# Green Infrastructure for Urban Resilience

## The role of ‘green’ in mitigating the effects of natural disasters

*Sam Banyard*

## Introduction

Cities in East Asia absorb 2 million new urban residents every month and are projected to triple their built-up areas in the coming two decades. Globally, the projected number of people exposed to tropical cyclones and earthquakes in large cities is expected to more than double by 2050 (World Bank 2012). As susceptibility to disaster increases then so too will the loss of life and property unless measures are mainstreamed into urban planning processes. In the coming decades, policy-makers in these regions will need to find ways of mitigating the effects of natural disasters. The aim of this paper is to discuss the role of green infrastructure as a mitigating strategy. The term green infrastructure refers to a network of green spaces providing various ecosystem services (Benedict and McMahon. 2002). The latter includes urban forests, tree stands, and parks which protect against landslides, erosion, floods, and drought. Green infrastructure provides substantial social and physical resilience against disaster and, like housing, can become a community driven initiative.

## Literature Review: Building Urban Resilience

Abhas et al (2012) provide an extensively researched set of guidelines for resilience in disaster prone countries for urban planners and practitioners. The guidelines explore intuitive ways to implement elements of resilience into the urban environment and governance of cities and towns. Firstly, there are tools that advise those in higher government positions who provide the finance for development. Secondly, there are tools that assist in the preparation for urban scale decisions and eventually their implementation. Finally, there is a focus on key infrastructural elements, namely energy water and transport systems.

With a strong focus on the urban scale Abhas et al (2012, vii) defines resilience as "the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard promptly and efficiently". The authors explore the notion that rapid expansion of urban areas can be seen as an opportunity rather than a hindrance to incorporate resilience at the outset as planners build and manage new areas. Critical to this window of opportunity is the immediate time after a disaster has occurred which gives practitioners an opening for implementing future corrective and preventative measures (Abhas et al. 2012). The broader discussion within the text is that urban planning must always be considered with resilience in mind, resilience must be part of everyday urban development, medium and long term investment and planning, urban governance, and hazard management. Urban systems therefore have a key role to play in ensuring the well-being and safety of those inhabitants affected by disaster.

In a more specific context, *Building Urban Resilience* highlights the implementation of Risk Assessment, Risk-Based Land Use Planning, Urban Ecosystem Management, Urban Upgrading, Community and Stakeholder Participation, Disaster Management Systems, Data Gathering, Analysis, and Application, Risk Financing and Transfer Approaches as the keys tools for making a city more resilient.

Risk Assessment has the primary objective of providing a quantitative measure of the impact of natural hazards. The data gathered has the ability to inform on the selection, design and investment of certain infrastructures and to enhance resilience to disasters and more long term climate change factors. An example of this is the city wide mapping of Uganda in terms of land rights and tenure. Given Uganda has a complex urban land tenure system the use of specialist GIS, GLTN (Global Land Tools Network) and STDM (Social Tenure Domain Model) has been used. The Uganda Slum Dwellers Federation was able to use these enumerations and maps to implicate on the investment and usage patterns of informal settlements with the overall objective to reach an estimated 200,000 families living in slums and register informal settlements (Abhas et al. 2012). Similarly, Risk-Based Land Use Planning aims at using mapping information to inform on the safest places for development to occur to reduce the impact of disaster. Ideally this method of planning would be regulated in countries most prone, but this is not the case. It is often low income households and informal settlers who live in locations which are most hazardous as these areas are untouched from organized development. A recent study of Istanbul showed that earthquake risk was increasing due to the deterioration of old buildings and poorly constructed newer ones. The study also found that in the event of a major earthquake emergency response would be hindered by the fact that 30% of its hospitals are in highly vulnerable areas. Since then the Istanbul Metropolitan Municipality derived a strategic plan at macro, mezzo and micro levels and a city wide contingency plan for high risk areas (Abhas et al. 2012).

