impacts mitigation	Securing society requirements	Securing resource productivity	Prioritization
Sewer system rehabilitation	5	5	4	5
Sanitation community capacity building	4	5	5	5
Improved solid waste management	4	3	4	4
Straightening social capital to improve sanitationand solid waste management	3	4	4	4
Channel and tank restoration	5	5	5	5
Channel and tank protection and management	4	4	4	4
Channel and tank community involvement	4	5	5	5
Flood & surface water infrastructure improvements	4	5	3	4
Flood & surface water capacity building	4	5	5	5
Water resources infrastructure improvements	4	4	3	3
Proposals for blue-green infrastructure coordination	3	4	5	5
Green city plan	4	4	4	5

4.5 India

In March 2013, the Climate Development Knowledge Network commissioned the Indian Institute of Human Settlements and the University College London to develop an action plan for future urban strategies of Bangalore and Madurai. The main objective of the project was developing policies for climate hazards and promoting a low-carbon economy as well as economic development and reducing poverty (Aktins, 2014). This collaboration is in its early stages. However, it has highlighted the role of water resources management and urban growth management and the criticality of their integration in Madurai's BGI. This involves surface and ground water management, water sanitation, water distribution, storm water management and drainage as well as urban development and natural habitats. Also, the first phase of this collaboration showed that BGI provides a mechanism to address the

vulnerabilities that Madurai faces (Aktins, 2014).

To find out how the project will tackle the desired objectives, a benefit / impact scorecard was established. The future proofing dimensions were defined as follows:

Climate Change Impacts Mitigation:

Preliminary evaluation on whether the project will be effective on climate change impact. These impacts include: variability in monsoons, higher temperatures, extreme rainfall events/flooding; 5 = very high, 4 = high, 3 = medium, 2 = low, 1 = very low / no impact.

Securing Society Requirements:

Preliminary evaluation on whether the project will decrease vulnerability of society and decrease multidimensional destitution by preparing basic facilities and health improvements; 1 - 5 scale.

Securing Resource Productivity:

Preliminary evaluation on whether the project will address resource efficiency such as food security, water shortage, and natural habitat; 1 - 5 scale.

Prioritization:

A preliminary evaluation was completed for the prioritization, which needs to be given to each policy within the overall strategy.

The summary of benefit / impact scorecard for future proofing projects of Madurai is illustrated in Table 5 (Aktins, 2014).

The action plan for the application of BGI in Madurai has six themes: water resources supply demand balance; flood and surface water management; sanitation; solid waste management; rehabilitation of channels and tanks; and governance and future proofing planning. As mentioned earlier, this project is fairly new, but the implementation of the action plan improves the governance and provides a framework for future proposals in the region. Based on the plans for Madurai city, the citywide BGI masterplan will deliver a flexible plan that results in a more sustainable city. The Madurai Master Plan will be fully implemented by 2031. The plan contains schedules to design resilience measures and tackle vulnerability in the short term as well as tackle the long term climate change impacts (Aktins, 2014).

4.6 Lessons

A wide variety of lessons can be extracted from the case studies explained in this review paper. All these lessons can be classified based on climate change adaptation and sustainable development. These lessons are mostly applicable in different spatial scales since they are standard and generic, and include the following:

- The importance of adaptation initiation; why it is necessary to adapt and what are the best ways of adaptation?
- The need for ongoing management beyond the life of the BGI project implementation phase
- Educating people, stockholders, and policy makers within the organizations regarding BGI impacts and the implementation process
- Cooperative working; impacts of internal and external cooperation for an effective adaptation framework
- Using the experiences related to other people or case studies to get the maximum benefits in a particular case study
- Public participation in planning and decision-making as citizens, residents, and stakeholders desire and expect to be involved in public projects
- Ongoing monitoring and evaluation of the results, which improves the project plans and efficiency as well as documents the results and experiences

Although several countries have benefited from embracing strategies based on BGI to approach climate change, the authors of this paper believe that among all the BGI solutions reviewed, the PLAN-IT methodology developed in The Netherlands (Snepvangers et al., 2011) is the most robust and holistic approach. It focuses on combined climate change adaptation measures for nature and water systems and creates multifunctional climate corridors that are effective for habitat conservation, as well as being efficient in the use of space and other resources (Koomen et al., 2012). It consists of a collaborative approach in which local stakeholders are involved in the

definition of ambitioned goals for different landscape/land use functions and in the assessment of alternative infrastructure options and their underlying synergies.

