RESILIENCE OF URBAN ECOSYSTEMS

A review of concepts, strategies and practices in resilient landscape planning and design

Priyasha Shrestha

LAR-750 | Advanced Seminar

00 TABLE OF CONTENTS

01 URBAN ECOSYSTEMS 3

Introduction to urban ecosystems

Components of urban ecosystems

- Biotic components
- Physical components
- Social components
- Built components

Interactions between social and ecological components

Integrating biotic and socio-cultural elements in the urban environment

02 RESILIENCE 7

Introduction to resilience

Concepts in resilience

- Resilience theory
- Basins of attraction
- Adaptive management and the adaptive cycle
- Adaptive capacity and resilience

Typologies of resilience in urban ecosystems

- Socio-economic resilience
- Ecological resilience
- Linkages between social and ecological resilience

03 URBANIZATION AND RESILIENCE OF URBAN AREAS 16

Introduction to urbanization

Regime shifts due to urbanization

Urban patterns in relation to resilience

- Urban form
- Land Use
- Connectivity

04 PLANNING FOR RESILIENCE 24

Introduction to landscape planning for resilience

Strategies for landscape planning for resilience

05 ASSESSMENT OF RESILIENCE IN PLANNING 28

Local Scale: Cheonggyecheon Stream Restoration

Regional Scale: Mombasa to Nairobi railway

Global Scale: The Kyoto Protocol

06 ROLE OF LANDSCAPE ARCHITECTS 35

Landscape architects and their role in resilience planning

07 CONCLUSION AND REFLECTIONS 37

08 REFERENCES 38

01 URBAN ECOSYSTEMS

INTRODUCTION TO URBAN ECOSYSTEMS

An urban ecosystem is an ecological system inherent to a city or an urban area. Urban ecosystems, like all ecosystems are composed of biological components, such as flora, fauna and other life forms, as well as physical components such as soil, water, climate, topography, which are characteristic of the urban area ("Urban Ecosystem" n.d.). Pickett and Grove (2009) assert, however, that urban ecosystems are not limited to just plants and animals, and the physical components such as the soil, water and climate. They include human beings and the interactions of each of these components with the socio-economic and cultural dynamics of human populations (Pickett and Grove 2009).

An example of an urban ecosystem, Central Park in New York, is an urban park in the metropolis and an important green space in the city core. Here, the urban ecosystem comprises of people, buildings, transportation networks and other infrastructure as man-made components, as well as the plant and animal life which base their living on the soil, water and other physical components of the city environment. Figure 1 shows an image of Central Park as the amalgam of natural and man-made components.

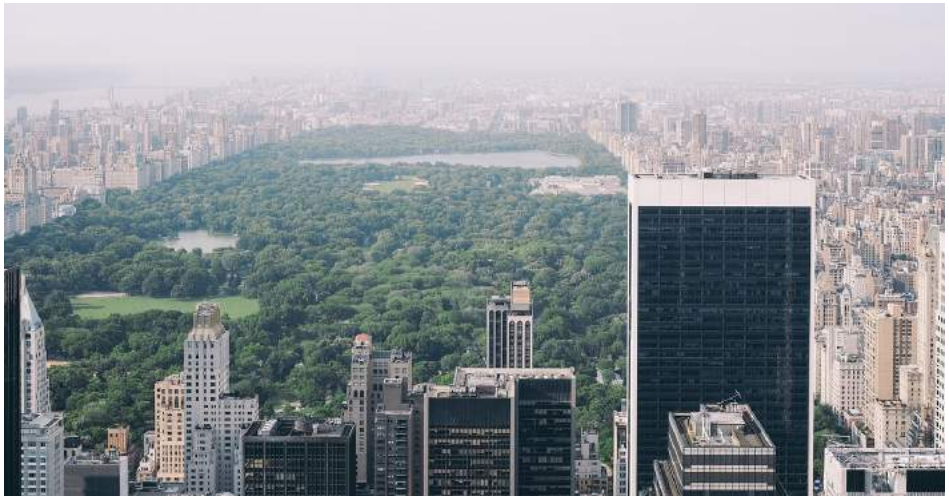


Fig 1: Central Park in New York City

Thus, urban ecosystems are spatially heterogenous and temporally dynamic systems (S. T. A. Pickett et al. 2017). The biotic, physical, social and built components and their interactions form a mosaic that constitutes the urban human ecosystem (Pickett and Grove 2009).

COMPONENTS OF AN URBAN ECOSYSTEM

1. **Biotic components**

Biotic components comprise of non-human living components such as the flora and fauna in the urban ecosystem (Pickett and Grove 2009).

2. **Social components**

The social components of an urban ecosystem constitute people, their demographical elements, economy, culture, organizations, and technological advancements in the human society (Pickett and Grove 2009).

3. **Physical components**

The physical components are made up of soil, water, and climate, which are integral base components in ecosystems (Pickett and Grove 2009).

4. **Built components**

The built components are comprised of buildings and infrastructure, which are a part of the urban city environment (Pickett and Grove 2009).

These components of urban ecosytems engage in intrinsic interactions and each affects the structure and function of the other.

INTERACTIONS BETWEEN SOCIAL AND ECOLOGICAL COMPONENTS

Urban ecosystems change over time due to interactions occurring between the human-established socio-economic components, and the inherent biophysical parts of the urban environment at varied scales (Alberti and Marzluff 2004). Effects of urbanization, such as fragmentation of natural habitats, homogenization of species composition, alteration of hydrological and topographical systems, and changes induced in energy flow and nutrient cycling are common in urban ecosystems (Alberti and Marzluff 2004). Interactions between the social and bio-physical components determine the use of land, land cover, production and consumption of food and resources, and disposal among many others factors (Pickett and Grove 2009). Figure 2 shows the different urban ecosystem components and figure 3 shows their interactions.

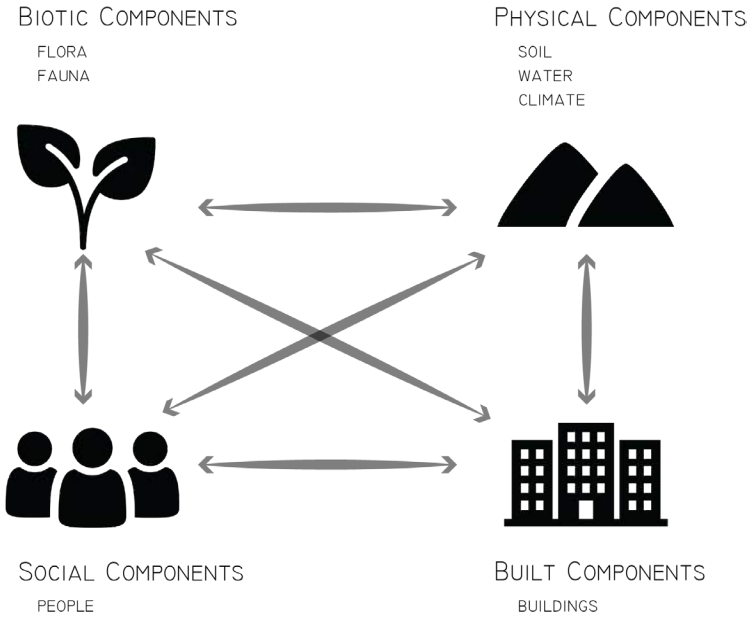


Fig 2: Components of an urban ecosystem (Adapted from Pickett and Grove 2009; thenounproject.com)

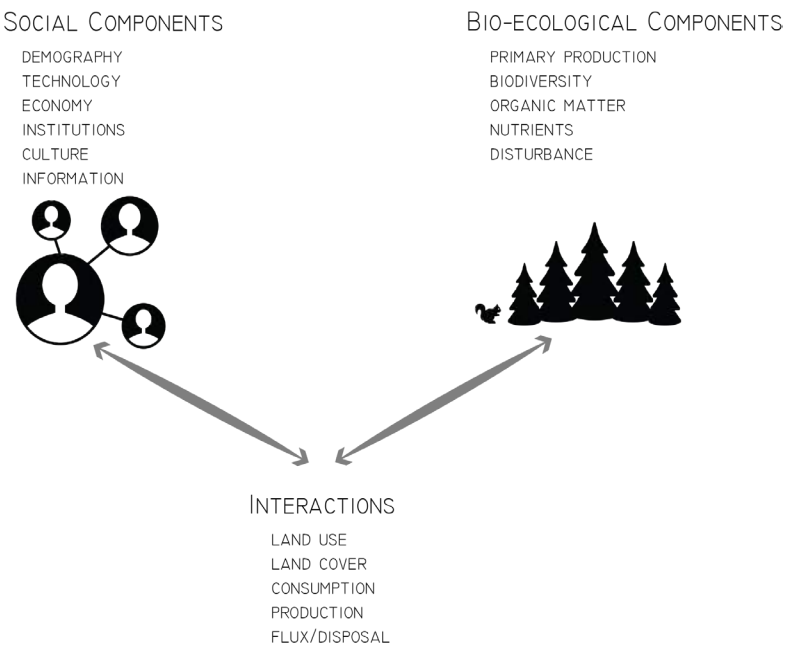


Fig 3: Interactions between components of an urban ecosystem (Adapted from Pickett and Grove 2009; thenounproject.com)

The different components of the urban ecosystem are inter-dependent, with each affecting how the others are shaped andhow they function. For instance, the built environment is largely shaped by the physical structure of the environment, which comprises of the topography, hydrology, geology, soil, climate, and also by vegetation and the biotic component. For example, topography limits the location and siting of development. Extreme elevated or depressed landforms considerably limit built spaces. The access, accessibility, costs, aesthetics, materials, and structural requirements of built spaces vary for flat topography versus sloped land. Structural requirements such as height and depth of footings for buildings, and mechanisms for retention of land would necessitate extensive thought while building on slopes. Topography also affects drainage and runoff, as well as microclimate and orientation of buildings and the built environment. Figure 4 shows an image of how topography has affected the layout of buildings in Pokhara, Nepal.

Fig 4: Building layout on terraced hills of Pokhara, Nepal (Wolkenkratzer 2013)

Similarly, water or hydrology is also affects how built spaces are planned and designed. Settlements have always been planned around water bodies for access to water for agriculture, recreation, transport and ultimately sustenance of societies, demonstrating a great dependence on water bodies for sustenance. Water bodies, however, also pose limitations. Building on the floodways can be detrimental, which is why there are building bye-laws restricting buildings to a certain distance away from water bodies. For good watershed-based planning, built spaces should be planned for the contributing zones of the watershed, and should avoid the collection zone and the conveying zone, which are more susceptible to drainage problems and flooding (Marsh 2010). In addition to surface water systems, the built environment is also affected by groundwater systems and flows. For instance, the depth of the water table can influence building structures and types of foundations.

The social components also affect the bio-physical components in urban environments. Changing the landform, hydrology, and vegetation can have adverse effects on the environment. Disturbances to slope through deforestation, cut and fill, and alteration of drainage can cause slope failures and erosion (Marsh 2010). As shown in Figure 5, an example is the landslide that occurred at the Kennecott Utah Copper's Bingham Canyon Mine in 2013 (DL Cade 2013). Building chemical factories near water bodies can pollute the water with chemical leachates flowing through the surface and the ground to the water bodies. Thus, we need to be very careful how we plan our development so we do not throw the other components off balance.

Fig 5: Landslide at Kennecott Utah Copper's Bingham Canyon Mine (DL Cade 2013)

INTEGRATING BIOTIC AND SOCIO-CULTURAL ELEMENTS IN THE URBAN ENVIRONMENT

Integration of nature has always been an important consideration in city planning. There are two extreme models constituting the integration of green space into the urban environment: dense built space with consolidated green space, versus sparse development with fragmented greenery. Most cities are usually at different middle points in the spectrum.

Fig 6: Hong Kong Park with its consolidated green space (left)and Singapore with its dispersed green spaces (right) ("City Aerial 4k Hong Kong Stock Footage Video (100% Royalty-Free) 9801899." n.d; "Aerial Filming / Aerial Surveying | Singapore Heli Services" n.d.)

The New York City area with Central Park, and Hong Kong with its dense development and centralized Hong Kong Park are examples where open green spaces are separated from the dense, concentrated development, as opposed to the dispersed green spaces of Singapore (Figure 6). Both of these models have their own advantages and limitations. The dense development model creates opportunities for greater ecological diversity in the natural space. However, it could also lead to social stratification of the built environment based on distance from the green space. The other model distributes green spaces to smaller fragments throughout the city. While this type of development creates better opportunities for the people to access the green spaces, they can only support limited biodiversity. The mixed development would provide bigger natural spaces while allowing access, but mediums are not always happy. Based on the size of the development, the mixed model would probably not be able to achieve social equity or biodiversity to the extent that is desired because the urban infringement would not allow above-average biodiversity, and the fragmentation would still be big enough to create more localized social stratifications, resulting in disjointed communities.

Personally, I am a bit more inclined towards the dense development and the unfragmented nature of green space because of the ecological diversity that it provides. Fragmentation of green spaces would create a Garden City-like development, ultimately morphing into suburban sprawl (lack of mixed-use development, vehicle-dependency, etc.). It could even mean a NIMBY (Not In My Back Yard)-type attitude towards the green spaces, or a sense of care only for their own green space. The dispersed green spaces would ensue more urban uses such as playgrounds and gardening, but not the ecological benefits that a nature preserve or national park would give. Having a large common natural space would create various recreational and economic opportunities, such as wildlife watches and ecological tourism. The social stratification problem could still minimized by providing good public transit and walkable/bikeable connections to the green space. Moreover, green spaces within the dense development areas could still be provided in the form of street trees, green roofs and other green infrastructure. Thus, I think a larger green space with good connections to it would be better.

02 RESILIENCE

INTRODUCTION TO RESILIENCE

Resilience has been defined in two ways. The classical inference of resilience measures it in time units as the rapidity with which a system brings itself back to a stable equilibrium state after a disturbance (Wu and Wu 2013). However, it has been established that ecosystems have different stable states, and so resilience has been defined as the "ability of a system to absorb change and disturbance without changing its basic structure and function or shifting into a -qualitatively different state" (Wu and Wu 2013). According to Wu and Wu (2013), this definition of resilience has been termed as "ecosystem resilience" and is based on persistence, change, and unpredictability. Boeckh(n.d.) reports three facets of resilient systems:

1. The amount of change the system can undergo and still retain the same controls on function and structure.
2. The degree to which the system is capable of self-organization.
3. The ability to build and increase the capacity for learning and adaptation.

Resilience of a system is evaluated in relation to the different natural and human-induced disturbances it is exposed to. According to Boeckh(n.d.), disturbances are abrupt events that change the characteristics of an ecosystem. Disturbances can be small-scale such as cutting a tree, or large-scale, such as air and water pollution (Hoover, n.d.). They can be natural or human-induced. Examples of natural disturbances are storms, flooding, volcanic eruptions, earthquakes, etc. whereas human-induced disturbances are climate change, agriculture, pollution, grazing, mowing, deforestation, etc. (Hoover, n.d.), a lot of which are related to urbanization. The amount of resilience that a system possesses relates to the magnitude of the disturbance that it can withstand (Hoover, n.d.). Various indicators can be used to demonstrate how resilient systems are. Several of these indicators are listed in the Figure 7.

