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URBAN FORESTS AND OPEN GREEN SPACES: LESSONS FOR JAIPUR, RAJASTHAN, INDIA

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Rajasthan State Pollution Control Board
The Rajasthan State Pollution Control Board is a body corporate constituted under section 4 of the Water (Prevention and Control of Pollution) Act, 1974. It was first constituted on February 7, 1975, with the objectives of prevention, and control of water pollution and maintaining or restoring of wholesomeness of water. Later, it was also entrusted with the responsibilities of prevention, control and abatement of air pollution under the provisions of Air (Prevention and Control of Pollution) Act, 1981. Water (Prevention and Control of Pollution) Cess Act, 1977 has been enacted to make the State Board financially independent. Under this act the State Board has been given powers to collect cess on the basis of water consumed by the industries and others. Enactment of the Environment (Protection) Act, 1986 has further widened the scope of the activities of the Board. This act being umbrella legislation, different rules for addressing the problems of various sectors have been enacted under this act. Currently, the State Board is engaged in implementation of the following rules under EPA, 1986:

- Environment (Protection) Act, 1986.
- Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008.
- Manufacture, Storage & Import of Hazardous Chemical Rules, 1989.
- Public (Liability) Insurance Act, 1991.
- Environmental Impact Assessment (Aravali) Notification Dated 7.5.1992.
- Environmental Impact Assessment Notification dated 14.09.06.
- Bio Medical Waste (Management & Handling) Rules, 1998.
- Recycled Plastic Manufacture & Usage Rules, 1999.
- Noise (Pollution Control & Regulation) Rules, 2000.
- Municipal Solid Waste (Management & Handling) Rules, 2000.
- Battery (Management & Handling) Rules, 2001.

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Summary

In an era of global climate change and rapid urbanization, innovations on governance of urban systems are critically required as 50% people are now living in less than 3% of the earth's urbanized terrestrial surface. Without careful production of knowledge, and large investments to link that knowledge to action, cities will be overwhelmed with environmental challenges. Both policy and science now emphasize the critical necessity of green areas within urban social-ecological systems. Here, we review the present status of urban forestry across the world, and draw lessons that can be applied for the governance of urban green spaces during the development of Jaipur as a world-class city in Rajasthan. We find wide variation both in coverage as well as per capita availability of green spaces. There are, however, some discernible trends emerging from cities renowned for their urban green spaces: approximately 20 to 30% coverage of the total geographical area, and 15 to 25 m^2 urban green spaces per capita. World Health Organization suggests ensuring at least a minimum availability of 9 m^2 green open space per city dweller. Finally, we provide strategies and lessons for connecting science to decision-making aimed at creating multifunctional landscapes to enhance urban resilience and human well-being.

1. Introduction

Cities occupy less than 3% of the global terrestrial surface, but account for 78% of carbon emissions, 60% of residential water use, and 76% of wood used for industrial purposes. In 1800, there was only one city, Beijing, in the entire world that had more than a million people; 326 such cities existed 200 years later (Brown 2001). Indeed, such rapid has been the pace of growth that in 1900 just 10% of the global population was living in urban areas which now exceeds 50% and is expected to further rise to 67% in the next 50 years (Grimm et al. 2008).

In developing countries, about 44 per cent of the population currently lives in urban areas, but in the next 20 to 30 years, developing countries in Asia and Africa are likely to cross that historic threshold, joining Latin America in having a majority of urban residents (UN-Habitat 2009, Montgomery 2008). Rapid urbanization in India is bringing complex changes to ecology, economy and society (DeFries and Pandey 2010). During the last 50 years the population of India has grown two and a half times, but the urban population has grown nearly five times (Taubenböck et al. 2009). About 60% of this urban population growth is attributable to natural growth, and the remaining 40% is due to migration and spatial expansion (Sivaramakrishnan et al. 2005). At a more regional scale, statistics in Rajasthan brings out an interesting aspect of growth. Over the last two and half decades spatial growth of cities has often been three-times faster than the growth of population (Jat et al. 2008). Undoubtedly, urbanization will continue to have substantial impact on the ecology, economy and society at local, regional, and global scales.