Urban Upgrading decides on appropriate investments in infrastructure, housing, livelihood and social resilience for the vulnerable urban poor. Urban Upgrading works to increase resilience for the urban poor by regulating slum expansions in hazardous areas through planned resettlement and regulation. It also enhances the capabilities of escape routes and critical infrastructure for sanitation and access to livelihood, and maximizes incorporation of slum areas into a citywide planning approach. Dar es Salaam, Jakarta, Mexico City, and São Paulo have all successfully addressed local risk through slum upgrading with early warning systems (World Bank 2011).

Urban Ecosystem Management makes use and maintains already present natural infrastructure in the area which can significantly reduce the cost of urban infrastructure projects. Furthermore, the more frequent implementation of green infrastructure into new or upgrading urban planning initiatives can ensure this cost reduction. Green infrastructure also provides essential urban resilience through minimizing the devastating effects of natural disaster such as landslides due to lack of vegetation or flooding from minimal surface runoff caused by little or no impervious surface treatments.

In order for green infrastructure management to be a successful tool for resilience it must be carried out in part by the community which interacts with it. Community-centered approaches to ecosystem management recognize that human impact and activities are elements of any urban area (Abhas et al. 2012). The learning process through community participation in the integration of green space and infrastructure into the urban context is likely to ensure the continued functioning of the infrastructure in mitigating disaster effects.

An example of this is the Maasin watershed rehabilitation program in the Philippines whose main aim was to regulate flow within the watershed and in downstream urban areas like Iloilo City. By preventing soil erosion through reforestation around the basin an increase in the flow of water in the basin could be achieved and in turn flooding would be prevented during rainy seasons and there would be an increase in water availability during the summer (Abhas et al. 2012). Improvements in agroforestry and management started in 1986 with the help of local farmers and residents who were hired as tree planters and were educated in the types of trees to be planted in the area. Furthermore commercial plantations were reforested with the fast-growing mahogany and gmelina species to provide a continual livelihood for the local residents. Providing the knowledge and practical skills necessary in implementing and maintaining the watershed and surrounding forestry areas lead to long term effectiveness.

# Argument, Critique or Discussion

The discussions of recovery planning and urban design seem to be at present disconnected. New ideas over the degree to which complex urbanism is being considered from a resilient approach has generated a large amount of writing on how to make a city more resilient. However, designing resilience requires a set of tools that have spatial implications where qualitative meet quantitative measures (Allen & Bryant, 2012). Studies reveal the appropriate level of open space for easy access and egress from a space during a disaster but fail to contribute to the qualities or implementation of these spaces. The role of the urban designer and authority then becomes central to the provision of meaningful green spaces that provide safety and resilience to/from natural disasters. Master planning must seek to furthermore bridge the separation of landscape and architecture design and act at not only one scale in order for a city to be flexible enough to resist or mitigate the effects of disaster.

Walker and Salt (2012) provide a set of variables that could contribute to the resilience of a city, each coming close to having spatial implications. Diversity and ecosystem services fall within this framework and imply that an abundance of green infrastructure are essential in building city resilience. A key example of this is when an earthquake struck San Francisco in 1906 which resulted in widespread fires. Within hours of the earthquake the key concern was for security and safety, the local parks and open spaces (especially those on higher ground for viewing the devastation) accommodated a large proportion of the population (Allen & Bryant, 2012). Distance to home and availability of water appeared to be the main driver in choosing a space to settle. There were reservoirs in a few hilltop parks dotted around the city and at Golden Gate Park "there was an independent water supply […] where were also lakes of fresh water of considerable size" (Ibid, 88). The open spaces were flexible enough to support a diversity of everyday functions where people became resourceful and spirits in general were high. Kitchens, restaurants and all types of commerce flourished.