5. Feasibility of Blue-Green Infrastructure

A key step in implementing the BGI concept is to first assess the suitability of BGI components for a given context. As such, we propose a possible decision framework (Figure 9) to assess the feasibility of BGI, which consists of two major parts: (i) Adaptation Components and (ii) Evaluation Tool. Different elements of Adaptation Components and Evaluation Tool will be described in this section.

5.1 Adaptation Components

Practical feasibility, site feasibility, and integrated evaluation are main parts of the adaptation components.

5.1.1 Practical Feasibility Evaluation

This evaluation needs the collection of environmental and watershed data.

Ecological features: Ecological characteristics of the watershed include geomorphologic conditions that define the amount of infiltration and retention in the soil (such as landscape slope, dynamics, groundwater depth, and soil type) and climatic conditions that impact the process of evapotranspiration and cooling (like solar radiation and temperature) (Fryd et al., 2012; Fletcher et al., 2013; Roldin et al., 2012).

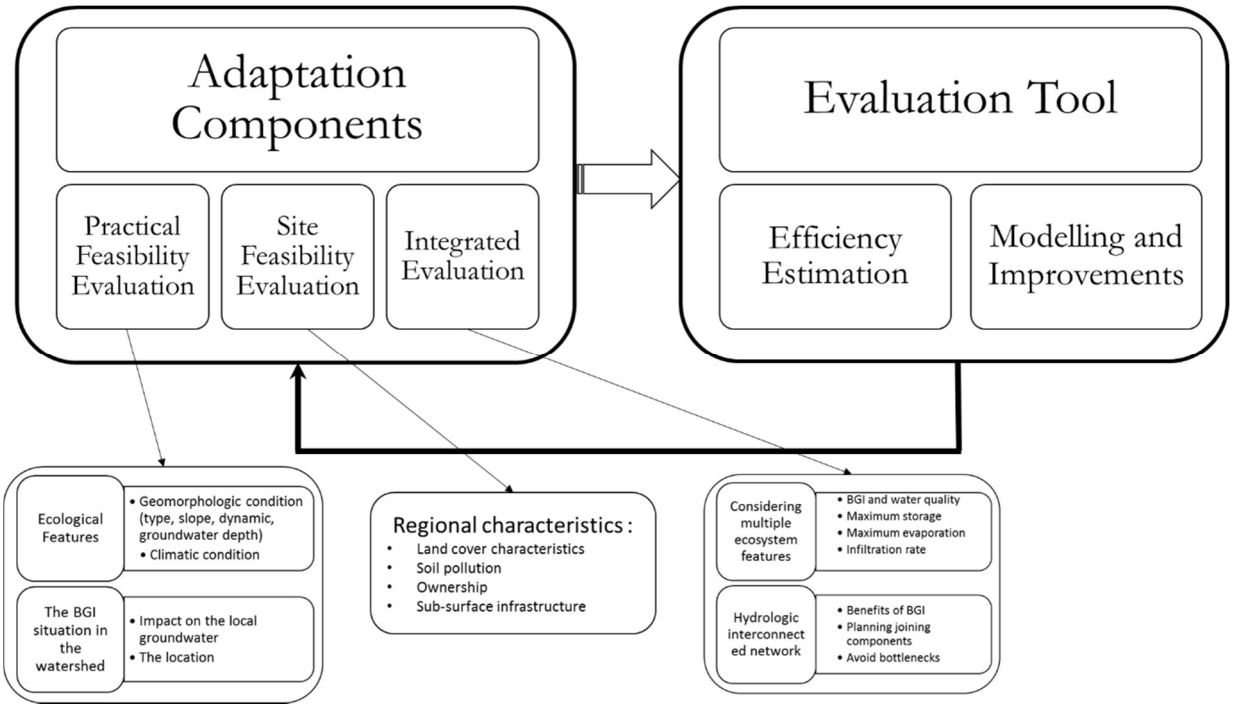


Figure 9: BGI Feasibility Set-up (Ghofrani et al., 2016a)

Depending on the ecosystem, BGI performance is affected by one or several of these ecological features.