It is logical, then, that scientists, planners and general public now urgently redesign urban systems that necessarily take into account the fact that 50% people are now living in less than 3% of the earth's urbanized surface. In addition, on the face of climate change, adaptation and mitigation actions for cities in India are critically required where the urban population is likely to grow by around 500 million over the next 50 years. Addressing multiple risks due to climate change—temperature and precipitation variability, drought, flooding and extreme rainfall, cyclone and storm surge, sea-level rise, and associated environmental health risk—is a serious public policy and adaptation management challenge for India (Revi 2008). Without careful production of knowledge, and large investments to link that knowledge to action, cities will be overwhelmed with environmental challenges. Foremost among these challenges is maintaining human well-being by provisioning for clean air and healthy living through conservation and restoration of urban green spaces and urban forests.

Many policy instruments and robust scientific evidence in last two decades have emphasized the critical necessity of green areas within urban social-ecological systems to ameliorate several problems of city-living. As this review will demonstrate, benefits of urban green spaces are wide-ranging including physical and psychological health, social cohesion, climate change mitigation, pollution abatement, biodiversity conservation and provisioning of the ecosystem goods and service to urban inhabitants. Accordingly, this review briefly examines the present status of urban forestry across the world, and draws lessons that can be applied for the governance of urban green spaces during the development of Jaipur as a world-class city in Rajasthan.

The term "urban green spaces" is used in this article as a comprehensive term, comprising all urban parks, forests and related vegetation that add value to the inhabitants in an urban area. The term "urban trees" includes trees growing both within the built environment as well as road-side avenues and public places in urban systems.

2. International Norms for Urban Green Spaces

The issue of required open green spaces per capita in urban systems has remained controversial. In 20th century, experts in Germany, Japan and other countries proposed a standard of 40 square meters (m^2) urban green space in high quality or 140 m^2 suburb forest area per capita for reaching a balance between carbon dioxide and oxygen, to meet the ecological balance of human well-being. Currently, developed countries have tended to adopt a general standard of green space of 20 m^2 park area per capita (Sukopp et al. 1995, Wang 2009).

International minimum standard suggested by World Health Organization (WHO) and adopted by the publications of United Nations Food and Agriculture Organization (FAO) is a minimum availability of 9 m^2 green open space per city dweller (Kuchelmeister 1998). There is yet another yardstick, which refers to London but has relevance to any city. Abercrombie (1943) prepared a plan in 1943-1944 suggesting that 1.62 ha (four acres) open space per 1000 population was a reasonable figure to adopt for London. The plan also explains that all forms of open space need to be considered as a whole, and to be co-ordinated into a closely-linked park system, with parkways along existing and new roads forming the links between the larger parks.

There are city-specific local guidelines that may provide us useful guidance. For instance, Aarhus, with a population of 0.3 million is the second largest city in Denmark. The Green Structure Plan was prepared as part of the planning reforms of the 1970s. The political vision of 'Aarhus surrounded by forest', had strong public support. It is used to control urban growth and to set standards: no dwelling should be more than 500 metres from a green area of at least 6,000 m^2 (Carmona et al. 2003). In terms of structural diversity, green spaces in urban systems should essentially be developed as networks (Cook 2002, Thompson 2002). Three main components of urban forest and green spaces are: Patch (urban domestic gardens, public and private parks, gardens, urban forest patches etc.), Corridor (roadside avenues, walkways and urban greenways etc.), and Network structure (layout of all the patches and the corridors connecting the patches).

3. A Global Perspective on Extent of Urban Forests

The information available globally suggests that the cities in developed countries, in general, have more trees compared to cities in developing countries, which often fall below the minimum standard set by WHO of 9 m^2 green open space per city dweller. Cover of green space in urban landscape around some portion of the globe has been presented in Table-1. In this section, taking examples from different regions of the world, we provide a selection of perspective on urban forests.

A comprehensive study across 386 European cities (Fuller & Gaston 2009) suggests that green space coverage in cities varied markedly, averaging 18.6 per cent and ranging from 1.9 (Reggio di Calabria, Italy) to 46 (Ferrol, Spain) per cent. Availability of urban green spaces per capita varied by two orders of magnitude, from 3 to 4 m^2 per person in Cádiz, Fuenlabrada and Almeria (Spain) and Reggio di Calabria (Italy) to more than 300 m^2 in Liège (Belgium), Oulu (Finland) and Valenciennes (France).

Urban tree cover in the United States ranges from 0.4% in Lancaster, California to 55% in Baton Rouge, Louisiana (Nowak et al. 1996), containing approximately 3.8 billion trees with an average tree canopy cover of 27 percent of urban areas (Nowak et al. 2001).