Fig 7: Indicators of Resilience (Boeckhn.d.; thenounproject.com)

CONCEPTS IN RESILIENCE

1. Resilience theory

Urban ecosystems undergo ecological, social, economic and evolutionary changes. In order to prevent these changes from pushing the systems across a threshold, the systems need to display a certain extent of resilience (Gravenstein 2014). According to ecologist C.S. Holling (1973), resilience allows a system to fluctuate and still persist. Thus, resilience is different from stability, which tries to return a system to the equilibrium position (Holling 1973). A system, according to Holling (1973), can be resilient even with low stability.

2. Basins of attraction

Resilience prevents systems to cross thresholds, or tipping points beyond which they cannot recover. Using the metaphor of a ball moving inside a basin, where the ball is a state of a social-ecological system and the basin is a set of states with similar functions and feedbacks, resilience has been explained as the characteristic of a system that prevents the ball from crossing the edge of the basin or the threshold (Gravenstein 2014). Feedbacks are the secondary effects one variable on another, such as the increase in carbon dioxide due to deforestation. This is illustrated in Figure 8.

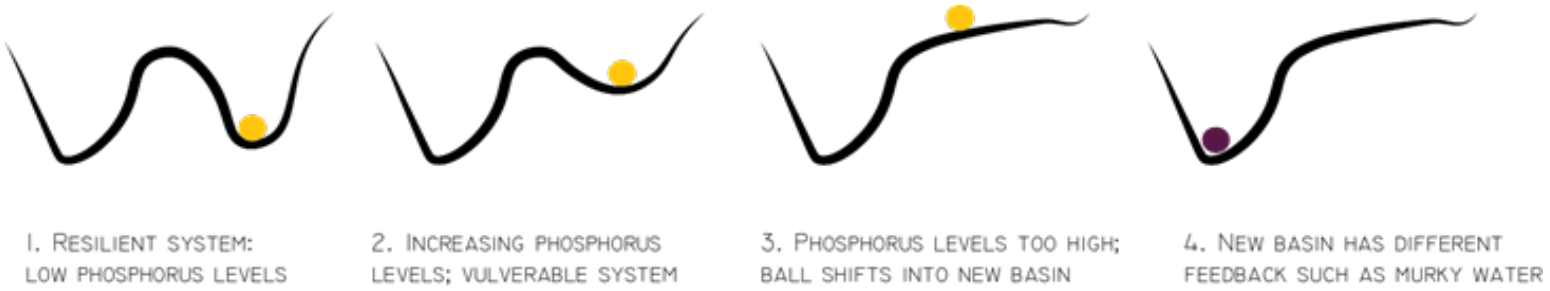


Fig 8: Resilience theory explained with the help of a ball in a basin (Adapted from Boeckhn.d.)

Gravenstein (2014) has explained an example of this basin-ball interaction: the ball or the system is constantly trying to reach a state of equilibrium or the bottom of the basin, such as low phosphorus levels in a lake. However, systems are changing continuously, so, the basin keeps changing form. At some point, if the system's dynamics are altered, such as phosphorus levels being added in the lake, and the feedbacks change (such as algae bloom), then the ball could move away from the bottom and move towards the edge (threshold), beyond which the ball moves into another basin of attraction, with another set of functions or structures (Gravenstein 2014). This process is illustrated in the diagram (Fig 8).

3. Adaptive management and the adaptive cycle

As reported by Gravenstein (2014), adaptive management is a social as well as scientific process of identifying uncertainties and then testing hypotheses concerning those uncertainties. It involves experimenting to learn about systems and reduce uncertainties to predict disturbances and shape management decisions ("An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico" at NAP.Edu n.d.). An example of adaptive management would be sea level rise planning based on predicted SLR levels in future years.

The adaptive cycle is how an ecosystem organizes itself in response to a changing world (Gravenstein 2014). There are four phases in an adaptive cycle for ecosystem and social-ecological system (Figure 9):

1. growth or exploitation
2. conservation
3. collapse or release
4. reorganization

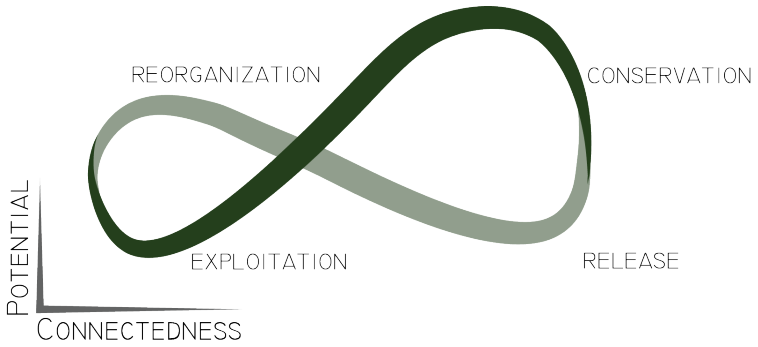


Fig 9: The adaptive cycle (Adapted from Gravenstein 2014)

Exploitation is the colonization of recently disturbed areas, which happens rapidly, and conservation is the accumulation and storage of energy and material, which is at a slower pace ("Resilience Alliance - Adaptive Cycle" n.d.). For example, in the succession of a forest ecosystem, the starting 'exploitation' phase is when the grasses and shrub species colonize the bare ground. Through time, this ecosystem matures into a forest structure. However, this growth does not occur forever. When it reaches a steady state, it reaches the 'conservation' stage, when accumulates biomass and stores energy. When disturbances such as a forest fire occurs, the system releases energy, and the existing forest biomass is all destroyed. Then the ecosystem reorganizes itself as it is now exposed to be colonized by different species once again ("Forest Fires - an Ecological Example of the Adaptive Cycle - RAWorkbook" n.d.). This forest succession is shown in Figure 10. A nested hierarchy of adaptive cycles represents a panarchy ("Resilience Alliance - Adaptive Cycle" n.d.).

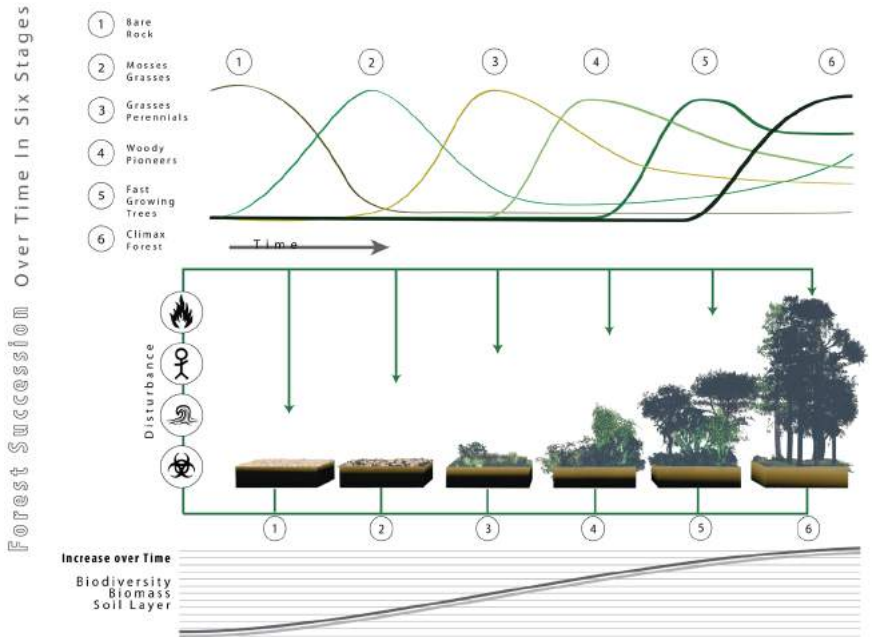


Fig 10: Forest Succession over time (LucasMartinFrey 2011)

4. Adaptive capacity and resilience

Adaptive capacity is the ability of the system to reorganize without changing its functions drastically ("Resilience Alliance - Adaptive Capacity" n.d.). According to the Resilience Alliance (n.d.), adaptive capacity of ecological systems is enhanced by genetic diversity, biological diversity, and the heterogeneity. In social systems, flexibility in problem solving, and balance in power of interest groups is important for adaptive capacity ("Resilience Alliance - Adaptive Capacity" n.d.). The Resilience Alliance (n.d.) asserts that resilience is important to enhance adaptive capacity of social-ecological systems in a constantly changing urban ecosystem. There are four critical factors that interact across temporal and spatial scales and add to adaptive capacity:

- learning to live with change and uncertainty;
- nurturing diversity for resilience;
- combining different types of knowledge for learning; and
- creating opportunity for self-organization towards social-ecological sustainability ("Resilience Alliance - Adaptive Capacity" n.d.).

TYPOLOGIES OF RESILIENCE IN URBAN ECOSYSTEMS

1. Socio-economic resilience

Social resilience is defined as "the ability of a human community to withstand, and recover from, external environmental, socioeconomic, and political shocks or perturbations" (Wu and Wu 2013). Social resilience depends upon the ability of social systems to "promote trust, reciprocity, collaboration, and knowledge between social systems on multiple scales" (Ragoschke 2014). According to Ragoschke 2014, social resilience is based on three functions. The first function is knowledge transfers, depending on the social capital, which includes the ability for people to build on the relationships they have with one another and learn from one another to increase their understanding of their environments and adapt to changes (Ragoschke 2014).

Secondly, 'norms of reciprocity' allow individuals or groups to create bonds within their social systems. The third function of social resilience, 'collaboration' between individuals and groups, allows for communication in times of need, such as during natural disasters that require collaborative coping strategies (Ragoschke 2014).

Thus, social resilience requires people to trust each other in times of need, and develop a bond with each other. This function of a society can largely be influenced upon how the city neighborhoods have been planned. A close-knit neighborhood, with communicative bonds between the residents, invokes a sense of responsibility and belonging among the residents, which ultimately adds to the social resilience of the society there. This concept of social resilience was advocated for by Jane Jacobs in New York against Robert Moses, who was trying to build huge infrastructure that would make regional connections, but would cut through neighborhoods, not only degrading people's properties and livelihoods, but also negatively impacting the social resilience of the communities.

The battle of Robert Moses and Jane Jacobs was very popular. Robert Moses was a parks commissioner and public official, also known as the "master builder", credited for the urbanization of the greater New York area, through his visions and implementation of infrastructure development, and the introduction of parks, parkways, public beaches, pools, bridges, roads, and grand vehicular expressways in 20th century America (Papacosma 2008). He believed that "cities are created by and for traffic," and without automobiles, cities turn into ghost towns (Graham n.d.). Robert Moses planned to clear slums and introduce grand expressways in the city. These plans were widely criticized by the neighborhood residents, who believed in a more traditionalist approach to planning; a rebellion was led by journalist, author and social activist, Jane Jacobs (Figure 11). She believed that Moses' approach was an "attack on city planning." (Graham n.d.) and that building grand expressways would fragment neighborhoods and communities, degrading their continuity.

Fig 11: Jane Jacobs in her battle against Robert Moses

As opposed to Robert Moses' grand regional moves, Jacobs' vision for the city was on a more intrinsic scale, encompassing the smaller city units: the city blocks. According to David Harvey, Robert Moses' brutal modernism increased suburbanization and a change in lifestyle that depended on roads, cars, refrigerators, and air conditioners, creating a culture of the automobile (Harvey 2008). His proposal of an 8-lane expressway in lower Manhattan would fragment the city, destroy historic structures and displace thousands of people, many of whom were low-income residents. David Harvey has pointed out that Moses could not displace affluent neighborhoods because high-income people could pay to refuse to give up their assets (Harvey 2008). An illustration depicting this battle between Jacobs and Moses is shown in Figure 12.

Fig 12: The battle between Robert Moses and Jane Jacobs (MASNYC n.d.)

Fig 13: Robert Moses with a plan for Battery Park (Stieglitz 1939)

David Harvey describes her vision to comprise of a "localized neighborhood aesthetic." (Harvey 2008) Jacobs considered cities to have a dynamic organized complexity with interdependent functions of the urban economy (Graham n.d.). Thus she was against Moses' plans of utilizing the capital surplus for expressways, since that could cause social stratification.

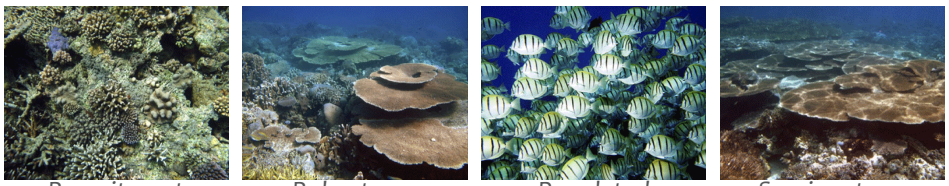
Jane Jacobs understood the importance of streets and the interactions that go on in them: the street was a place where neighbors could meet and get to know each other, and children could play on the sidewalks, and a mix of uses such as retail and residential could help people connect better to the neighborhoods. Her "eyes on the street" concept states that people will look out for each other on streets (Hancock 2016). As opposed to the suburbanization brought on by the grand automobile infrastructure of Robert Moses, Jane Jacobs believed in density, and unified social and economic diversity of people. Her vision of the city incorporated sharing public spaces, public transit, and various economic classes living in harmony. She fought for the minority social groups. Thus, when the time came, the residents of the city neighborhoods rallied beside her and stopped Robert Moses' plans of the urban expressway in lower Manhattan.

The neighborhood aesthetic that Jane Jacobs advocated for also supports socio-economic resilience. By maintaining social and physical connectivity these neighborhoods could embrace knowledge transfers, collabortion, and reciprocity, all of which are characteristics of a socially resilient system. By preventing social and economic divides such as race and income-based gentrification from fragmenting the people, the intrinsic interactions between people could promote diversity in livelihoods, ideas, and engagement. This could build on social capital and help absorb social, political, environmental, or economic change rather than being vulnerable to them. Such social resilience could also be beneficial in managing ecological resources such as neighborhood green spaces, which would also add to the ecological resilience of the places. Thus, while infrastructure is important for egional connectivity and development, it should not fragment communities and livelihoods, since that would make these social components prone to disturbances and potential collapse. Jane Jacobs' vision for the society promoted resilience, so people came together to support her endeavors, which is another display of social resilience.

2. Ecological resilience

Ecological resilience, also called ecological robustness, is "the ability of an ecosystem to maintain its normal patterns of nutrient cycling and biomass production after being subjected to damage caused by an ecological disturbance." ("Ecological Resilience" n.d.). In cities and urban areas, natural habitats are being fragmented, species biodiversity is declining, resulting in homogenization, hydrological systems are being disrupted, altering the flow of energy and nutrients, thus making these city ecosystems prone to ecological disturbances (Alberti and Marzluff 2004). Many settlements have collapsed in the past because the climatic shifts and disturbances crossed thresholds of the carrying capacity of the settlements (i.e. cities built and abandoned by the Mayas, Anasazi, the Incas) (Alberti and Marzluff 2004).