The BGI situation in the watershed: While checking the conditions for feasibility of BGI, we have to consider how BGI will influence regional and local groundwater levels. In these systems, soil water infiltrates and drainage of shallow groundwater by sewers happens when regional and local groundwater levels become higher than the depth of the drainage or sewer system in the soil [Hamel et al., 2013; Fletcher et al., 2013; Rodriguez et al., 2008; Roldin et al., 2012). Moreover, at the beginning of the planning procedure, it is crucial to evaluate the location of the BGI in the catchment. Applying BGI can impact the hydrological load downstream when the position is upstream in the catchment (Fryd et al., 2013).

5.1.2 Site Feasibility Evaluation

This is a data-extensive phase that utilizes basic field data.

Regional characteristics: Regional characteristics, such as land cover features, soil pollution, ownership, and existence of subsurface infrastructure, play an important role in site complexity [Bastien et al., 2010; Fryd et al., 2013). The more complex the situation is, the more challenging it is to apply BGI. We have to consider density of the land cover of the regional area as well as subsurface infrastructure, soil, and groundwater pollution when choosing the BGI. Moreover, as it is more challenging to implement BGI on private property, ownership is one of the most important obstacles in implementing the BGI in regional areas (Fryd et al., 2013; Sauerwein, 2011).

5.1.3 Integrated Evaluation

For generating regional resilience to flooding and drought and in order to optimally use BGI, a composition of effective and cost efficient measures based on the characteristics of the site should be implemented.

Considering multiple ecosystem parameters: Some main parameters such as evapotranspiration on a hot day for cooling, retention for extreme precipitation events, peak discharge reduction, seasonal water storage at beginning of drought period, extra groundwater recharge, and the influence of BGI on water quality should be identified in order to assess the contribution of the BGI to the climate change mitigation and sustainability improvement (Voskamp and Van de Ven, 2015).

Hydrologic interconnected network: BGI is significantly different from conventional "hard" built infrastructure such as roads, sewerage and drainage systems, and utility lines. BGI components' connection is very important, as most of the BGI advantages arise from its interconnected networks of components. Storage and infiltration components can be interconnected via linear water transition components. In this situation, components can provide support for one another, and if full capacity of one component is reached, another component can take over and collect the water (Jefferies et al., 2009; Villarreal et al., 2004). During heavy rainfall, when all existing storage capacity in the system is to be deployed, connectivity is very important (Villarreal et al., 2004). Planning the joining of components and their spatial positioning is essential to avoid bottlenecks and other unwanted flow phenomena (Villarreal et al., 2004). As an integrated evaluation, we have to compute the total scores of the BGI on practical feasibility and site feasibility to estimate their complementarity to the existing system capacities.

5.2 A Proposed Evaluation Approach

Efficiency estimation, modelling, and improvement are the main parts of the evaluation approach.

5.2.1 Efficiency estimation

As shown in Figure 9, adaptation components will be applied to a project area and its efficiency will be evaluated by an efficiency valuation device such as a Planning Support System (PSS). Figure 10 illustrates the key components of a PSS (under a common ArcGIS platform). PSS serves as the command centre of implementable BGI components, managing the data exchanges between different parts of the system.