**Green infrastructure for storm water management:**

Green infrastructure is an effective way of managing storm water runoff. It mimics the natural infiltration and runoff reduction functions of natural ecosystems (Abhas et al. 2012). Initiatives such as green roofs, bioswales, retention ponds and permeable pavements are a few examples that can be used in an urban context and urban green spaces. In most areas, rainwater flows into combined storm water and sewer drainage system. High levels of precipitation can surpass the capacity of these systems which can lead to flooding, backed up sewage and public health hazards. The diagram below depicts the likely effects of urbanization on the level of water runoff; this is primarily due to more impervious surfaces being used in urbanized areas, a larger consideration for green infrastructure in built up areas becomes evident. Furthermore, compared to rehabilitating or even replacing an entire network of combined storm water/sewer systems, green infrastructure is a more cost-effective way to manage storm water.

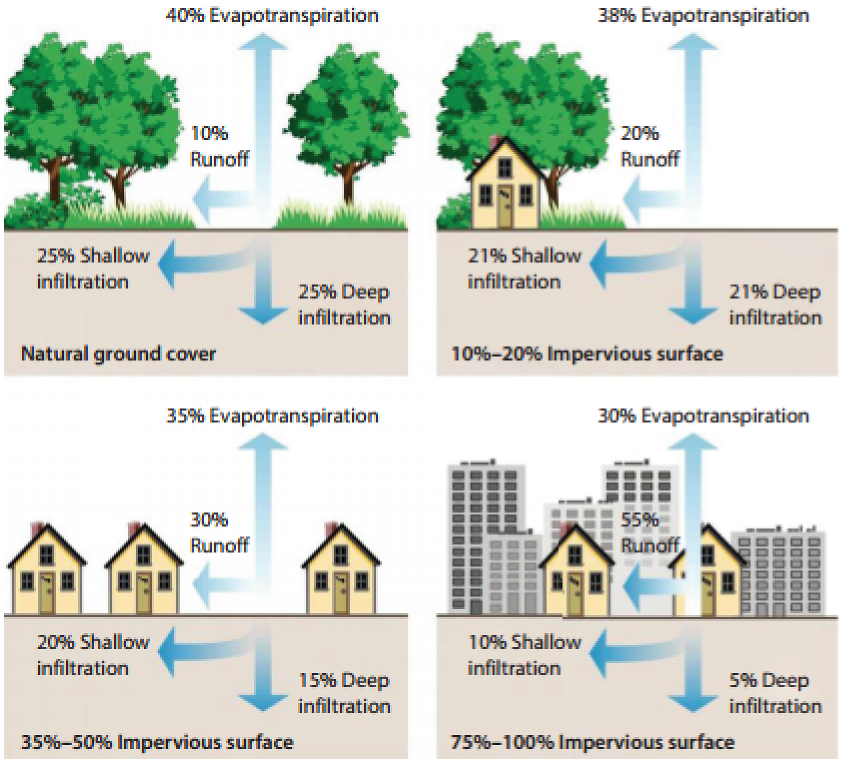


**Diagram 1:** Change in runoff after urbanization.

**Owner/ Community Driven:**

The term Owner driven reconstruction (ODR) refers to the program by which those who have lost their dwelling are given some combination of cash, vouchers, and technical assistance to rebuild. Traditionally this has resulted in the work being undertaken by the affected people, family labor or by employing a local contractor(s). Although the construction may not necessarily be completely done by the owner, the contractors are accountable to the homeowner rather than to an external agency as in the ‘agency driven approach’ to reconstruction. This approach common in Latin America proves to be an empowering approach to reconstruction and a learning process which provides invaluable skills contributing to a holistic social resilience (Abhas et al. 2012). Some key examples of this method in the developing world include reconstruction following the 2001 earthquake in Gujarat in India and reconstruction after the 2004 Indian Ocean Tsunami in Thailand and Sri Lanka. In the most recent case, official World Bank documents and evaluations carried out by other agencies that pursued this approach confirm that this was the most successful housing reconstruction strategy.