Disturbances such as eutrophication (excessive increase in nutrients in water causing plant life to flourish and animal life to diminish), desertification (fertile land turning into a desert due to improper agriculture, deforestation and drought) try to push an ecological system towards a threshold beyond which the characteristics of the system drastically change to turn the system into another stable state ("Ecological Resilience" n.d.). An example of a system change is when coral reefs undergo steady domination by seaweed. If the coral reef is able to recover the current system before it is outcompeted by seaweed, then the coral reef system is resilient, otherwise the system changes its character from a coral dominated system to a seaweed-dominated one (Mumby et. al. 2014). This is demonstrated in Figure 14 and Figure 15.



Recruitment Robustness Populated Survive stress

Fig 14: Resilient coral reef characteristics ("Coral Reef Resilience | Reef Resilience" n.d.)

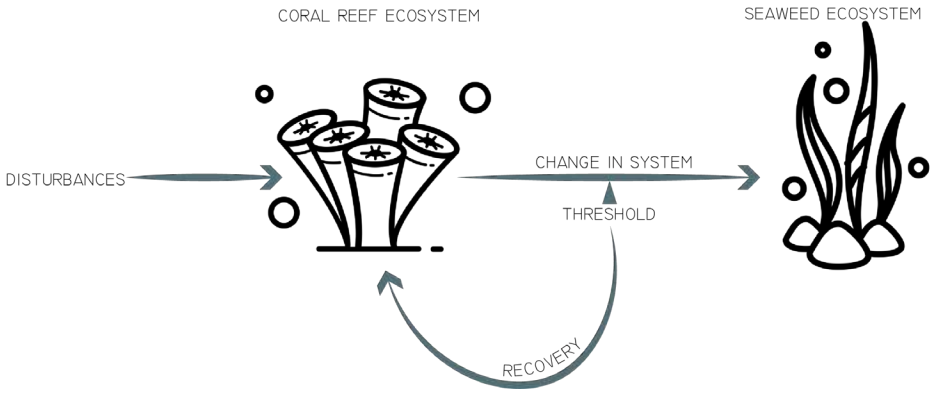


Fig 15: Resilience of coral reefs (thenounproject.com)

Human activities pose various disturbances that risk the resilience of ecological systems. Human activities such as deforestation, extensive use of resources, and pollution are some factors that cause ecosystems to undergo massive changes that they cannot recover from. An example of resilience of ecological systems being altered due to human development is portrayed in the video 'Walking with Wolves,' which shows how pre-existing ecosystems have had to transform through time due to human intervention, and how cultural perceptions of nature and ecosystems have shaped how humans interact with nature. The video shows how wolf populations have slimmed down in the plains of south central India due to human settlement encroachment for farmland and fields. Wolves are natural predators, and they help maintain the balance in the ecosystem by controlling the population of species such as deer, which are lower down in the ecological pyramid. However, human settlements encroaching upon natural habitats has been the cause of the declining populations of these predators. The documentary tells the tale of "Bent Ear" (Figure 16), a male wolf, head of the family, surviving through any means possible, adapting to human society gaining dominance over their lands, and changing their diets to livestock and bananas to survive.

Fig 16: Resilience of coral reefs (Narayanan n.d.)

Aldo Leopold described the hunting and killing of a wolf with great emotion in A Sand County Almanac, by writing that a fierce green fire had died in her eyes, and an ecological imbalance had been caused. Humans throughout the world take pleasure in hunting animals, usually predators that are less in number and harder to track down. They do not realize the implications of these actions: overpopulation of animals such as deer, without a predator to control them. Such a shift in ecosystem dynamics hinders the structure and resilience of the ecosystem.

The video also shows positive impacts of cultural beliefs on the ecosystem. Some people are seen to hesitate to hunt because of a myth that spoke of a curse put by one brother on his two other brothers for betraying him while sharing livestock. Legend said that the brother's spirit lived on in the form of a wolf, so they did not kill them. So the documentary is an interesting example of how local cultural beliefs drive decision-making and how animal and human populations have been able to coexist because of them, changing the nature of traditional human-animal relationships. As human beings, we should realize that our actions can have serious implications on the environment and its balances. Activities such as hunting, poaching, and expanding our settlements to natural lands educes the resilience of ecosystems to disturbances. We need to be sensitive of our actions, and should respect species that are holding the ecosystems together.

3. Linkages between social and ecological resilience

Social and ecological resilience of urban ecosystems is interlinked. Adger (2000) considers the relationship between social and ecological resilience to be well-defined, especially for social groups that depend upon the environment and its resources for their livelihood and economy. Adger also asserts that there is a history of human intervention and technological advancements causing ecosystem resilience to decline due to reduction in diversity (Adger 2000).

Adger further explains this linkage through an example of mangrove conversion in Vietnam for agricultural use and due to pollution. Vietnam has observed a shift in economy from central planning to a market-oriented economy, leading to the privatization of land and resources. The change of mangrove land use to agriculture and aquaculture has reportedly affected communities that were dependent on the coastal forests for resources. These changes could take place due to the ascendancy of private property and a policy called 'New Economic Zones.' (Adger 2000) It has been found that poorer households were more dependent on mangrove resources and were more affected by their loss, and richer households benefitted from the conversion. Effects on resilience on a household as well as a community level were found. At the household level, it lead to a decrease in household livelihood security for the mangrove-dependent households. At the community level, Adger (2000) reports that conflicts arose in management of the remaining mangroves, thus leading to noncooperative exploitation of the mangrove areas, inequality in income and the unequal distribution of resource benefits among different classes of people (Adger 2000). Here, the disturbance to the institution was the process of conversion, and that lead to the breakdown of collective management of the remaining resources (Adger 2000). Also, Adger (2000) reports that mangrove loss results in coastal flooding, thus causing greater variability in economic returns for the smaller group of people who are converting the mangroves for aquaculture. The ability of social systems to absorb such economic and political change determines how resilient these systems are.

In this case, the external driver was the land reclamation policy, which directly resulted in ecosystem change, which then fed back to the institutional management structures (Adger 2000). This is a good example of the linkages between social and ecological resilience because the resilience of the management system of extracting fish from the remaining mangroves depended upon the resilience of the fish stock and the mangrove themselves to withstand fishing pressure (Adger 2000). Thus, property rights and other such institutional structures influence the sustainable or unsustainable use of natural resources, and are a central component linking social and ecological resilience (Adger 2000).

Fig 17: Mangrove conversion in Vietnam for aquaculture (FAO 2016)

Another example of a system that lacks resilience is the Pink Lake City proposed for Senegal. The proposed design does not respond well to the existing conditions of the people, the natural environment or the culture of the place. The design is portrayed to be planned as a clean slate, wiping out whatever natural and built environment that exists there. The city has been described as an "International city," without it being a city for the people that are actually going to be living there. It lacks economic sustainability because the design of the city seems expensive and probably not affordable by the local people. The infrastructure, housing, and businesses being proposed seem intended more for attracting affluent residents and visitors from other places. It lacks environmental sustainability because it is destroying the natural environment to introduce development.

It lacks ecological resilience because coastal developments with views to the sea, and lakefront developments are all encroaching upon important natural habitat (Figure 18). It does not take facts such as sea level rise and deforestation into account, because the coastal development could be flooded in a matter of years, forcing people to migrate inwards, and causing great environmental and economic loss that they may not be able to recuperate from.

Fig 18: Pink Lake City in Senegal ("Space Dsign Group Illo | Senegal Pink Lake City Master Plan" n.d.)

The planned development is also inconsiderate of the existing means of livelihood of the people currently residing there. Thus, it also lacks social resilience, since the design has great likelihood of creating social divisions and gentrification due to the displacement of the local population by affluent people migrating in for the upgraded lifestyle that has been promised. This also compromises social resilience by fragmenting social connectivity and reducing the bonds between the residents. It also reduces ecological resilience by making the area less vulnerable to disturbances due to deforestation and clearing the land for resource extraction and development.

Also, poverty is an issue in Senegal, so if the people who will be using it will not have the means of affording the development, then where will they go? How will the city sustain itself? And how will the other phases be built? The design is said to provide economic growth and enhance the standard of living. However, a city is not just infrastructure and economy. The urban fabric of a city is made of people, societies, culture, and the interactions they have with each other and the surroundings, which the Proposal does not give justice to.

03 URBANIZATION & RESILIENCE OF URBAN AREAS

INTRODUCTION TO URBANIZATION

Urbanization is the increase in population in urban areas, mainly due to the shift of people from rural to urban areas in search of opportunities and increased standard of living. Some causes of urbanization are outlined below:

1. Transformation and growth of economy, and change in lifestyle: Industrialization has been a cause for the onset of urbanization in many cities. Due to industrialization, agrarian economies transform into non-agricultural, industrial ones, causing changes in work typologies and habits, an increase in employment opportunities, and an alteration in lifestyle of the residents. American cities such as New York and Philadelphia grew immensely in the late 19th century due to industrial factories being located in or near the cities. New York expanded to over 7 times of its population between 1850 and 1900, and Philadelphia increased its inhabitants from 100,000 to over 1.2 million people in this part of the century (Rees 2016). Such transformations cause the inhabitants to flock to the places with job opportunities and better lifestyle (compact living, enhanced communication facilities, and varied recreational opportunities), causing urbanization.

2. Rural-to-urban migration due to difference of opportunities and resources: Migration is one of the main causes of urban growth of cities. People migrate from rural areas to urban areas in search of better employment opportunities, educational resources, and an enhanced standard of life with ease of access to transportation, infrastructure and civic facilities. In Nepal, internal migration is the main cause of urban growth of the capital Kathmandu, due to which the population is increasing in a rapid rate (4% per year) ("Managing Nepal's Urban Transition" n.d.). A majority of the city dwellers are not indigenous inhabitants, but immigrants in search of educational and employment opportunities.

Fig 19: Urbanization

3. Fertility and natural increase in population: According to Barbara Boyle Torrey (2004), another major cause of urbanization is the fertility of the urban population. Although the fertility rates of urban people tends to be less than rural people, it still contributes considerably to urban growth (Torrey 2004). Increasing birth rates, and declining death rates of the urban population due to medical advancements increases the urban population and causes urban growth.

Different patterns of urban development affect how built and natural land cover are interspersed and in what amount, as well as the demands of societal systems on natural ecosystems (Alberti and Marzluff 2004). Alberti and Marzluff (2004) have asserted that alternative urban patterns comprising of urban form, land use distribution, and connectivity affect ecosystem dynamics and resilience in varied ways.

REGIME SHIFTS DUE TO URBANIZATION

Urban ecosystems are ever-evolving, mainly due to interactions between the social, economic and the natural processes that are occurring at multiple scales. These interactions give rise to a complex system that is dominated by humans and are not always beneficial for the environment. Pollution, traffic congestion, and sprawl are outcomes of these socio-ecological interactions arising from the link between human decisions at different levels (households, businesses, developers, governments) and ecological processes. According to Alberti and Marzluff (2004), urbanization causes a shift in the system from a natural state to a sprawl state, characterized by a fragmentation in the landscape, which causes the substitution of ecological functions with human ones, to reduce the capacity of ecological system to further support human development (Alberti and Marzluff 2004).

Regime shifts are large, abrupt changes that occur in an ecosystem and usually affect how ecological and socio-cultural systems function (Alberti 2013). They may be caused by large calamities such as volcano eruptions or tectonic shifts, and also by gradual processes, such as habitat loss, that occur over a long period of time (Alberti 2013). These changes have adverse effects on human health, access to resources, safety, security, and overall wellbeing of the human populations (Alberti 2013). Alberti (2013) asserts that regime shifts occur where people have induced changes such as reducing biodiversity, altering the hydrological cycle, and the biogeochemical cycles. Climate change, pollution, and natural disasters such as hurricanes, tsunamis, floods, invasive plant species, are all causes of regime shifts that pose threats to urban regions and make them vulnerable (Alberti 2013).

Regime shifts cause systems to change from one state to another. An example would be the eutrophication of a coastal aquatic ecosystem, due to agricultural encroachment or stormwater runoff into the water body, changing the ecosystem from clear water to murky water, which would affect ecosystem services such as recreation, fisheries, and water quality of the coastal waters (Rocha, Peterson, and Biggs 2015).

URBAN PATTERNS IN RELATION TO RESILIENCE

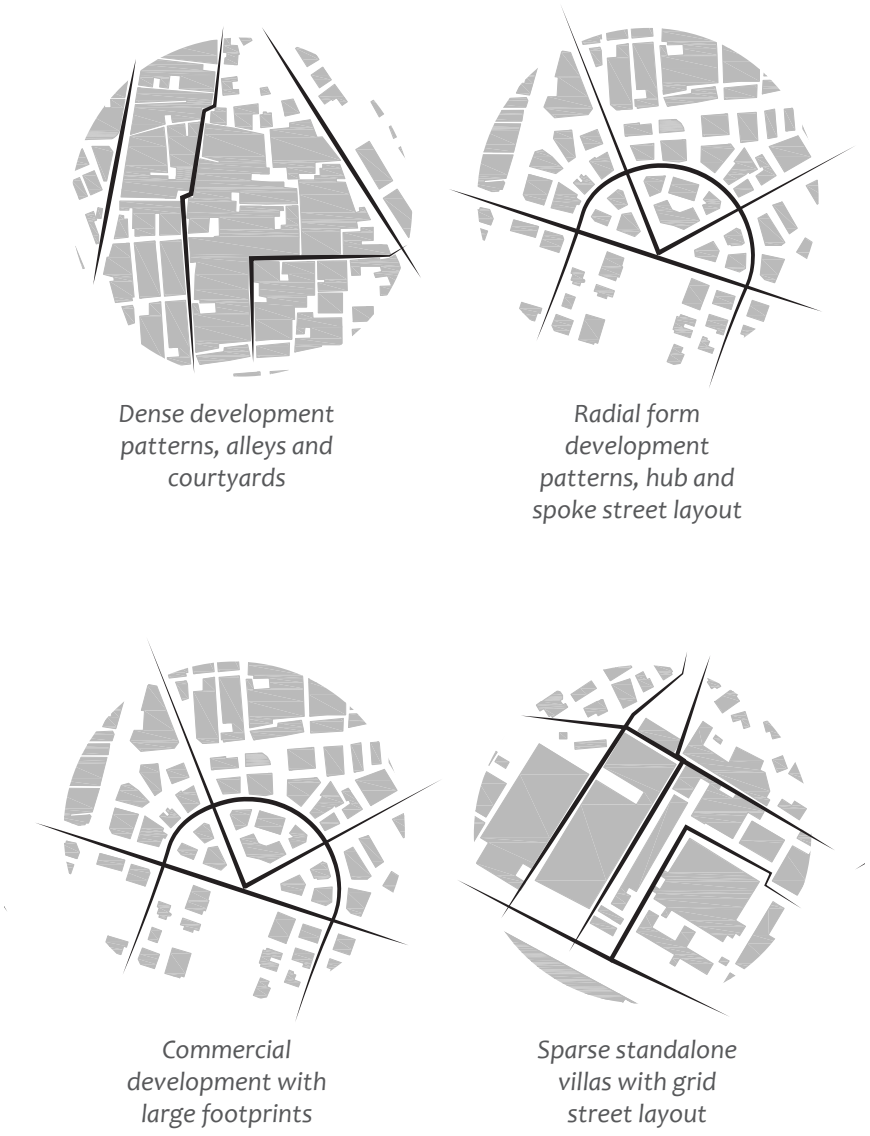


Fig 20: Urban forms in Maadi, Cairo and network linkages

Alberti and Marzluff (2004) assert that urban patterns alter resources and the structure and the physical and biological components of ecosystems. Different configurations of the urban structure, form, land use, and connections give rise to alternative outcomes in the amount and distribution of the built and natural land cover, and thus have differential effects on ecological processes (Alberti and Marzluff 2004). The authors also observe that urban patterns affect resource flows in the system by affecting the distribution of nutrients and solar radiation, and indirectly by limiting the resources accessible for human activities (Alberti and Marzluff 2004).