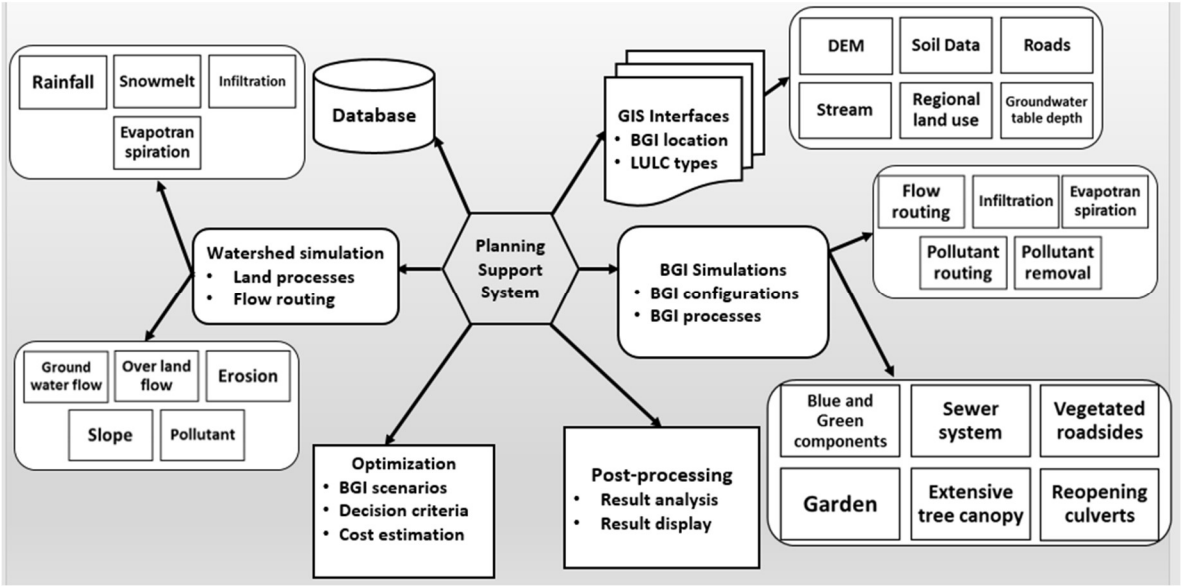


Figure 10: Key Components of BGI Planning Support System (Ghofrani et al., 2016b)

The GIS-based PSS will directly compute estimates of expenditures, benefits, and multiple parameters on agro-ecosystems. This evaluation will provide users with a means of comparison before and after the implementation of BGI.

5.2.2 Modelling and Improvement

As soon as the users have carefully chosen a number of practicable alternative adaptation components through efficiency estimation techniques, water administrators can provide more comprehensive investigation of the water quantity and quality dynamics during extreme precipitation, drought, and flooding while designers can create more comprehensive plans. Based on these investigations, they can further improve their plans and the efficiency of their estimations.

After considering the BGI feasibility in the area, implementation is the next step. Based on the purpose of implementing BGI in the area and also based on the scale of the project, different approaches can be considered (although a discussion of this aspect is beyond the scope of this paper). However, it is important to mention that different approaches determine the likelihood to move forward and are not necessarily contradictory (Alterra, 2007). Although there are many unresolved questions about implementation, maintenance, and ongoing monitoring of BGI, it is possible to make some recommendations based on the literature outlined in this review:

- It is essential to have a manager's role well-defined and the quality and improvements of the different activities supervised to get the optimum results from BGI. It is highly suggested to bring added value in terms of management and governance knowledge through the horizontal and vertical management directions and the experience of statesmen and agencies. Plan-led development involves a complex trade-off between investment in the key infrastructure underpinning production and productivity increases (e.g. water-related infrastructure, low cost/emission energy) with the associated facilities necessary to deliver products to national and global markets in a timely and efficient manner (Sposito et al., 2014; Alterra, 2007).
- It is necessary that executive members of the managing group have effective communications with themselves as well as with the rest of the group and people for successful implementation. There should be opportunities for shareholders and citizens to express their demands with regard to the development of the area. Decisions and reasons for the selected components should be openly communicated with investors and financiers in the entire area (Koomen et al., 2012; Alterra, 2007).