Curitiba, with a population of 1.7 million, is one of Brazil's large cities. In the 1970s, growing population has reduced urban green space to 1 m^2/person. A clear priority and consistent efforts by local authorities have successfully developed green open space, which now measures to 51.5m^2/person (Carmona et al. 2003).

Canberra, the national capital of Australia, is a planned city established on grazing lands in the southern tablelands of New South Wales. At the beginning of the 1900s, the Canberra plain was largely treeless. With the selection of Canberra as the site for the new capital of Australia, extensive tree plantings began in 1911. Today, the urban forest on public lands contains 400,000 trees belonging to some 200 species in streets and parklands (Banks and Brack 2003). Melbourne is Australia's second largest city that has a population size similar to Jaipur (3.50 million). It has an extensive integrated network of open spaces that harbor more than 40 per cent of the nationally listed threatened ecological vegetation (Carmona et al. 2003).

Wellington, New Zealand's capital, with a population of less than two lacs, is surrounded by steep hills. It was a well-forested tract until the Europeans settled in 1840. Originally built around the harbor on low-lying land, it spread onto the steeper hillsides as urbanization took place. Despite development pressures Wellington has 200 m^2/person of green space (Carmona et al. 2003).

Tokyo suffers from a shortfall of green open space which averages 6.1 m^2/ person to 8.5 m^2/ person in Japan (Carmona et al. 2003), but it has a large forest of 21,630 ha to conserve water. The city management started planting many treeless areas more than 100 years ago. Now its forest management systems have changed to multi-storied forests from single-storied to improve water conservation. Forests in Hannou City, one hour from Tokyo, include many artificial forests which covered 84 percent of the city area in 1990, with a rich average stock volume of 287 m^3/ha (Uozumi 1995). The core of Metropolitan Area has green spaces of less than 20%, while surrounding area has 60-80% green spaces. From an ecological perspective, some studies have suggested that a realistic target of 10% of tree cover throughout urban areas is necessary to create an ecologically sustainable city (Hashimoto et al. 2005).

A study of 439 cities in China in 1991 noted that the overall green space was 380,000 ha or 20.1% of the urban area. Some 40% of the cities had more than 30% green cover in 1991 (Ming and Profous 1993). The green space coverage and public green area per capita were 16.9%, and 3.5 m², respectively, in 1986 and increased to 23.0%, and 6.52 m² by 2000 (Wang 2009). Further, by the end of 2006, greening coverage in China's cities has increased to 32.54%. Since 1994 some 34 million trees have been planted in and around Nanjing city, China giving a figure of 23 trees per city dweller (Jim and Liu 2000). While Beijing has experienced extensive urbanization in the past two decades Beijing Municipality has rich vascular plant diversity (2,276 species), including 207 species of conservation concern such as endemic, threatened and protected species (Wang et al. 2007).

In India, except for a few cities, urban forests are not well-studied. There are, however, some studies on Bangalore (Sudha and Ravindranath 2000, Nagendra and Gopal 2010), Chandigarh (Chaudhry 2006; Chaudhry and Tewari 2010a, b; FSI 2009) and Delhi (FSI 2009). Some issue-specific studies such as biodiversity and carbon storage are also available for Bhopal (Dwivedi et al. 2009), Delhi (Khera 2009), Jaipur (Verma 1985, Dubey and Pandey 1993), Mumbai (Zérah 2007) and Pune (Patwardhan et al. 2001). A few studies are also available for specific locations within the urban ecosystems, such as NEERI Campus, Nagpur (Gupta et al. 2008) and Indian Institute of Science Campus, Bangalore (Mhatre 2008). The most robust studies on urban forests using satellite imageries have been for Delhi and Chandigarh. The estimates suggest that Chandigarh and Delhi have 35.70 and 20.20 per cent urban forests, respectively (Action Plan, 2009-10 and FSI 2009).

Bangalore is an interesting case of the fastest growing city in India, which spread from 2 km² in 1537 to 360 km² in 1994. With respect to tree vegetation, tree crown cover of the city has shown a decline from 1912 to 1980. But, during the period 1980-1985, there has been an increase in crown cover from 3.8 to 19.9% of the land area (Behera et al. 1985). A comprehensive study on urban forests of Bangalore found 374 species in the different land-use categories. Species richness was found highest in parks (291 species), followed by residential areas (164), institutions (126), temples (107) and commercial areas (Sudha and Ravindranath 2000). Although, density of street trees in Bangalore is lower than many other Asian cities, the species diversity is high (Nagendra and Gopal 2010).