**Community Participation Implementation: Seattle, US**

Given the success of community/owner driven household reconstruction, why not apply similar strategies for the implementation of green space and green infrastructure? An example of this can be found in the management of green infrastructure in Seattle (Abhas et al. 2012). Intense precipitation and steep slopes mean that landslides are a common hazard in Seattle, Washington, and the impacts on transportation systems can be heavy. In the 1990's a city wide study carried out by the government found that a lack of vegetation cover was a major cause of slope instability and new regulations enforced the maintenance and restoration of vegetation in these hazardous areas. The beginning of the project was a landslide map that showed information on areas most susceptible to landslide included a database of the occurrence of 1400 landslides in the city of Seattle over the previous 100 years. This provided an evidence base for decision making and drafting of policy for resilience against landslides. Since then, there is specification on the type and use of vegetation on steep slopes/buffer zones and further stipulation that removal of trees or vegetation requires city approval. During the research phase, public outreach was conducted to gather citizen opinions on the approach to hazard mapping. The studies arising from the Seattle Landslide Project were then made available to the public, particularly to communities interested in working on landslide reduction. Since 1997, workshops on landslide hazards and mitigation have been held for Seattle residents and developers. The workshops discuss the causes of landslides, proper drainage for sloping sites, and how to maintain vegetation on slopes.

**Urban Planning Implementation: Curitiba, Brazil**

Brazil has the 4th largest urban population after China, India, and the US, with an annual urban growth rate of 1.8% between 2005 and 2010. The city of Curitiba was able to successfully address this challenge by implementing innovative systems over decades that have inspired other cities and beyond It was in 1964, Mayor Ivo Arzua solicited proposals for Curitiba's expansion which was won by a team of Architects led by Jaime Lerner, who later became mayor. The proposal suggested strict controls on urban sprawl, reduced traffic in the downtown area, preservation of Curitiba's Historic Sector, an abundance of green space and a convenient and affordable public transit system. Curitiba has been able to grow in population from 361,100 (in 1960) to 1.828 million (in 2008) without experiencing typical drawbacks from congestion, pollution and reduction of public space. While the population density has multiplied three-fold from 1970 to 2008, the average green area per person has increased from 1km$^2$ to 50km$^2$ (UNEP, 2009)..

One of the key considerations of urban planning in achieving these results was the decision for growth to occur in a ‘linear-branching pattern’, which protected both density and green areas. This also encouraged, with a combination of mixed-use zoning and provision of public transport, a diversion of traffic from the city center and the development of housing, services and industrial locations along radial axis (diagram 2). Additionally, through the implementation of an efficient public transport system and integrated urban planning, Curitiba has the highest rate of public transport use in Brazil and one of the country’s lowest rates of urban air pollution.

The dramatic increase in green area per person not only serves to increase the recreational activity of Curitiba’s residents but also helps to mitigate the effects of natural occurrences (Diagram 3). By turning areas vulnerable to flooding into parks planted with many trees, and creating artificial lakes to hold floodwaters, Curitiba has managed to address its potentially costly flooding problem, increasing drainage and reducing surface runoff. The cost of this strategy, including the relocation costs of slum dwellers, is estimated to be five times lower than building concrete canals and as a result, the property values of neighboring areas appreciated, and tax revenues increased.

**Diagram 2:** Development along linear branching axis shown in red.

**Photo 1:** Green infrastructure in Curitiba.

**Implementation Going Forward:**

*Developers:*

Traditionally, the policies, tools, and mechanisms for implementing green infrastructure into land use planning have tended to be regulatory rather than incentive-based. A shift in focus toward incentive-based tools can help produce significantly more wide-spread implementation. Incentives encourage stakeholders to safeguard the integrity of green infrastructure services voluntarily; for instance, preferential tax treatments can be granted in exchange for providing environmental buffers within a development.

*Households:*

Through organizations such as SHFC (Social Housing Finance Corporation) in the Philippines who provide finance to Informal Settlers, the implementation of green infrastructure, namely permeable ground covers, green roofs and vegetation can occur.

**Green infrastructure for social resilience:**

By providing substantial green space which actively mitigates the effects of disaster, community spaces which are essential for congregation in the event of a disaster can also be provided. Common meeting places prove essential in organizing the community and ensuring everyone's safety.