- BGI project monitoring and control policies should occur in parallel with project implementation procedures. Therefore, while the project is being implemented, it is being monitored and controlled by applying the suitable level of reformative functions. This allows the improvement of the project to be judged for its effectiveness.
- The current situation should be mapped for each function in relation to the established goals. The purpose is to determine the extent to which the desired goals are already (partly) fulfilled by existing infrastructure, what the current developments in the area are, and what is still missing to achieve the desired goals.
- Spatial rules should be formulated per function, describing the positive or negative contribution of landscape elements for the respective goals. Based on these spatial rules, the contribution of different landscape elements to a particular function according to their location can be determined and represented in maps showing the guidelines for the effective planning of landscape elements for specific functions. Workshops with stakeholders should be carried out in order to explore opportunities for the development of a spatially efficient and multifunctional BGI network. The use of quantitative planning rules creates involvement and understanding of stakeholders, and choices are based on objective goals rather than personal perceptions (Kazmierczak and Carter, 2010; Alterra, 2007).
- In order to investigate the costs and benefits of BGI, it is useful to perform an organized inventory of short-term and long-term impacts using a Cost Benefit Analysis (CBA) (including determination of Net Present Value of the options). Applying BGI will require primary funds as well as investments for management in the long term, which leads to financial responsibilities for involved committees. Considering how the benefits and costs will be divided into different investors/parties and different spatial and geographical scales will provide us with possible ways of financing the construction of the BGI (e.g. private–public partnerships) (Sposito et al., 2014; Alterra, 2007).

6. Discussion and Conclusions

The Earth's climate has changed in the past, is changing now, and further changes seem unavoidable in the foreseeable future. Thus, there is an imperative need to prepare for climatic change, and we need to anticipate the changes and develop and implement adaptation actions now (Bates et al., 2008; Meehl et al., 2007; Rahman et al., 2010; Wenger et al., 2013).

Environmental management in a changing climate will be very complex because of increased scarcity and increased competition for natural resources such as water. These new challenges alter the role of natural resource managers and planners. They will have to incorporate land-use planning with blue-green bodies for designing an environment that is compatible with the expected future climate (Falkenmark and Rockström, 2006; Lawson et al., 2014; Preston and Jones, 2006; Thorne et al., 2015; Walsh et al., 1999; Whetton et al., 2002).

Climate change impact mitigation includes a comprehensive and continuous assessment and social investigation. Here "comprehensive" means entire climate change hazard and "continuous" means the requirement for its ongoing monitoring by society (Schanze, 2006). Unlike the short-term mitigation of climate change impacts, long-term management emphasizes the construction, control, and implementation of policies to deal with the climate change consequences of the future. Therefore, the dynamic of the environment and its effects need to be discovered such that environmental managers can assess the appropriateness of an alternative approach for the future. On the other hand, the future is highly unpredictable and will bring its own new requirements to the managing process (Schanze, 2006).

As an increase in the variability and potential impact of climate change in the future is predicted, we can expect more environmental damage (Lawson et al., 2014; Thorne et al., 2015). The climate change impacts will be further exacerbated by the expected increase in urbanization and economic growth. Therefore, a demand for new and inventive research to decrease the consequences of climate change is inevitable. In ad-

dition, the research should help to design sustainable regions to climate change considering the economic development (Bates et al., 2008; Lawson et al., 2014).

The creative use of Blue-Green Infrastructure is one of the most promising actions for adaptation to rapidly changing human and environmental circumstances. This needs to be recognized in the planning process, especially in the formulation of Regional (Spatial) Development Strategies. Above all, the development of this important concept can be a key component for: (i) mitigating observed and likely future climate impacts, (ii) securing water for regional and agricultural development, and (iii) creating jobs for urban/regional areas. The scale and inter-connectedness of the problematic situations confronting regional systems, its human communities, and natural ecosystems are such that only well thought out systemic intervention practices, which are ethical, take account of multiple viewpoints, and are sensitive to the ecology we are a part of, would offer hope of successfully tackling them (Sposito et al., 2014).

The multiple benefits of adopting BGI will span both the local/regional and global/international scales. Here are some benefits of BGI:

- As BGI improves land connectivity and secures marine ecologies, it is a driver for biodiversity
- As BGI provides groundwater storage, stability for water systems, improvement in water quality, and water purification, it is a very vital water-related network service
- As BGI mitigates the impact of climate change and improves water management systems, it is a very significant tool for designing resilient regions and improving the flexibility and adaptability of infrastructure
- As BGI secures space for social, exercise, and recreational activities, it usually improves human physical and mental health; thus, it can save health costs as well
- BGI attaches people with nature, and it can support humans' relationship with nature as it links people with natural forms, features, or processes
- As BGI decreases the global warming effects, moderates the temperature, and supplies air ventilation, it plays an important role as a moderator for climate
- As BGI improves open/protected space usage for families gathering and group activities, it provides social collaboration
- BGI decreases storm-water financial costs in a holistic and long-term way
- BGI enriches a region's credit, as it hints at a region's general livability and attractiveness
- As BGI improves the aesthetic and social attractiveness of the environment, it will increase property (land and building) values