Alberti and Marzluff (2004) observe that from an ecological perspective, urban development produces various disturbances by inducing physical changes in the landscape.

1. It rescales natural disturbances by reducing or increasing their magnitude, frequency, and intensity (Alberti and Marzluff 2004).
2. It introduces new disturbances, time-based stresses, biological and geographic barriers, new and unnatural forms and shapes, and degrees of connectivity (Alberti and Marzluff 2004).
3. It homogenizes natural patterns by altering land use and modifying the levels of diversity by changing natural processes (Alberti and Marzluff 2004).

These changes produce abrupt or slow-paced changes in urban patterns and risk the ecological and social resilience of urban ecosystems. Urban form, land use distribution and connectivity are urban patterns that affect ecosystem dynamics and resilience (Alberti and Marzluff 2004). These constituents of urban patterns are described in the following sections, with explanations of how they affect the resilience of urban ecosystems.

1. Urban form

Urban form is constituted by density, housing/building type, transport infrastructure, layout, and land use, arranged across macro-, meso-, and micro-scales in the urban setting (Sharifi and Yamagata 2018). As reported by Sharifi and Yamagata (2018), the macro-scale lens sees urban form as the structure position, and its future development of the city in relation to other surrounding cities and networks. The meso-scale approach to urban form looks at neighborhoods and districts, and their structure. At the micro-scale, urban form is observed at the building level, their locations with respect to one another and to pedestrian and traffic networks (Sharifi and Yamagata 2018). Figure 21 shows the scales of urban form and their linkages to resilience.

Fig 21: Different scales of urban form with respect to resilience (Sharifi and Yamagata (2018)

Fig 22: Fukushima Daiichi Nuclear Disaster ("Fukushima Daiichi Nuclear Disaster – Jennifer Straka." n.d.)

Resilience is measured in respect to natural and man-made disturbances. These disturbances can be causal effects to each other. For instance, natural hazards such as earthquakes can cause the failure of manmade infrastructure and systems and cause man-made disasters such as the Fukushima Daiichi nuclear disaster (Figure 22), and human-induced climate change can cause rising sea-levels and storm surges (Sharifi and Yamagata 2018). Sharifi and Yamagata (2018) assert that some urban form measures may enhance resilience to some hazards, but render the city vulnerable to others. For instance, high density is desirable to prevent sprawl, and provide environmental benefits such as conservation of parks, they can also decrease security and increase urban heat island effects (Sharifi and Yamagata 2018). Another example is connectivity, which is desirable for escape during natural disasters, but may be detrimental to the spreading of health epidemics (Sharifi and Yamagata 2018). City size and degree of clustering also affects resilience. Resilient systems aim at enhancing characteristics such as robustness, stability, redundancy, resourcefulness, modularity, complexity, flexibility, multi-functionality, self-organization, and efficiency (Sharifi and Yamagata 2018).

2. Land use

Land uses employed in the urban fabric affect the resilience of urban ecosystems. For instance, coastal land uses, if segregated for wetland habitats can help mitigate the risks of sea level rise on the coastal developments. The approach to land use planning has the capacity to determine how resources are used, and how they can be conserved. Production and consumption choices determine the level of resource extraction and generation of emissions and wastes. Alberti and Marzluff (2004) have asserted that because urban development patterns affect spatial heterogeneity of urban ecosystems, alternative urban patterns that emerge from human and ecological interactions play an important role in the dynamics and resilience of urbanizing regions (Alberti and Marzluff 2004). Urban patterns should be able to support both natural ecosystems and human development.

According to Armstrong (2016), planning approaches should deploy land use to:

a. Realize multiple benefits: The city plans should be designed such that multiple benefits can be realized, such as larger economic, social, or quality of life goals. Certain strategies could be limiting height and density, restricting development on vulnerable coastal zones or seismic areas, and creating mixed-use commercial and retail centers to gain income (Armstrong 2016).

b. Share risk and responsibility between all city stakeholders: Land use policies must encourage joint investment between public, private and non-profit sectors, so that certain behaviors can be incentivized and promoted (Armstrong 2016).

c. Rethink scales of influence: Urban influences are not limited to jurisdictional boundaries. Cities affect large areas such as watersheds, and migratory pathways of wildlife. Cities need to consider how different scales of influence can be integrated into land use policies and practices (Armstrong 2016).

Fig 23: Deforestation (IUCN n.d.)

Fig 24: Chipko Movement in India (India Today 2017)

An example of a land use designation problem that affects the resilience of urban ecosystems is deforestation, as shown in Figure 23. Deforestation can cause loss of carbon storage, change in precipitation patterns, erodibility of soil, and loss of ecological integrity and habitat ("Deforestation, Climate Change Threaten the Ecological Resilience of the Amazon Rainforest" n.d.) According to Tom Prugh (2016), urbanization is a cause for deforestation because cities usually expand to areas with natural habitats. Urbanization also inclines people towards meat products and processed food, which is only obtainable at the cost of forest areas being used extensively for agriculture, fodder or grazing of animals (Prugh 2016). A major part of our lifestyle is based on forest-based products such as lumber, paper, and food products, hence deforestation is occurring at an alarming rate. Deforestation is possible when land use planning is inconsiderate of existing forests and allows the cutting of trees. Accelerated rates of forest clearance cause various adverse effects on the climate, ecological habitat, and can cause natural disasters.

Strategies to reduce deforestation vary in scale, from individual efforts to regional planning efforts and large-scale policy implementation. Since increase in income causes the use of more meat products, which require forests to be cleared, decreasing the consumption of such products can be an individual-scale strategy catered towards decreasing deforestation. Similarly, planting trees, and employing the 3 Rs: Reduce, Reuse and Recycle in the use of forest-based products are other strategies targeted at reducing deforestation.

As Prugh (2016) outlines, conservation of forests in some parts of the world requires the clearance of forests in other parts to import goods and sustain the population. A more local-regional scale solution is eco-forestry, which recognizes that the human use of forests is inevitable, and allows strategic choice of trees for harvesting, while maintaining the rest of the forest intact (Madaan 2016). Awareness programs, implementation of policies and regulations, and localized reforestation and community forestry initiatives help reduce deforestation. These initiatives have sometimes taken the form of movements, such as the 'Chipko' movement in India, where women of a Rajasthan community hugged the trees to stop the contractors from felling them ("The Chipko Movement" n.d.), as shown in Figure 24. A planning approach that has been mentioned by Prugh (2016) is density building, and discontinuing expansion to surrounding natural land.

Belfast, Ireland brought together governments, organizations and citizens to plant over 200,000 trees since 1998 ("3 Cities Taking Urban Forestry to the Next Level | World Resources Institute" n.d.). Guyana achieved nearly zero deforestation while developing socio-economically. Costa Rica gains income through ecotourism based on its forests ("Report Finds Successful Efforts to Reduce Deforestation" n.d.).

Such efforts decrease deforestation, and also increase the resilience of the cities where it occurs. Deforestation is a form of disturbance in forest ecosystems. It reduces the ability of forest ecosystems to recover their functions, and increases the risk of colonization by invasive species. Thus, deforestation reduces the resilience of forest ecosystems to disturbances, and should be reduced with strategies of forest conservation such as community forestry, so that habitats remain intact, and forest resources do not diminish.

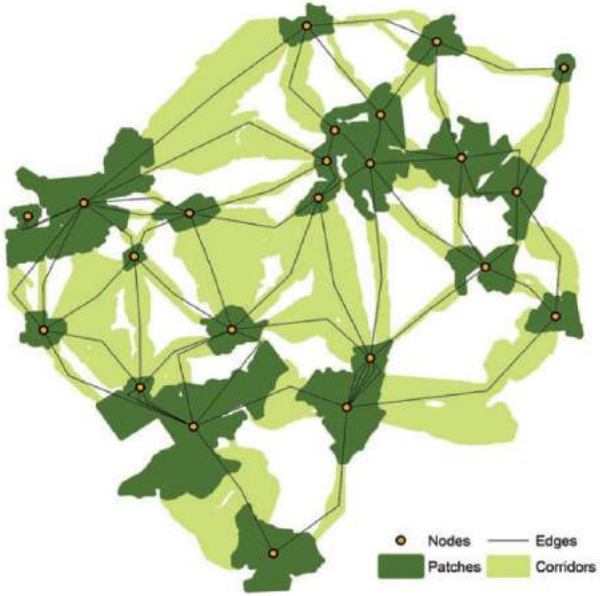


Fig 25: Landscape Connectivity (Rudnick et. al. 2012)

3. Connectivity

Connectivity means the ability by which resources and species migrate, distribute or interact across patches, habitats, or social domains across socio-ecological systems (Stockholm Resilience Center n.d.). Patches of interlinked green spaces in an urban ecosystem are examples that demonstrate connectivity and how species move from one patch to another (Stockholm Resilience Center n.d.). Connectivity is important for resilience of an ecosystem because it can either prevent disturbance from spreading or facilitate recovery (Stockholm Resilience Center n.d.). Thus, it can be both a good and a bad thing. Connectivity is facilitated by habitat corridors (Figure 25), and in case of people, transportation networks (Stockholm Resilience Center n.d.). Well connected habitat patches facilitate the maintenance of biodiversity. The Yellowstone-to-Yukon Project in North America is an example of conservation planning that reconnects large habitat patches by re-establishing wildlife corridors (Stockholm Resilience Center n.d.).

According to the Stockholm Resilience Center (n.d.), too much connectivity, however, can also be a problem. Limiting connectivity can help prevent the spread of disturbances such as a forest fire and diseases(Stockholm Resilience Center n.d.). A system that is too connected can reduce population survival when all populations are trying to avoid the same disturbance (Stockholm Resilience Center n.d.).

The Stockholm Resilience Center (n.d.) asserts that in human social networks, connectivity can build resilience of ecosystems by adding to governance opportunities. Connectivity between social groups facilitates the sharing of information, resources, and trust. Connectivity through transportation networks helps escape disturbances such as disasters and disease. However, too much connectivity can also decrease diversity, with homogenization of thinking, cultures and negative practices as well disturbance (Stockholm Resilience Center n.d.).

Fig 26: Bagmati river corridor (Burohappold Engineering n.d.)

Fig 27: Bagmati river edge housing religious activities (Uwe Gille 2008)

Connectivity of habitats in urban ecosystems can be in the form of corridors connecting patches of green spaces. Other forms of connectivity can be in the form of rivers, which act as continuous connections of aquatic habitats, as well as riparian species on the banks, which can be important corridors for migration of species as well. Moreover, in many parts of the world, rivers can also enhance social connectivity because the riverbanks act as places of great cultural and religious importance, where a concentration of activities brings people together and connects people across vast regions. An example of such a form of connectivity is the Bagmati river and riverfront in Kathmandu, Nepal, which is shown in Figure 26.

The river is a major part of the urban landscape of Kathmandu, and the banks are flanked with religious complexes. The Bagmati river is about 371 miles in length, under 100m wide in most parts of Kathmandu, and fairly shallow most of the year. The river basin encompasses urban settlements mostly in the Kathmandu valley, and agricultural land in the rural parts through which it flows. In Kathmandu, the river is bordered with religious temple complexes in over ten places (as shown in Figure 27), including 'Pashupatinath' and 'Guhyeshwori', legal and illegal residential developments in others areas, and forested woodlands in several spots. In these forested river edges, the Bagmati river corridor supports wetlands and around 100 species of winter birds. (Thapa, Paudel, and Bk 2008). Fish are found in the upstream areas of the Gokarna forest than in the core Kathmandu area (Ram Mehta, Kumar, and Kushwaha 2017).

Fig 28: Monkeys along the Bagmati river edge (National Geographic 2015)

In addition to people, the river banks also host a significant number of monkeys (Rhesus macaque), which have made a livelihood in the temple complexes (Figure 28). The river and the riverbank acts as important connectivity corridors for all of these aquatic and riparian plant and animal species.

The most extensive use of the river in the Kathmandu valley is for religious rituals and cultural gatherings. Major festivals, such as Shivaratri and Chhath, are hosted on the banks of the Bagmati river. Steps leading to the water's edge allow people to directly access the holy river, and litter it with flowers, vermillion powder and food as offerings. Stone platforms that cut through the steps on the river banks in Aryaghat used to cremate dead bodies as per Hindu ritual. This is a significant cultural use of the river, but it also adds to the air and river water pollution since the remnant ashes are cast into the river water. People also engage in illegal sand mining in the Bagmati river, which has caused riverbank erosion and extreme repercussions such as the collapse of a bridge in Kathmandu in 1991 (The Third Pole 2017).

The river connects urban and rural towns and villages regionally, but it has not been used for transportation historically, nor is it used today, mostly because of the fluctuating terrain through which the river flows, resulting in waterfalls and rushed river currents. Longitudinally, the Bagmati river connects various religious hubs throughout the city, some of which are at walking distances to one another, and are connected through riverfront walkways and roads. The temple complexes on the banks of the river serve as hubs for lateral connectivity, drawing in people from all over the city regularly, and from India, substantially during major religious festivals. Lateral connectivity is enhanced by the pedestrian-scale roads and walkways aligning the river's edge. Vertical connectivity is defined by the stone steps that lead down to the river at the temple complexes. At other places, the river edge is less accessible due to the difference in height between the accessible banks and the water level.

Thus the river is an important corridor for ecological and social connectivity. It facilitates aquatic and riparian habitat connections, and also socio-cultural connectivity through riverfront activities and exchange traditions and dialogue. However, it is extremely polluted and the corridor also acts as a means by which water-borne diseases is spread through a significant length of the river. Thus this river is an example of how connectivity is both good and bad for the resilience of the urban ecosystem.

Realizing the importance of the river corridor, an environmental movement called the Bagmati Cleanup Campaign has been organized in Kathmandu. Every week, people gather together for several hours and clean up sections of the river. On the 100th week, over 100,000 volunteers from various communities all over the city joined hands and formed a mega-chain on the banks of the river to commemorate their efforts to save the Bagmati River. Over 1600 organizations are involved in the campaign at different fronts, and over 3000 tons of waste has been collected from the riverbanks till date. In addition to the cleanup efforts, organizations such as the Armed Police Force and the Jorpati Club have built gardens on the riverbanks at certain locations.