# Urban Shelter Design

The Country Assistance Strategy (CAS) is a three year plan the World Bank draws up with a country's authorities for allocating support according to country priorities (Abhas et al. 2012). The 2010-12 CAS for the Philippines outlines four strategic objectives, one of which is to reduce vulnerability. The Philippines is exposed to natural disasters due to a high incidence of severe weather – especially floods, typhoons, and drought – and a large number of earthquakes and active volcanoes. The effects of global climate change are likely to exacerbate this inherently high disaster risk. The resultant human and economic costs are significant; estimates suggest that every year natural disasters cost the Philippines 0.5 percent of gross domestic product (GDP) (World Bank, 2012).

Effective green infrastructure implementation at an urban scale can help reduce $CO^2$ emissions into the atmosphere and reduce the urban heat island over the Philippines which cause temperature increases and a further reliance on energy consuming cooling methods. Higher levels of green infrastructure in the forms of parks, forestry, green roofing, bioswales, and permeable ground cover have also been proven to reduce the devastating effects of flooding by reducing runoff. Also, by providing this infrastructure there is a greater capacity for recreation, well-being and a reduced reliance on motor vehicles.

**Photos 3 & 4:** Baseco (L) and Cavite, Metro Manila (R) showing impervious ground cover.

# The Role of Architects/Urban Planners

Travelling to the Philippines was an experience which will leave a lasting impression on both my personal and professional life. It was immediately apparently that despite the atrocities the country has faced in the way of natural disaster, the people are strong and seemingly happy in day to day life. To meet the required housing and slum reduction targets in the Philippines a lot of development must be undertaken and it is therefore imperative that architects and planners as the trained professionals they are, take a leading role in ensuring social and urban resilience. In the way of green infrastructure, it was visible in the Philippines that some strides had been made to 'greenify' the city through parks and green patches. However, this was only in higher income areas and generally, the government driven social housing we visited were concrete laden and impervious at ground to roof level. Though this may be seen as a cost saving method, in both the short and long term, strategies such as green roofing and natural groundcover are more cost effective and environmentally beneficial. Furthermore, with the introduction of more green spaces and infrastructure, architects and planners must actively engage with communities they are providing for to ensure continued maintenance and understanding. They cannot simply adopt a top-down approach and expect long lasting, cost effective results.

# Bibliography

Allan, Penny, and Bryant, Martin. 2011. *Resilience as a framework for urbanism and recovery*. Journal of Landscape Architecture 6 (2): 34-45.

Benedict, M. and E. McMahon. 2002. *Green infrastructure: Smart conservation for the 21st Century*. Arlington, VA: The Conservation Fund and Sprawl Watch Clearinghouse.

Jha, Abhas K., Miner, Todd W., and Stanton-Geddes, Zuzana. 2012. *Building Urban Resilience: Principles, Tools, and Practice*. Washington, DC: World Bank.

Jha, Abhas K., Brecht, Henrike. 2012. *Building urban resilience in East Asia*. An eye on East Asia and Pacific ; no. 8. Washington, DC: World Bank.

Otto-Zimmermann, Konrad. 2010. *Resilient Cities: Cities and Adaptation to Climate Change*. Germany: Springer Science & Business Media.

United Nations Environment Programme (UNEP). 2009. *Sustainable urban planning in Brazil*. http://www.unep.org/greeneconomy/SuccessStories/SustainaibleUrbanPlanninginBrazil/tabid/29867/Default.aspx (Accessed 19-04-2015).

Walker, B.H. and D. Salt. 2006. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Washington, D.C: Island Press.

**Images/Diagrams:**

Diagram 1: Jha, Abhas K., Miner, Todd W., and Stanton-Geddes, Zuzana. 2012. *Building Urban Resilience: Principles, Tools, and Practice*. Washington, DC: World Bank.

Diagram 2: Horizons International Solutions Site. 2000. http://www.solutions-site.org/node/83

Photos 1: More than Green. 2012. http://www.morethangreen.es/en/the-curitiba-of-jaime-lerner/

Photos 2 & 3: Taken by author.