References

Ahern, J. (1995), "Greenways as a planning strategy", *Landscape and Urban Planning*, 33(1):131–155

Allison, H. E. and Hobbs, R. J. (2004), "Resilience, adaptive capacity, and the lock-in trap of the Western Australian agricultural region", *Ecology and Society*, 9(1)

Ashby, W. R. (1957), "An introduction to cybernetics", Chapman & Hall Ltd

Baker, S. (2007), "Sustainable development as symbolic commitment: Declaratory politics and the seductive appeal of ecological modernization in the European Union", *Environmental Politics*, 16(2):297–317

Bastien, N., Arthur, S., Wallis, S., and Scholz, M. (2010), "The best management of SuDS treatment trains: a holistic approach", *Water Science & Technology*, 61(1)

Bates, B., Kundzewicz, Z. W., Wu, S., and Palutikof, J. (2008), "Climate change and water: Technical paper VI", *Intergovernmental Panel on Climate Change (IPCC)*

Benedict, M. A. and McMahon, E. T. (2002), "Green infrastructure: Smart conservation for the 21st century", *Renewable Resources*, 20(3):12–17

Benedict, M. A. and McMahon, E. T. (2006), "*Green Infrastructure: Linking Landscape and Communities*", Island Press

Berkes, F., Colding, J., and Folke, C. (2008), "*Navigating social-ecological systems: Building resilience for complexity and change*", Cambridge University Press

Chapin III, F. S., Kofinas, G. P., Folke, C., and Chapin, M. C. (2009), "Principles of ecosystem stewardship: resilience-based natural resource management in a changing world", *Springer Science & Business Media*

Cruijsen, A. (2015), "Design opportunities for flash flood reduction by improving the quality of the living environment: A Hoboken City case study of environmental driven urban water management" *PhD thesis*, TU Delft, Delft University of Technology

De Vleeschauwer, K.Weustenraad, J., Nolf, C.,Wolfs, V., De Meulder, B., Shannon, K., and Willems, P. (2014), "Green-blue water in the city: quantification of impact of source control versus end of pipe solutions on sewer and river floods", *Water Science and Technology*, 70(11):1825–1837

Fábos, J. G. and Ryan, R. L. (2006), "An introduction to greenway planning around the world", *Landscape and Urban Planning*, 76(1):1–6

Faggian, R., Romeijn, H., and Sposito, V. (2012), "Soil data necessary for land suitability assessments in the Gippsland region", Technical report, *Agriculture Victoria Services Pty. Ltd., Melbourne*

Faggian, R. and Sposito, V. (2009), "Systemic regional development - a system thinking approach", *In Proceedings of the 53rd Annual Meeting of the ISSS*

Falkenmark, M. and Rockström, J. (2006), "The new blue and green water paradigm: Breaking new ground for water resources planning and management", *Journal of water resources planning and management*, 132(3):129–132

Fletcher, T. D., Andrieu, H., and Hamel, P. (2013), "Understanding, management and modelling of urban hydrology and its consequences for receiving waters: A state of the art", *Advances in Water Resources*, 51:261–279

Fryd, O., Backhaus, A., Birch, H., Fratini, C. F., Ingvertsen, S. T., Jeppesen, J., Panduro, T. E., Roldin, M., and Jensen, M. B. (2013), "Water sensitive urban design retrofits in copenhagen-40% to the sewer, 60% to the city", *Water Science & Technology*, 67(9):1945–1952

Fryd, O., Dam, T., and Jensen, M. B. (2012), "A planning framework for sustainable urban drainage systems", *Water Policy*, 14(5):865–886

Gentle, N., Kierce, S., and Nitz, A. (2001), "Economic costs of natural disasters in Australia", *Australian Journal of Emergency Management*, 16(2):38–43