04 PLANNING FOR RESILIENCE

INTRODUCTION TO LANDSCAPE PLANNING FOR RESILIENCE

Environmental and landscape planning and development has gone through various eras to reach where it is today. The industrial revolution (the first era), is a focal point in the history of landscape planning. The phase prior to industrialization saw the importance of nature and designed landscapes to fit the human purpose in terms of aesthetics and innovation, and hence was ecologically resilient. The 19th century industrialization changed the socio-economic position of the American people, and handed them immense power through the ability to manufacture goods.

The industrial revolution saw America shift from a predominantly agrarian society to an urbanized, industrial one, but also brought environmental deterioration and poor living conditions to the low-income societies. As a response, parks, playgrounds and urban design and planning strategies, such as the garden cities of Ebenezer Howard and the City Beautiful Movement, were introduced to bring back nature and order into the chaotic and deteriorating industrial society. A major milestone in this era was the introduction of the railway system, leading to decentralization of elite population from the main city core to suburbs.

This onset of urbanization and both good and bad effects on the resilience of the cities. While transportation networks were being introduced extensively and connecting people regionally, they were also acting as barriers to social cohesiveness and decreasing social capital. Natural habitats were being encraoched for development, leading to ecological habitat shift into other states, mostly dedfined by human development. Problems such as the extensive use of automobiles, the degradation of the natural environment for settlement, and homogeneity in the social and economic make of the suburban population were introduces, all of which are still existent today.

This era also saw two seemingly diverging theories on environmental protection come into play: John Muir's theory of preservation, which stated that wilderness should preserved in its pristine state, and Gifford Pinchot's notion of conservation of natural resources for sustained human benefit. John Dixon Hunt, in his essay 'Reading and Writing the Site' (1992), talks about the different degrees of nature: first nature is described as the purest form of nature or 'wilderness' uninfluenced by humans; first nature turns into second nature with any physical or mental intervention; third nature occurs when nature is deliberately shaped by incorporating functions of use and aesthetics. John Muir believed in preserving first nature, however I am skeptical whether first nature exists at all.

Pinchot's notion of conservation acknowledges the dynamism of nature and of the human population, and tries to work out solutions that benefit both. Thus, conservation advocates for resilience of both the ecological and social aspects of the urban ecosystem. Landscape planning must involve "action with foresight" (Steinitz 2008). Natural resources are being used for human benefit and will continue to be depleted by the growing population unless the world is engulfed by a natural disaster, or climate change. So it is wise to effectively induce planned management of natural resources, which makes them available to people for recreation, scientific investigations and other harmless practices, but also conserves them for future use by both biodiversity and mankind.

An outcome of industrialization was the advent of ecological planning in the 20th century (2nd era), which involved the integration of natural habitat in planning. Systematic environmental planning processes were introduced to respond to growing urbanization, and acts such as the National Environmental Protection Act (NEPA) sought to integrate environmental values into development.

In the late 20th century, modern environmental planning (3rd era) was born and the government took up an active role in the cleanup of the environment. Environmental agencies such as the Environmental Protection Agency (EPA) and acts such as the Clean Air Act (1970) and the Safe Drinking Water Act (1974) were introduced. In the fourth era, economic development outweighed environmental regulation. Financial incentives were given to companies for reducing emissions and conserving energy, but the administrators were unable to improve on mass transit, renewable energy sources or managing suburban sprawl. The fifth era, or the sustainability phase, was another one of the most important eras in my opinion. This era looked at sustainability as a goal. Landscape Urbanism was a major milestone in this era. Landscape Urbanism rejected the binary distinction between landscape and city, and encouraged the design of ecological infrastructure, using landscapes as organizing elements of public space. Another important, but somewhat differing notion was New Urbanism, which encouraged mixed use, pedestrian friendly, transit-oriented, livable communities. These milestones are important because they constitute a part of urban ecological planning for resilience, and have shaped progressive cities in the US such as Chicago and Chattanooga.

Heterogeneity of natural and human components of urban ecosystems and their connectivity affect the stability of systems ver time (Alberti 2013). Such concepts are the bases for assessing the fragility and robustness of urban human-natural systems and testing them for resilience (Alberti 2013). Resilience of urban ecosystems depends on the ability of the ecosystems to provide various natural, social and economic benefits to its constituents. Resilient urban ecosystems are defined by robustness, redundancy, and resourcefulness, and these goals can be achieved by promoting green spaces and infrastructure, community gardening and other such community participation events, and incorporating uncertainty in planning and management decisions ("Building a Climate-Resilient City: Urban Ecosystems | WeADAPT" n.d.).

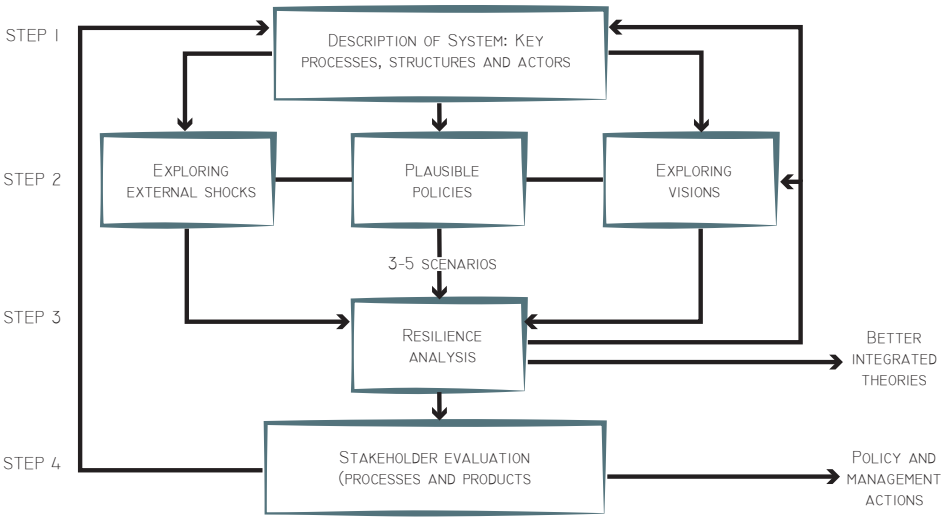


Fig 29: Steps in planning for resilience (Boeckhn.d.)

Some examples of cities that are planning for resilience, as discussed by Armstrong (2016), are as follows:

1. Christchurch, New Zealand plans to make use of vacant land left from the 2011 earthquake to put community garndening into use, with the aim of enhancing social cohesion and a sustainable return to nature (Armstrong 2016).

2. Mexico City uses green and blue infrastructure to mitigate stormwater runoff along with flood protection mechanisms to create multi-functional public open spaces (e.g. Parque de la Viga) (Armstrong 2016)

3. Paris is using watershed analysis, with land use and topography studies, to restore land upstream of the Seine to store water and reduce floods in the city areas (Armstrong 2016)

4. New Orleans is issuing policies mandating private landowners to manage 1.25" of stormwater on site and thus sharing the risk and responsibility of managing stormwater (Armstrong 2016)

STRATEGIES FOR LANDSCAPE PLANNING FOR RESILIENCE

Landscape planning for resiliene constitutes the following strategies:

Table 1: Strategies for landscape planning for resilience (Gravenstein 2014)

Strategy	Author	Resilient effects
Multifunctionality	Jack Ahern (2011)	Combination of functions that support response diversity in relevant functions; examples include stormwater wetlands, floodplain parks, etc.
Redundancy	Jack Ahern (2011)	Multiple elements providing similar backup functions; helps in spreading risks across geography, time and systems
Biological and social diversity	Jack Ahern (2011)	Social, physical, and economic diversity; helps sustain the systems, and recover from disturbances;
Multi-scale networks and connectivity	Jack Ahern (2011)	Trails with linkages to public transit, urban drainage swales, etc.; redundant circuitry provided that maintains connectivity after disturbances
Adaptive planning and design	Jack Ahern (2011)	Policy influencing landscape processes and functions; monitoring and analysis can enhance knowledge for decision makers
Diversity	Walker and Salt (2006)	Increase system's capacity to respond to change and helps respond to disturbances in different ways
Ecological variability	Walker and Salt (2006)	Needed to decrease variability; e.g. forest which is never allowed to burn will not develop fire-resistant species

Strategy	Author	Resilient effects
Modularity	Walker and Salt (2006)	Pattern of connections; overconnected systems are bad for resilience since they are susceptible to shocks
Acknowledging slow variables	Walker and Salt (2006)	Slow variables can cause regime shifts; knowing these variables such as sediment concentration and population age structures helps manage resilience of the system
Tight feedbacks	Walker and Salt (2006)	Thresholds are secondary effects of one variable on another, and help identify thresholds before reaching them
Social capital	Walker and Salt (2006)	Promotes trust and well-developed social networks; increases the ability of the people to respond to disturbances
Innovation	Walker and Salt (2006)	Focuses on embracing experimentation, change and locally-derived rules; helps embrace disturbances than denying them
Overlap in governance	Walker and Salt (2006)	Increases the response diversity and flexibility of the system
Ecosystem services	Walker and Salt (2006)	Provide ecosystem-based values to society

05 ASSESSMENT OF RESILIENCE IN PLANNING

LOCAL SCALE: CHEONGGYECHEON STREAM RESTORATION

Fig 30: Plan of Cheonggyecheon Stream, Seoul ("Cheonggyecheon Stream The Restoration Project" n.d.)

Fig 31: Cheonggyecheon Stream, Seoul (Anzolar 2014 at wikimedia commons)

Location: Seoul, Korea

Completion year: 2005

Project type: urban renewal, park/open space, stream restoration

Designers: SeoAhn Total Landscape

Background

The Cheonggyecheon Stream restoration project in downtown Seoul, Korea, is an urban renewal project completed in 2005, which transformed a heavily polluted urban stream channel into a public recreation space. The Cheonggyecheon stream had turned into an open sewer due to post-war economic development in the 1950s, and was hence covered with concrete for sanitation purposes. In 1976, an elevated highway was constructed over the stream. As a part of his mayoral activities, Mayor Lee Myung-bak had the elevated highway removed and attempted to restore the stream sewer channel back into the recreational and ecological infrastructure that it had the potential to be.

Good aspects

The stream restoration project was a successful urban renewal project, which created a 3.6 mile-long linear green waterfront park in the middle of the dense city. It turned the concrete-covered sewer into a day-lit stream corridor, which attracted over 60,000 visitors each day, many of whom were tourists, boosting the tourism industry and businesses in the area. Along with the stream restoration, the bus transit system was also upgraded, which increased the bus ridership by 15.1% and subway ridership by 3.3%, and created multi-modal lateral and longitudinal connections to the stream corridor. Land prices in the immediate vicinity increased by 30-50%, and the number of businesses increased by 3.5%. The biodiversity increased by over 600%, boosting the number of plant, fish, bird, insect, mammal and amphibian species

Fig 32: Process of Cheonggyecheon stream restoration ("Cheonggyecheon Stream The Restoration Project" n.d.)

in the area, thus providing ecological benefits. It also provided flood control and protection up to 200 years. Most importantly, the project introduced much-needed green space in Seoul, and a place where people could gather, interact with the water and vegetation, and engage in a variety of waterfront activities.

Bad aspects

The stream restoration project required heavy investment: $380 million USD was required to take down the highway, restore the stream and implement the waterfront landscape design. Also, although the project increased the biodiversity in the area, the water that flowed in it was drawn from the Han river, treated, and then pumped into the stream channel, so it was not a complete natural restoration. The stream does not support water purification functions because the stream bottom is made of concrete. The Cheonggyecheon area also used to house a bustling flea market, which was evacuated to make room for the project, displacing the businesses of numerous people. It also involved tearing down a significant transportation infrastructure at great cost, which altered the traffic flow. The maintenance costs are increasing by 30% each year, largely because of an algae problem in the stream. Hence, although the project was successful overall, and had immense public support, it had several shortcomings that drew a lot of criticism.

Achievement of goals

I think the stream restoration project achieved its goals of social connectivity since it drew people from all over the city to the stream-front, and also connected them longitudinally and vertically. It became a valuable park space for public and tourist use, and supported various daytime and nighttime uses social gatherings and art installations, increasing the economic prospects of the Cheonggyecheon area. It also achieved its goals of improving the environmental circumstances of the stream, and improved the air quality and urban biodiversity of the surroundings. So, overall, I think the steam restoration project was successful.

Is it resilient?

The stream restoration project checks many of the boxes for being a resilient system. It promotes social capital by bringing people of different fronts together, and promoting trust and interaction. It also promotes diversity of aquatic and terrestrial species of flora and fauna along the green corridor. In order to improve the resilience performance of the stream however, I would utilize recycled overflow water from the impervious city surfaces rather than pumping water from the Han River. I would also de-channelize and re-naturalize the stream using plants for bank stabilization at strategic locations instead of a concrete base. I would plan the project for a longer term ecological recovery instead of the fast-paced politically-driven development that it is criticized to be. But generally, I appreciate the project for attempting to restore the concrete-covered stream into a public waterway and green space in Seoul, and adding to the resilience of the city.

REGIONAL SCALE: MOMBASA TO NAIROBI RAILWAY (MADARAKA EXPRESS)

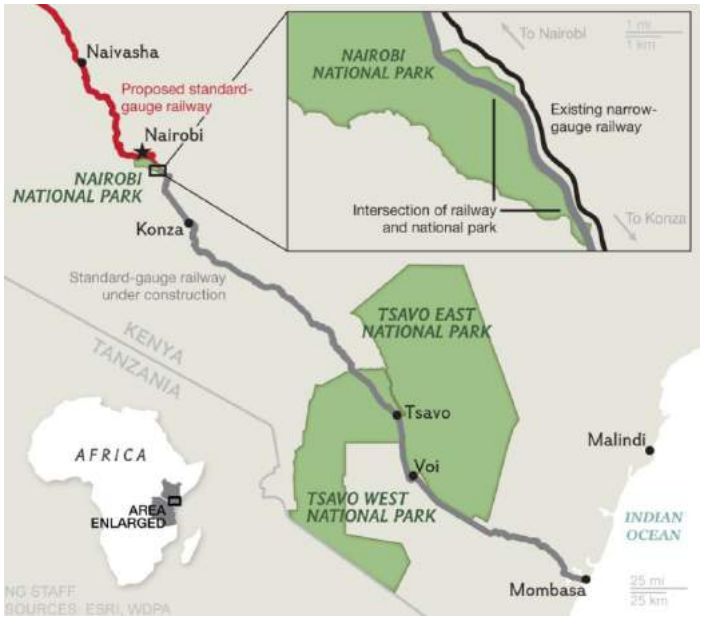


Fig 33: Mombasa to Nairobi railway route (EJAtlas n.d.)

Fig 34: Mombasa to Nairobi railway elevated (Coastweek 2018)

Locations connected: Mombasa and Nairobi, Kenya

Contractors: China Road and Bridge Corporation

Background

The standard gauge railway (SGR), completed in 2017, is a line for passengers and cargo in Kenya, which has a route length of 472 km for the first phase and a total length of 609 km. It runs through the counties of Mombasa, Kilifi, Kwale, Taita-Taveta, Makueni, Kajiado, Machakos and Nairobi. It connects the largest city of Kenya to the large port-city of Mombasa (Figure 33), thus increasing feasibility in trade, travel, and the economy of the places it runs through. It runs parallel to the meter-gauge Uganda Railway, a century-old rail line, but the designers aligned it straighter for higher speeds. It was built according to Chinese railway standards and is planned to be connected to Sudan, Congo, Rwanda, Burundi and Ethiopia to the Indian Ocean in the future. There is also an adjacent highway called Mombasa Highway.