Ghofrani, Z., Faggian, R., and Sposito, V. (2016a), "Designing resilient regions by applying blue-green infrastructure concepts", *WIT Transactions on Ecology and the Environment, 204, pp.493-505*

Ghofrani, Z., Faggian, R., and Sposito, V. (2016b), "Infrastructure for development: blue green Infrastructure", *Planning News*, 42(7):14–15

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*, 33(1):115–133

Gunderson, L. H., Allen, C. R., and Holling, C. S. (2012), "*Foundations of ecological resilience*", Island Press

Hamel, P., Daly, E., and Fletcher, T. D. (2013), "Source-control storm water management for mitigating the impacts of urbanization on base flow: A review", *Journal of Hydrology*, 485:201–211

Holling, C. S. (1973), "Resilience and stability of ecological systems", *Annual Review of Ecology and Systematics*, pages 1–23

Jefferies, C., Duffy, A., Berwick, N., McLean, N., and Hemingway, A. (2009), "Sustainable urban drainage systems (suds) treatment train assessment tool", *Water Science and Technology*, 60(5):1233–1240

Jongman, R. H. G. and Pungetti, G. (2004), "*Ecological networks and greenways: concept, design, implementation*", Cambridge University Press

Kazmierczak, A. and Carter, J. (2010), "Adaptation to climate change using green and blue

infrastructure. A database of case studies", Technical report, University of Manchester

Koomen, E., de Moel, H., Steingröver, E. G., van Rooij, S. A. M., and van Eupen, M. (2012), "Land use and climate change", Technical report, *National Research Programme Climate Changes Spatial Planning*

Lawson, E., Thorne, C., Ahilan, S., Allen, D., Arthur, S., Everett, G., Fenner, R., Glenis, V., Guan, D., Hoang, L., Kilsby, C., Lamond, J., Mant, J., Maskrey, S., Mount, N., Sleigh, A., Smith, L., and Wright, N. G. (2014), "Delivering and evaluating the multiple flood risk benefits in blue-green cities: an interdisciplinary approach", *WIT Transactions on Ecology and the Environment*, 184:113–124

Leary, N. (2012), *Climate change and adaptation*, Earthscan

Atkins Ltd, A. (2014), "Future proofing Madurai action plan for blue-green infrastructure", Technical report, Madurai Corporation

Meehl, G. A., Stocker, T. F., Collins, W. D., Friedlingstein, P., Gaye, A. T., Gregory, J. M.,Kitoh, A., Knutti, R., Murphy, J. M., Noda, A., et al. (2007), "Global climate projections", *Climate change*, 3495:747–845

Mell, I. C. (2008), "Green infrastructure: concepts and planning", In FORUM ejournal, pages 69–80

Middlemann, M. H. and Middelmann, M. (2007), "*Natural hazards in Australia: identifying risk analysis requirements*". Geoscience Australia

Intergovernmental Panel on Climate Change (IPCC). (2014), "*Climate change 2014: impacts, adaptation, and vulnerability*". Cambridge University Press Cambridge, New York, NY

Pötz, H. and Bleuze, P. (2012), "Urban blue-green grids for sustainable and dynamic cities", Technical report, *Delft: Coop for life*

Preston, B. L. and Jones, R. N. (2006), "*Climate change impacts on Australia and the benefits of early action to reduce global greenhouse gas emissions*", CSIRO Canberra

Rahman, A., Haddad, K., Ishak, E., Weinmann, E., and Kuczera, G. (2010), "Regional flood estimation in Australia: An overview of the study in relation to the upgrade of Australian rainfall and runoff", *Flood Management Association*

Rodriguez, F., Andrieu, H., and Morena, F. (2008), "A distributed hydrological model for urbanized areas–model development and application to case studies", *Journal of Hydrology*, 351(3):268–287

Roldin, M., Fryd, O., Jeppesen, J., Mark, O., Binning, P. J., Mikkelsen, P. S., and Jensen, M. B. (2012), "Modelling the impact of soakaway retrofits on combined sewage overflows in a 3 km2 urban catchment in Copenhagen, Denmark", *Journal of Hydrology*, 452:64–75