Good aspects

The project is said to be one of the biggest infrastructure developments in Kenya. The railway not only connects the capital city and several other towns to a port, facilitating trade, the Chinese construction technology also decreases the travel time between the two locations, from 12 hours to 4.5. The economy tickets cost 900 Kenyan shillings ($9; £7), which is slightly cheaper than a bus ticket. The business class tickets are $30. It was also said to increase jobs in the vicinity; approximately 30,000 jobs were expected to be created during the construction. The rail line simplified transport operations across the borders of the different cities it passes through. By 2035, the railway is said to transfer 22 million tons a year of cargo (40% of the cargo amount at the port), thus reducing the use of the road and accidents. It is expected to attract investors into the region, and improve the trade, tourism, service and hospitality industries in Kenya.

Fig 35: Embankments supporting the railway (NatGeoUK 2017)

Bad aspects

The railway has been called the 'Lunatic Express 2' by critics for being constructed at a heavy investment of $3.8 million (USD), 80% of which has been loaned by China. This cost is said to amount to 6% of the GDP of Kenya. It is anticipated that Kenya will be in debt for a long time to come. The 'Lunatic Express' was the Uganda Railway, which linked the Port of Mombasa to Lake Victoria, which was very costly and caused the death of thousands of workers from harsh working conditions, and from wild animal attacks. A 2013 World Bank study had concluded that building an entirely new corridor with wider standard gauge rails would be expensive and unnecessary as compared to simply refurbishing the existing one to carry more cargo. The railway also has various environmental implications, because it cuts through Nairobi National Park and Tsavo National Park, thus segregating the wildlife habitats in those regions. The railway track has been built on huge embankments (Figure 35) that animals such as elephants cannot cross. It has several underpasses under viaducts, but more study is required on whether the animals are migrating to and through them. During the construction phase, the use of a tall wire fence broke up the habitat connectivity and caused elephants to be trapped inside the fence. Moreover, noise, vibration and artificial night light during and after construction, in addition to soil and water contamination hazards in sensitive wildlife habitats and migratory zones.

Achievement of goals

I think the railway project achieved its goals of economic growth, creating connections between the port and the city, and faster travel times, but at the expense of an enormous debt to China, and the fragmentation of critical habitats in the national parks.

Is it resilient?

No, I do not think this railway project is resilient. The project is too expensive, and it will be very difficult to recover from the costs that were incurred, thus reducing economic resilience. Merely refurbishing the old railway with numerous overpasses designed as vegetated hills would cut down on costs. The railway also fragments ecological habitat and connectivity, thus reducing ecological resilience as well. The railway could have been built on stilts instead of embankments, for minimizing impacts on habitat connectivity. I would adopt a route that would avoid the national parks entirely. Now that the railway is built, I would suggest the following guidelines:

1. Implement wildlife monitoring and an impact study to assess the implications of the railway on the wildlife, and design fences to funnel wildlife to underpasses.
2. Build speed bumps and wildlife overpasses along the Mombasa Highway.
3. Attract more freight to increase the value for money invested. Critically monitor costs incurred and income produced from the railway for repaying the debt to China.
4. Make the railway ambience respond more to Kenyan culture, since there has been criticism that the railway atmosphere seemed like it does not belong to Kenya.
5. Electrify the railway to lessen the use of diesel and make it environmentally friendly.

GLOBAL SCALE: THE KYOTO PROTOCOL

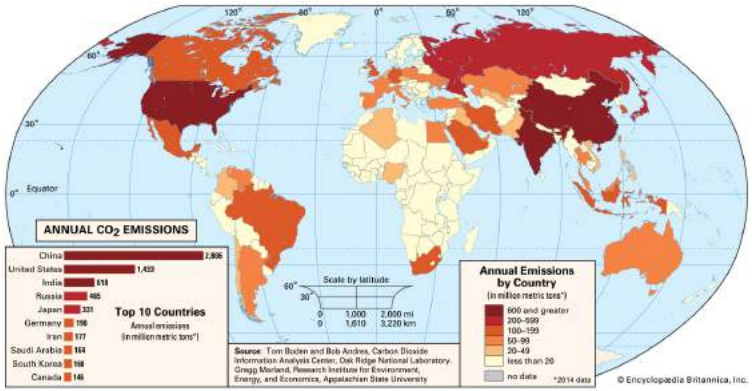


Fig 36: Annual carbon emissions by country ("Kyoto Protocol | History, Provisions, & Facts" n.d.)

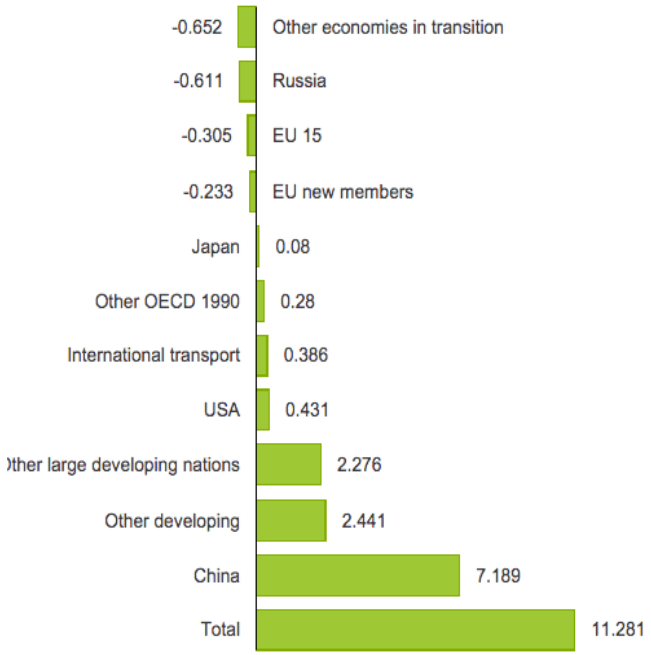


Fig 37: Change in CO2 emissions between 1990 and 2011 (Duncan 2012)

Introduced: 1992; Finalized in 1997; Came into effect: 2005; Commitment period: 2008-2012

Scope: Global

Organization: The United Nations

Background

The Kyoto Protocol is an international treaty that aimed to reduce the emission of greenhouse gases that contribute to global warming. It was an outcome of the United Nations Framework Convention on Climate Change (UNFCCC), which was an international environmental treaty, opened for signature at the Earth Summit in Rio de Janerio in May 1992. The objective of the UNFCCC was to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." (United Nations Framework Convention on Climate Change 1992) Discussions after the UNFCCC lead to the conclusion that stabilizing emissions at 1990 levels was not adequate, and so the Kyoto Protocol was put in force since 2005. The protocol was targeted at reducing six greenhouse gases: to 5.2% below the 1990 levels, in the countries that signed the treaty, for a 'commitment period' of 2008-2012. It was considered one of the most significant treaties ever signed for bringing the world together regarding issues of climate change and global warming, although critics have questioned its effectiveness. Each developed country that agreed to the treaty was given a binding target to reduce overall emissions by a certain percent from 1990 levels. Developing countries were only expected to voluntary limit their emissions to a certain degree. Some developing countries could even increase emissions: Iceland could increase their emissions by 10% and Portugal by 27%. Developed countries such as the United States and the EU were expected to reduce their overall emissions (7% and 8% respectively). The protocol also provided means for countries to reach their targets, which are outlined below:

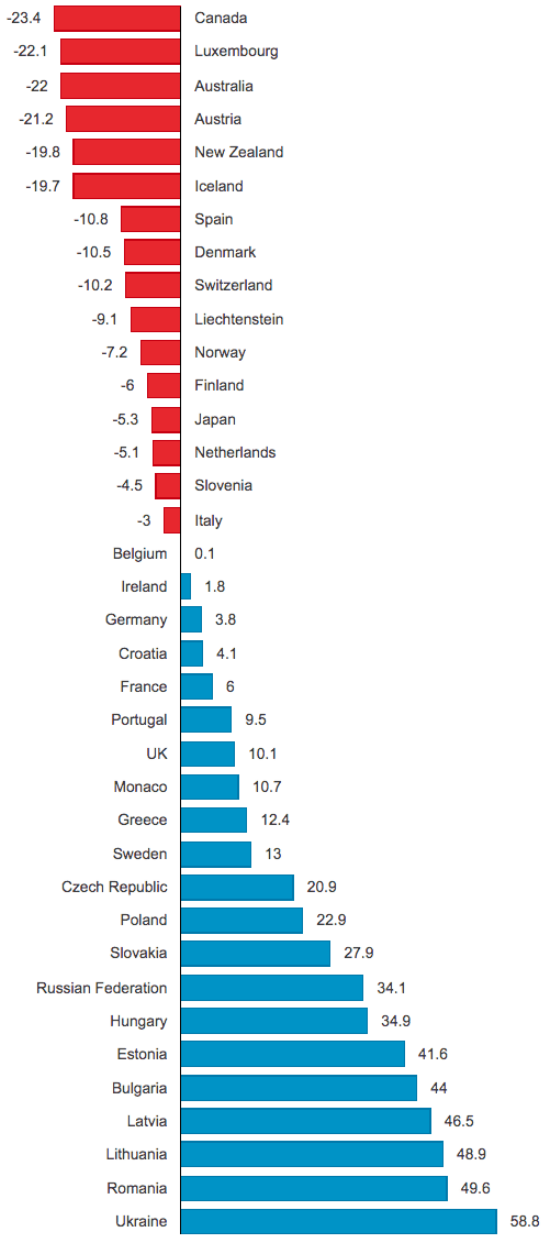


Fig 38: Successes (blue) and failures (red) of the Kyoto Protocol (Duncan 2012)

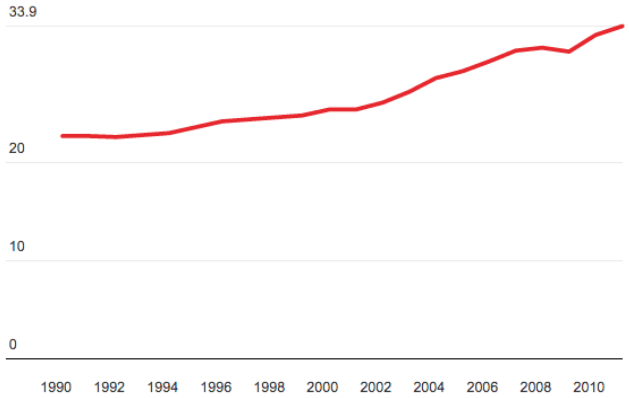


Fig 39: Increase in global emissions despite the Kyoto Protocol (Duncan 2012)

The protocol also provided means for countries to reach their targets, which are outlined below:

1. To use "sinks," or natural processes to remove atmospheric greenhouse gases. Example: planting trees
2. To adopt the Clean Development Mechanism (CDM), which encouraged developed countries to invest in technology (such as natural gas instead of coal) to reduce emissions in developing countries and gain credits towards meeting the protocol requirements.
3. To trade emissions, or buy and sell emissions rights, thereby placing an economic value on greenhouse gas emissions.
4. To employ joint implementation, by means of which developed countries could sponsor foreign research in reducing emissions in developing countries, and earn credits.

Countries that failed to meet their emissions targets would be required to make up the difference between their targeted and actual emissions, and an additional penalty of 30 percent, in the following commitment period (2012-2020). Failure to decrease emissions resulted in losing face, and having to present a plan analyzing the causes of failure and future steps to meet targets.

Good aspects

The Kyoto Protocol introduced mandatory targets for the developed countries that signed it, instead of voluntarily acting on reducing emissions. The developed countries or regions, such as the European Union, that worked towards the target were successful in reducing emissions by 22.6%. It also brought awareness to the fact that climate change is happening and we need to reduce greenhouse gas emissions to reduce the impacts of climate change. Thus, it was a good starting point for countries all around the world to start thinking about these issues, and work together to tackle them. The protocol also paved the way for the Paris Agreement, which aims to limit global temperature increase to 2 degree Celsius.

Bad aspects

The inception and administration had many flaws, because of which the protocol was not entirely successful. Only developed countries were given binding targets, and developing countries were left to voluntarily decrease emissions to not hinder their economic development. So even though the number of developed countries that cut emissions was greater than the number of countries that didn't, the overall reduction was not very significant, and the global emission levels still went up (Figure 37). The major cause of this was that major contributors to greenhouse gas emissions such as China and India were considered developing countries and were not mandated to reduce emissions (India and China's emissions increased 103% and 150% respectively). Due to this reason another major emitter, the United States, did not ratify the treaty. Moreover, it took a long time to finalize, which wasted valuable time in which the countries could have reduced emissions.

Achievement of goals

Many of the participating developed countries met their goals, but their input was not enough to make too much of an impact on global emissions.

Is it resilient?

The Kyoto Protocol is an effort towards resilience, however, it was not entirely successful due to substantial flaws in its division of responsibility, execution, and enforcement. Climate change is a substantial disturbance threatening cities, towns, and rural areas all over the world. The Kyoto Protocol acknowledged climate change as a slow variable that an cause a major disturbance to human settlements. But for a global treaty, it lacked overlap in different scales of governance because it did not respond to the local scale. Hence, the Kyoto Protocol's objectives were very significant, but, although the treaty's outreach was global, its impact could not hit the mark because it could not include major global forces in greenhouse gas emissions from binding targets. Although 192 countries ratified the treaty, only 37 developed countries were mandated to reduce emissions and three major GHG emitters (China, US, and India) were not included. Thus, in this sense, the treaty in tself was not resilient, because it failed the first time around, which resulted in even more countries opting out of the second phase. Some direct action recommendations for the traty are listed below.

Direct action recommendations:

1. Developing nations should also be given a binding target considering their economic implications and their GHG emissions. A better analysis of the economic status of the countries and their capacity to reduce emissions should be a basis for their allotted targets.
2. The countries should be given a longer commitment period to reduce emissions, and also a more substantial target so that it can have a greater impact on the global warming scenario.
3. The ramifications for not meeting the goals should be more substantial, since several countries have backed out (e.g. Canada) at the last moment, when they figured they could not meet their targets.

06 ROLE OF LANDSCAPE ARCHITECTS

LANDSCAPE ARCHITECTS AND THEIR ROLE IN RESILIENCE PLANNING

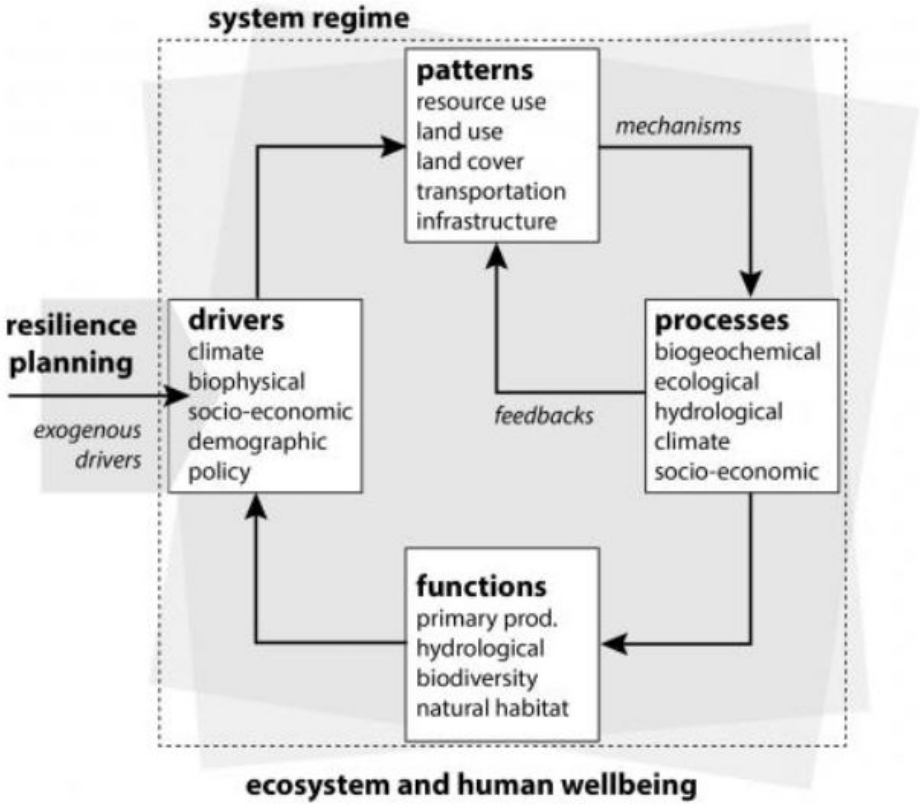


Fig 39: Resilience in urban ecosystems (Alberti 2013)

Strategic decisions about urban infrastructure and growth management need to be based on learnings from the past and predictions for the future. Figure 39 shows the different drivers, functions, processes, and patterns that influence the resilience of urban ecosystems (Alberti 2013). As landscape architects, we are well-versed with each of these components, making our role in resilience planning substantial.

The Landscape Architecture Foundation (LAF) Landscape Declarations of 1966 and 2016 have summarized the values that landscape architects practice the profession: a concern for the environment, the people and the connections between them. Both declarations express a sense of urgency in regards to the environment, which is why resilient thinking in design, implementation and management is necessary. From localized problems like lakes and rivers in the US being polluted with sewage and septic waste, to global problems like climate change, desertification, sea level rise, species extinction and resource depletion, we are dealing with numerous disturbances that are threatening the existence of flora, fauna and human life. Under these circumstances, the role of landscape architects in resilience planning becomes vital.

The profession well-known and respected as one that deals with the design and understanding of built and natural environmental spaces, systems and processes. These declarations express apprehension for the environment and about the unwise use of natural resources, which is a valid concern considering their deteriorating condition. A lot of what we do as landscape architects is related to nature and incorporating the natural environment with built form to shape spaces for the people. Thus a socio-cultural aspect of landscape architecture in addition to the environmental is necessary. Much like the landscape proession, the declarations advocate for social and ecological justice for humans as well as species of flora and fauna.

The LAF declarations acknowledge the necessity of collaboration of different skills in the field of landscape architecture. This collaboration also necessitates a merge of ideas, values and interdependent environmental and built systems to produce solutions to complex social, cultural and natural problems. This collaboration mandates the coexistence of different aspects of the landscape such as sustainability, resiliency, equity and democracy. This sort of collaboration is also essential for building social capital and social resilience in urban ecosystems through trust, communication, and socio-cultural bonds.

Mark Treib, in his 2016 talk at the Landscape Architecture Foundation Summit, talked about the importance of a consensus between the functional, and cultural values of a landscape, sustainability and beauty. He advocates for an inclusive domain in landscape architecture instead of an exclusive one, which is coherent with the Landscape Declaration of 2016, which notes that "landscape architects bring different and often competing interests together so as to give artistic physical form and integrated function to the ideals of equity, sustainability, resiliency and democracy." (LAF 2016)

With increasing urbanization, public and green spaces are becoming sparse, natural resources are dwindling, and people are getting to spend less time outdoors interacting with the environment. In my opinion, people are realizing these problems and the role of landscape architects in solving them. Moreover, with climate change increasing the temperature on earth, puncturing holes in the ozone and raising sea levels, people are realizing the significance of environment-responsive development. We have more knowledge and resources today, to tackle these problems, than we did in the past. We also have more challenges. The problems we are trying to tackle are paramount, and we are a young profession. We have to balance our perception of landscape architecture as an income generating profession, with our values concerning the environment and the people who we serve.

As landscape architects, we understand urban patterns and the need for diversity in urban patterns and forms to increase variation to respond to disturbances. City networks and systems are heterogeneous and modular. In times of disturbance, alternative and flexible modes of transportation and communication can be key in finding ways out (Alberti 2013). Enhancing these multi-modal forms of connectivity by enhancing pedestrian and bike infrastructure, and ecological connectivity, are well under the radar of landscape practice. As landscape architects, we work with nature, instead of against it. Traditional responses to catastrophes are heavily infrastructure based. However, as landscape architects, we come up with solutions that integrate nature: maintaining wetlands as barriers to rising sea levels, green infrastructure to mitigate stormwater runoff amd control flooding, green roofs to reduce urban heat island effects. all of these methods and utilize natural processes to deal with disturbances to the urban ecosystems, and create places where people can come together at the same time, as a means to increase social resilience. Wildlife corridors to facilitate habitat connectivity, urban greening to provide shade and ecosystem services during temperature rise, and building in response to topography, hydrology and climate to avoid landslides, are some landscape planning concepts that can be applied for resilient systems.

The importance of landscape architecture is being realized throughout the world, due to its unique problem-solving approaches that are informed by creative design, natural processes and human interactions with place. I think landscape architecture is headed in the right direction in many ways. We just need to come together to implement our vision for the resilient and sustainable environments that we seek to create and improve.

Fig 40: Green roofs as multi-functional solutions to excess stormwater and urban heat island effects, which are also urban ecosystems (Shrestha 2017)

07 CONCLUSION AND REFLECTIONS

Fig 41: Word mapping resilience ("Planning for Climate Change." 2013)

The world is prone to disturbances: many are natural (volcanoes, floods, earthquakes, etc.) and others are man-made (climate change, fires, deforestation, desertificaion, etc.). Urban ecosystems, which comprise of natural and man-made systems, must display an extent of resilience to these disturbances to avoid shifting to another state.

In 2015, there were two massive earthquakes in Nepal, which not only shook the ground, but also the lives of people, by destroying property, livelihoods, and human and ecological communities. In such circumstances, if there had been planned open spaces linked together by multi-modal networks in place, and disaster response functions designed in the buildings, infrastructure and public spaces, then maybe so many casualties would not have occurred. If planning initiatives had taken into consideration risk locations and improvised density according to that, then maybe Kathmandu would have had a much easier time recuperating from the loss of life, livelihood and infrastructure. Thus, the concept of resilience is of substantial importancein urban planning and landscape considerations.

Human activities are putting critical habitats at risk. Activities such as resource mining, deforestation, pollution, uncontrolled urbanization, are all causing the loss of habitats and the shift of stable ecosystem states to other homogenized states lacking in diversity and reduced ecosystem functions. Rise in sea levels due to increase in global temperature is one of the many crucial issues that requires resilience planning. Coastal development in places such as Florida, are being put at risk because of excessive flooding and storm surges that occur due to the rising sea levels. In such places, planning that allows for preparedness to tackle such disturbances is necessary. Landscape onsiderations such as retaining coastal wetlands for protection against rising water levels, and habitat corridors that allow the movement of these wetland flora and fauna inland, as well as well-planned escape routes and adaptation mechanisms are all examples of resilience planning.

As landscape architects, we understand the nature and importance of critical interactions between the different components of the ecosystem. With this understanding and with the power to create meaningful public open spaces we can create places that respond to the context, ecology and the needs of the people. The field of landscape architecture has the strength to be at the forefront of advocating for sustainability and resilience, and in tackling multi-scale problems such as climate change, habitat loss, social inequity in public spaces, and diminishing natural resources. As a future landscape architect, I plan on striving towards environmental conservation, socio-ecological resilience, and cultural sensibility in my design and planning efforts, and strive to extend awareness of the field across scales and borders. I believe that resilience thinking is necessary to achieve these goals.

08 REFERENCES

"3 Cities Taking Urban Forestry to the Next Level | World Resources Institute." n.d. Accessed October 14, 2018. https://www.wri.org/blog/2016/03/3-cities-taking-urban-forestry-next-level.

Adger, W. Neil. 2000. "Social and Ecological Resilience: Are They Related?" Progress in Human Geography 24 (3): 347–64. https://doi.org/10.1191/030913200701540465.

"Aerial Filming / Aerial Surveying | Singapore Heli Services." n.d. Accessed November 27, 2018. http://singaporeheliservices.com.sg/commercial/aerial-filming-aerial-surveying/.

Alberti, Marina. 2013. "Planning Under Uncertainty: Regime Shifts, Resilience, and Innovation in Urban Ecosystems." The Nature of Cities (blog). January 22, 2013. https://www.thenatureofcities.com/2013/01/22/planning-under-uncertainty-regime-shifts-resilience-and-innovation-in-urban-ecosystems/.

Alberti, Marina, and John M. Marzluff. 2004. "Ecological Resilience in Urban Ecosystems: Linking Urban Patterns to Human and Ecological Functions." Urban Ecosystems 7 (3): 241–65. https://doi.org/10.1023/B:UECO.0000044038.90173.c6.

Armstrong, Amy. 2016. "Planning for Resilience: Innovative Land Use Policies for Building a Resilient City." 100 Resilient Cities. December 8, 2016. https://www.100resilientcities.org/planning-for-resilience-innovative-land-use-policies-for-building-a-resilient-city/.

"An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico" at NAP.Edu. n.d. Accessed November 27, 2018a. https://doi.org/10.17226/18387.

"An Outlook for the Non-Compliance Mechanism of the Kyoto Protocol on Climate Change | Maljean-Dubois | Amsterdam Law Forum." n.d. Accessed November 11, 2018. http://amsterdamlawforum.org/article/view/133/255.

Uwe Gille. 2008. "Bagmati River." Wikipedia. https://en.wikipedia.org/w/index.php?title=Bagmati_River&oldid=870604331.#/media/File:Pashupatinath2.jpg

"Bagmati Clean-up Campaign in 100th Week – General – The Kathmandu Post." "Bagmati Clean-up Campaign in 100th Week – General – The Kathmandu Post." n.d. Accessed October 7, 2018. http://kathmandupost.ekantipur.com/news/2015-04-11/bagmati-clean-up-campaign-in-100th-week.html.

"Bagmati Clean-up Marks 200th Week – Capital – The Kathmandu Post." n.d. Accessed October 7, 2018. https://kathmandupost.ekantipur.com/news/2017-03-12/bagmati-clean-up-marks-200th-week.html.

Boeckh. Kristina. n.d. "Disturbance and Resilience," 19. http://www.uni-kiel.de/ecology/users/fmueller/salzau2006/ea_presentations/Data/2006-05-10_-_Disturbance_and_Resilience.pdf

"Building a Climate-Resilient City: Urban Ecosystems | WeADAPT." n.d. Accessed December 7, 2018. https://www.weadapt.org/knowledge-base/urban-adaptation-to-climate-change/building-a-climate-resilient-city-urban-ecosystems-0.

Burohappold Engineering. N.d. "Bagmati River Basin - BuroHappold Engineering." n.d. Accessed December 9, 2018. https://www.burohappold.com/projects/bagmati-river-basin/.

Cade, D.L. 2013. "Photograph of the Largest Landslide Ever Recorded in the United States." n.d. Accessed December 8, 2018. https://petapixel.com/2013/06/12/photograph-of-the-largest-landslide-ever-recorded-in-the-united-states/.

"Cheonggyecheon." 2018. Wikipedia. https://en.wikipedia.org/w/index.php?title=Cheonggyecheon&oldid=848876837.

Cheonggyecheon StreamSeoulMap. 2011. "Cheonggyecheon Stream Restoration Project." Landscape Performance Series. December 1, 2011. https://www.landscapeperformance.org/case-study-briefs/cheonggyecheon-stream-restoration.

"Cheonggyecheon Stream The Restoration Project." n.d. Accessed December 8, 2018. http://blogtalkwithejay.blogspot.com/2014/10/cheonggyecheon-stream-restoration.html.

Anzola, Francisco. 2014. "Cheonggyecheon_stream_(1510072356).Jpg (3072×2304)." n.d. Accessed December 8, 2018. https://upload.wikimedia.org/wikipedia/commons/a/a8/Cheonggyecheon_stream_%281510072356%29.jpg.

Christie Todd. n.d. Deforestation Effects on Climate. Accessed October 14, 2018. https://www.youtube.com/watch?v=Nc7f5563azs.

"City Aerial 4k Hong Kong Stock Footage Video (100% Royalty-Free) 9801899." n.d. Shutterstock. Accessed November 27, 2018. https://www.shutterstock.com/video/clip-9801899-city-aerial-4k-hong-kong-shot-general.

Clark, Duncan. 2012. "Has the Kyoto Protocol Made Any Difference to Carbon Emissions?" The Guardian, November 26, 2012, sec. Environment. https://www.theguardian.com/environment/blog/2012/nov/26/kyoto-protocol-carbon-emissions.

Coastweeek. 2018. "Coastweek - The Most from the Coast." n.d. Accessed December 8, 2018. http://www.coastweek.com/4021-Xis-special-envoy-to-attend-opening-ceremony-of-mombasa-nairobi-railway.htm.

"Coral Reef Resilience | Reef Resilience." n.d. Accessed December 8, 2018. http://reefresilience.org/understanding-coral-reef-resilience/.

Cutts, Steve. 2012. MAN.

Daniels, Thomas L. 2009. A Trail Across Time: American Environmental Planning from City Beautiful to Sustainability. Journal of the American Planning Association.

"Deforestation, Climate Change Threaten the Ecological Resilience of the Amazon Rainforest." n.d. Accessed December 7, 2018. https://news.mongabay.com/2012/01/deforestation-climate-change-threaten-the-ecological-resilience-of-the-amazon-rainforest/.

"Ecological Resilience." n.d. Encyclopedia Britannica. Accessed December 8, 2018a. https://www.britannica.com/science/ecological-resilience.

EJAtlas. n.d. "Standard Gauge Railway Project Phase 1 Mombasa to Nairobi, Kenya | EJAtlas." Environmental Justice Atlas. Accessed December 9, 2018. https://ejatlas.org/conflict/standard-gauge-railway-project-from-mombasa-to-nairobi-kenya.

FAO. 2016. "161220_05_Vietnam_policy_presentation.Pdf." n.d. Accessed December 8, 2018. http://www.fao.org/fileadmin/templates/rap/files/meetings/2016/161220_05_Vietnam_policy_presentation.pdf.