Sandström, U. G. (2002), "Green infrastructure planning in urban Sweden", Planning Practice and Research, 17(4):373–385

Sauerwein, M. (2011), "Urban soils–characterization, pollution and relevance in urban ecosystems", *NIEMELÄ, Jari; BREUSTE, Jürgen H.; ELMQVIST, Thomas*, pages 45–58

Schanze, J. (2006), "Long-term planning of flood risk management", *Climate Change Impacts on the Water Cycle, Resources and Quality*, 25:86

Showstack, R. (2014), "Floods, climate change, and urban resilience: One policy maker's perspective", *Eos, Transactions American Geophysical Union*, 95(24):201–203

Snepvangers, J., Kamerling-Baake, A., Rooij, S. A. M. v., and Steingröver, E. G. (2011), "*Plannen met multifunctionele groenblauwe netwerken in Salland*", Technical report, Ecologische Netwerken

Sposito, V., Faggian, R., Diogo, V., and Romeijn, H. (2014), "Blue-green infrastructure for creating resilient regions, a case study in the Gippsland Region, Victoria, Australia", Technical report, *Deakin University*

Sposito, V. A. (2012), "Multifunctional agriculture and regional development", Technical report, *Department of Primary Industries, Melbourne*

Stafford, B. (1981), "Brain of the Firm", Wiley, Chichester

Steingröver, E. G., Geertsema, W., and van Wingerden, W. K. R. E. (2010), "Designing agricultural landscapes for natural pest control: a transdisciplinary approach in the Hoeksche Waard (The Netherlands)", *Landscape Ecology*, 25(6):825–838

Thomas, K. and Littlewood, S. (2010), "From green belts to green infrastructure? The evolution of a new concept in the emerging soft governance of spatial strategies", *Planning, Practice & Research*, 25(2):203–222

Thorne, C., Lawson, E., Ozawa, C., Hamlin, S., and Smith, L. (2015), "Overcoming uncertainty and barriers to adoption of blue-green infrastructure for urban flood risk management", *Journal of Flood Risk Management*

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kazmierczak, A., Niemela, J., and James, P. (2007), "Promoting ecosystem and human health in urban areas using green infrastructure: A literature review", *Landscape and urban planning*, 81(3):167–178

Van der Ryn, S. and Cowan, S. (2013), "*Ecological design*", Island Press

Verburg, P. H., Koomen, E., Hilferink, M., Pérez-Soba, M., and Lesschen, J. P. (2012), "An assessment of the impact of climate adaptation measures to reduce flood risk on ecosystem services", *Landscape Ecology*, 27(4):473–486

Villarreal, E. L., Semadeni-Davies, A., and Bengtsson, L. (2004), "Inner city storm water control using a combination of best management practices", *Ecological Engineering*, 22(4):279–298

Voskamp, I. and Van de Ven, F.H.M. (2015), "Planning support system for climate adaptation: Composing effective sets of blue-green measures to reduce urban vulnerability to extreme weather events", *Building and Environment*, 83:159–167

Alterra research institute (2007), "Green-blue veining: agro-biodiversity as innovation for sustainable agriculture", Technical report, *VROM Dutch Ministry of Housing, Spatial Planning and the Environment, Den Haag*

Walker, B. H. and Salt, D. A. (2006), "*Resilience Thinking: sustaining ecosystems and people in a changing world*", Island Press

Walsh, K., Allan, R., Jones, R., Pittock, B., Suppiah, R., and Whetton, P. (1999), "Climate change in Queensland under enhanced greenhouse conditions", *First Annual Report, CSIRO Atmospheric Branch, Aspendale, Victoria, Australia*

Wenger, C., Hussey, K., and Pittock, J. (2013), "Living with floods: key lessons from Australia and abroad", Technical report, *National Climate Change Adaptation Research Facility, Gold Coast*

Whetton, P. H., Suppiah, R., McInnes, K. L., Hennessy, K. J., and Jones, R. N. (2002), "Climate change in Victoria: high resolution regional assessment of climate change impacts", *Department of Natural Resources and Environment*