"Forest Fires - an Ecological Example of the Adaptive Cycle - RAWorkbook." n.d. Accessed November 27, 2018. http://wiki.resalliance.org/index.php/Forest_fires_-_an_ecological_example_of_the_adaptive_cycle.

"Fukushima Daiichi Nuclear Disaster – Jennifer Straka." n.d. Accessed December 9, 2018. https://sites.suffolk.edu/jstraka/2015/10/30/fukushima-daiichi-nuclear-disaster/.

Graham n.d. "Jane Jacobs vs. Robert Moses: urban fight of the century." Performed by Vince Graham.

Gravenstein, Gretchen. 2014. "Resilience in Urban Civic Spaces: Guidelines for Designing Resilient Social-Ecological Systems." Report. Kansas State University. http://krex.k-state.edu/dspace/handle/2097/17642.

Hancock, James Gulliver. 2016. "Everything You Need to Know About Jane Jacobs in Illustrated Form." Curbed. May 4, 2016. https://www.curbed.com/2016/5/4/11582798/jane-jacobs-illustrated-guide-james-gulliver-hancock.

Harvey, David. 2003. "The Right to the City." International Journal of Urban and Regional Research 27 (4): 939–41. https://doi.org/10.1111/j.0309-1317.2003.00492.x.

Holling. C.S. Reviewed. 1973. "Resilience and Stability of Ecological Systems." Annual Review of Ecology and Systematics, 1–23.

"How the Cheonggyecheon River Urban Design Restored the Green Heart of Seoul | Inhabitat – Green Design, Innovation, Architecture, Green Building." n.d. Accessed October 28, 2018. https://inhabitat.com/how-the-cheonggyecheon-river-urban-design-restored-the-green-heart-of-seoul/.

Hunt, John Dixon. 2002. "Reading and Writing the Site." In Theory in Landscape Architecture, by Simon Swaffield, 131-135. Philadelphia: University of Pennsylvania Press.

India Today. 2017. "Chipko Movement Founder Sunderlal Bahuguna: The Defender of Himalayas Turns 90 - Education Today News." n.d. Accessed December 8, 2018. https://www.indiatoday.in/education-today/gk-current-affairs/story/sunderlal-bahuguna-952506-2017-01-09.

IUCN. 2017. "Deforestation and Forest Degradation" Accessed November 10, 2017. https://www.iucn.org/resources/issues-briefs/deforestation-and-forest-degradation.

"Jane Jacobs." 2018. Wikipedia. https://en.wikipedia.org/w/index.php?title=Jane_Jacobs&oldid=870326909.

MASNYC. N.d. "Jgh_janejacobs_FINAL_flat.0.Jpg (1920×1386)." n.d. Accessed November 27, 2018. https://cdn.vox-cdn.com/thumbor/8ah3DL0Oft4JE4F2vEd2I8OeKQ8=/0x0:3000x2166/1920x0/filters:focal(0x0:3000x2166):format(webp):no_upscale()/cdn.vox-cdn.com/uploads/chorus_asset/file/6433301/jgh_janejacobs_FINAL_flat.0.jpg

Kacungira, Nancy. 2017. "Is Kenya's New Railway Good Value for Money?," June 8, 2017, sec. Africa. https://www.bbc.com/news/world-africa-40171095.

Kondolf, G. Mathias, and Pedro J. Pinto. 2017. "The Social Connectivity of Urban Rivers." Geomorphology, Connectivity in Geomorphology from Binghamton 2016, 277 (January): 182–96. https://doi.org/10.1016/j.geomorph.2016.09.028.

"Kyoto Protocol | History, Provisions, & Facts." n.d. Encyclopedia Britannica. Accessed December 8, 2018. https://www.britannica.com/event/Kyoto-Protocol.

Landscape Architecture Foundation. 1966. "A Declaration of Concern."

Landscape Architecture Foundation. 2016. "The New Landscape Declaration."

LucasMartinFrey. 2011. English: An Abstract Diagram Showing Forest Succession over Time. Increase in Biomass, Biodiversity and Soil Thickness Are Also Shown, as Well as the Fluctuation of Different Plant Communities over the Process of Succession. Own work. https://commons.wikimedia.org/wiki/File:Forest_succession_depicted_over_time.png.

Madaan, Sonia. 2016. "8 Fantastic Solutions to Deforestation." Earth Eclipse (blog). February 27, 2016. https://www.eartheclipse.com/environment/fantastic-solutions-to-deforestation.html.

"Managing Nepal's Urban Transition." n.d. Text/HTML. World Bank. Accessed October 14, 2018. http://www.worldbank.org/en/news/feature/2013/04/01/managing-nepals-urban-transition.

"Marc Treib: Less a Declaration Than Some Thoughts from Landscape Architecture Foundation on Vimeo." n.d. Accessed September 9, 2018. https://player.vimeo.com/video/171748739.

Marsh, William M. 2010. Landscape Planning: Environmental Applications, 5th Edition. John Wiley & Sons.

Marshall, Colin. 2016. "Story of Cities #50: The Reclaimed Stream Bringing Life to the Heart of Seoul." The Guardian, May 25, 2016, sec. Cities. https://www.theguardian.com/cities/2016/may/25/story-cities-reclaimed-stream-heart-seoul-cheonggyecheon.

Mishra, Binaya K., Ram K. Regmi, Yoshifumi Masago, Kensuke Fukushi, Pankaj Kumar, and Chitresh Saraswat. 2017. "Assessment of Bagmati River Pollution in Kathmandu Valley: Scenario-Based Modeling and Analysis for Sustainable Urban Development." Sustainability of Water Quality and Ecology 9–10 (November): 67–77. https://doi.org/10.1016/j.swaqe.2017.06.001.

"Mombasa-Nairobi Standard Gauge Railway Project – Railway Technology." n.d. Accessed November 3, 2018. https://www.railway-technology.com/projects/mombasa-nairobi-standard-gauge-railway-project/.

"Morel and Shishlov – 2015 – EX-POST EVALUATION OF THE KYOTO PROTOCOL FOUR KEY.Pdf." n.d. Accessed November 11, 2018. https://www.i4ce.org/wp-core/wp-content/uploads/2015/09/14-05-Climate-Report-n%C2%B044-Analysis-of-the-KP1.pdf.

Mumby, Peter J, Iliana Chollett, Yves-Marie Bozec, and Nicholas H Wolff. 2014. "Ecological Resilience, Robustness and Vulnerability: How Do These Concepts Benefit Ecosystem Management?" Current Opinion in Environmental Sustainability, Environmental change issues, 7 (April): 22–27. https://doi.org/10.1016/j.cosust.2013.11.021.

Narayanan, Nayantara. n.d. "A Nomads' Legend Keeps the Indian Wolf Alive: An Unconventional Conservation Story." Text. Scroll.In. Accessed December 8, 2018. https://scroll.in/article/761811/a-nomads-legend-keeps-the-indian-wolf-alive-an-unconventional-conservation-story.

National Geographic. 2015. "What the River Knows: Bagmati River, Nepal – National Geographic Blog." Accessed December 9, 2018a. https://blog.nationalgeographic.org/2015/08/01/what-the-river-knows-bagmati-river-nepal/.

NatGeoUK. 2017. "Controversial Railway Splits Kenya's Parks and Threatens Wildlife." Controversial Railway Splits Kenya's Parks and Threatens Wildlife | National Geographic. October 31, 2017. http://www.nationalgeographic.co.uk/photography/2017/10/controversial-railway-splits-kenyas-parks-and-threatens-wildlife.

Njumbi, Steve. n.d. "Kenya Railway Line's Effects on Development, Animal Welfare." IFAW – International Fund for Animal Welfare. Accessed November 3, 2018. https://www.ifaw.org/united-states/news/kenya-railway-line%E2%80%99s-effects-development-animal-welfare.

"Noun Project." n.d. Noun Project. Accessed November 27, 2018a. https://thenounproject.com.

Papacosma, Kate. 2008. Review of Review of Slum Clearance and the Superblock Solution, ; Robert Moses and the Modern City: The Transformation of New York, Hilary Ballon, by Hilary Ballon and Kenneth T. Jackson. The Public Historian 30 (1): 146–49. https://doi.org/10.1525/tph.2008.30.1.146.

Pickett, S. T. A., M. L. Cadenasso, E. J. Rosi-Marshall, K. T. Belt, P. M. Groffman, J. M. Grove, E. G. Irwin, et al. 2017. "Dynamic Heterogeneity: A Framework to Promote Ecological Integration and Hypothesis Generation in Urban Systems." Urban Ecosystems 20 (1): 1–14. https://doi.org/10.1007/s11252-016-0574-9.

Pickett, Steward T. A., and J. M. Grove. 2009. "Urban Ecosystems: What Would Tansley Do?" Urban Ecosystems 12 (1): 1–8. https://doi.org/10.1007/s11252-008-0079-2.

"Planning for Climate Change." 2013. Great Lakes Coastal Resilience Planning Guide. March 14, 2013. http://greatlakesresilience.org/climate-environment/planning-climate-change.

Prugh. Tom. 2016. Rural-Urban Migration, Lifestyle, and Deforestation. In The World Watch Institute (Ed.), Can a City Be Sustainable? (pp. 263–272). Islan Press.

Ragoschke, Adam S. 2014. "Social Resilience: Goals and Objectives for Engaging Urban Design." Report. Kansas State University. http://krex.k-state.edu/dspace/handle/2097/17762.

Ram Mehta, Kripa, Ujjawal Kumar, and Ujjawal Kushwaha. 2017. "A Vast Aquatic Diversity Reveals the Richness of Bagmati Biodiversity." Bioscience and Bioengineering 3 (January): 11–16.

Rees, Jonathan. 2016. "Industrialization and Urbanization in the United States, 1880–1929." Oxford Research Encyclopedia of American History, July. https://doi.org/10.1093/acrefore/9780199329175.013.327.

"Report Finds Successful Efforts to Reduce Deforestation." n.d. Union of Concerned Scientists. Accessed October 14, 2018. https://www.ucsusa.org/news/press_release/report-finds-deforestation-successes-0420.html.

"Resilience Alliance - Adaptive Capacity." n.d. Accessed November 23, 2018. https://www.resalliance.org/adaptive-capacity.

"Resilience Alliance - Adaptive Cycle." n.d. Accessed November 27, 2018a. https://www.resalliance.org/adaptive-cycle.

"Resilience Alliance - Adaptive Management." n.d. Accessed November 23, 2018. https://www.resalliance.org/adaptive-mgmt.

Rocha, Juan Carlos, Garry D. Peterson, and Reinette Biggs. 2015. "Regime Shifts in the Anthropocene: Drivers, Risks, and Resilience." PLoS ONE 10 (8). https://doi.org/10.1371/journal.pone.0134639.

Rudnick, Deborah A, Sadie J Ryan, Paul Beier, Samuel A Cushman, Fred Dieffenbach, Clinton W Epps, Leah R Gerber, et al. 2012. "The Role of Landscape Connectivity in Planning and Implementing Conservation and Restoration Priorities," 21.

"Seoul Tears down an Urban Highway and the City Can Breathe Again." 2011. Grist (blog). April 5, 2011. https://grist.org/infrastructure/2011-04-04-seoul-korea-tears-down-an-urban-highway-life-goes-on/

Sharifi, Ayyoob and Yamagata, Y. 2018. "Resilient Urban Form: A Conceptual Framework." n.d. ResearchGate. Accessed December 9, 2018a. http://dx.doi.org/10.1007/978-3-319-75798-8_9.

"SPACE DESIGN GROUP Illo | Senegal Pink Lake City Master Plan." n.d. Accessed December 8, 2018. http://illo.co.kr/?portfolio_page=senegal-pink-lake-city-master-plan.

Stockholm Resilience Center. N.d. "Applying Resilience Thinking" Accessed December 7, 2018. http://stockholmresilience.org/download/18.10119fc11455d3c557d6928/1459560241272/SRC+Applying+Resilience+final.pdf.

"Standard Gauge Railway – Briefing – 4 Jan Updated .Pdf." n.d. Accessed November 3, 2018. https://wedocs.unep.org/bitstream/handle/20.500.11822/25184/Standard%20Gauge%20Railway%20-%20Briefing%20-%204%20Jan%20updated%20.pdf?sequence=4&isAllowed=y.

Stieglitz, C. M. World Telegram staff. 1939. Deutsch: Robert Moses Library of Congress. New York World-Telegram & Sun Collection. http://hdl.loc.gov/loc.pnp/cph.3c36079. https://commons.wikimedia.org/wiki/File:Robert_Moses_with_Battery_Bridge_model.jpg.

Steinitz, Carl. 2008. Landscape planning, a history of Influential ideas. Journal of Landscape Architecture., 3(1), 74–83.

"Tasso Azevedo: Hopeful Lessons from the Battle to Save Rainforests – YouTube." n.d. Accessed October 14, 2018. https://www.youtube.com/watch?v=u70RZtCJ_rI.

Thapa, Saroj, Shambhu Paudel, and Dipak Bk. 2008. "An Assessment on Bird's Diversity in Bagmati River Corridor." The Initiation 2 (1): 34–40. https://doi.org/10.3126/init.v2i1.2520.

"The Chipko Movement." n.d. Accessed October 14, 2018. http://edugreen.teri.res.in/explore/forestry/chipko.htm.

"The Kyoto Protocol Accomplishments and Failures.Pdf." n.d. Accessed November 11, 2018. https://atmos.washington.edu/2009Q1/111/ATMS111%20Presentations/Folder%201/ChavezM.pdf.

"The Kyoto Protocol :: Challenges." n.d. Accessed November 11, 2018. https://www.mtholyoke.edu/~danov20d/site/challenges.htm.

"The Kyoto Protocol :: Essence and Goals." n.d. Accessed November 11, 2018. https://www.mtholyoke.edu/~danov20d/site/goals.htm.

The Third Pole, May 5, and 2017. 2017. "Sandmining Is Destroying Asia's Rivers." The Third Pole (blog). May 5, 2017. https://www.thethirdpole.net/en/2017/05/05/sandmining-is-destroying-asias-rivers/.

Torrey, Barbara Boyle. 2004. "Urbanization: An Environmental Force to Be Reckoned With." Accessed December 9, 2018. https://www.prb.org/urbanization-an-environmental-force-to-be-reckoned-with/.

"UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHA. Pdf." n.d. Accessed November 9, 2018. http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.

"Urban Ecosystem." n.d. Encyclopedia Britannica. Accessed November 20, 2018. https://www.britannica.com/science/urban-ecosystem.

Wolkenkratzer. 2013. Deutsch: Terrassenlandwirtschaft 3 Km Nordwestlich Pokhara (Luftaufnahme). Own work. https://commons.wikimedia.org/wiki/File:Nepal,_Pokhara_Pame.jpg.

Wu, Jianguo, and Tong Wu. 2013. "Ecological Resilience as a Foundation for Urban Design and Sustainability." In Resilience in Ecology and Urban Design: Linking Theory and Practice for Sustainable Cities, edited by S.T.A. Pickett, M.L. Cadenasso, and Brian McGrath, 211–29. Future City. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-5341-9_10.