Chandigarh, one of the planned and modern cities of India, has more than 35 % of its geographical area under forest and tree cover, making it one of the greenest cities of India (FSI 2009). Two economic valuation methods, i.e., Contingent valuation method and Travel cost method were applied for the estimation of recreational use value of its public parks, gardens and Sukhna wild life sanctuary from the point of view of residents and tourists. The mean willingness to pay (WTP) for the betterment of existing green landscape features and for creating new parks/gardens on the part of each reasonably earning family residing in the city was found at INR 153 per year for a period of five years, which converts to an annual recreational use value of city's urban forestry assets to INR 27.50 millions at 2002-03 prices. This estimate of WTP is a most conservative one as all zero bids, i.e., about 36 percent respondents who showed unwillingness to pay for the cause of urban greenery, have also been considered in mean WTP estimation. Contingent valuation method (open ended) was also used for this purpose and primary data was collected from 2358 residents of the city (Chaudhry 2006).

Table 1: Estimates on urban green spaces in different regions of world

Region/Country/ City	Estimated size of urban green space/woodland resource
Europe	The study of 386 cities suggests 18% average woodland cover. Another study suggests 18.5% cover within municipal limits of 26 large European cities, i.e., about 104 m^2/ inhabitant (Konijnendijk 2003).
France/Paris	About 80 m^2 of urban forest per inhabitant in Greater Paris region (Konijnendijk 2003).
The Netherlands	Average green space cover is about 19% for 22 largest Dutch cities, i.e., about 228 m^2/inhabitant (Konijnendijk 2003).
Australia/ Canberra	Estimated crown cover of about 24 million metre square amounting to 80 m^2/inhabitant (Brack 2002).
USA	Average green space cover is about 27%, i.e., about 32 m^2/ inhabitant
China/Nanjing/ Wuhan	On an average China's cities have 32.54% green cover. This varies greatly in Chinese cities like Nanjing and Wuhan, i.e., 44.3 m^2 /person and 10.3 m^2/person respectively (Jim and Wendy 2009).
Hong Kong	Average green space cover is about 1.81%, i.e., about 3 m^2/ inhabitant
Singapore	Average green space cover is about 17.8%, i.e., 7.5 m^2 per capita
India/Delhi	Average tree and forest cover is about 20% of geographical area and about 21 m^2/ inhabitant (FSI 2009, as per population data 2001).
India/Chandigarh	Average tree and forest cover is about 35.7% of geo-graphical area, i.e., about 55 m^2/inhabitant (Action Plan 2009-10, as per population data 2001).

The study found that people in developing countries have willingness to pay (WTP) for better maintenance of urban parks/gardens and urban green landscapes with the hope that their contribution for this purpose would be utilized properly and not go in to corrupt hands. Education plays a crucial role in making citizens more aware towards a better living environment. Educated and younger generation showed more WTP for the cause of urban greenery in comparison to elder and aged ones. Likewise, people already associated with some kind of environmental activities in one way or other; are more inclined towards urban greenery and have shown more WTP for the maintenance of urban parks/ gardens.

Thus, ruling governments must take the opinions and sentiments of the local people in to consideration, while deciding about urban land use planning and should not create mere concrete jungle for short-term returns on investment. A more systematic investment on environmental education and environment improvement facilities like clean and green public parks, gardens and landscapes would provide a long-term return to the society on sustainable basis. This would also contribute increasing tree cover outside forest areas.

Indian case studies show that a few patches of urban remnant forests, grasslands or wetlands harbour between a quarter to half the total biodiversity in their biogeographic region (Patwardhan et al. 2001). For example, urban forest in 43 ha of NEERI campus at Nagpur, Maharashtra has 135 vascular plants including 16 monocots and 119 dicots, belonging to 115 genera and 53 families. The taxa included 4 types of grasses, 55 herbs, 30 shrubs and 46 trees. The large number of species within very small area indicates rich biodiversity in this urban forest (Gupta et al. 2008).

In Jaipur city, as per the existing land use analysis the area under park, open space is around 5.43 km^2 in Jaipur city for a population of 3.30 million. Accordingly, per capita open space works out to be 1.60 m^2 per person. The areas of reserved forests and protected forests in surrounding hills that amount to approximately 75 km^2 are excluded in the above calculations. According to the proposed Master Development Plan 2025, it is proposed to enhance the per capita of open space to 8.80 m^2 (JDA pers. comm.). For a population projected to grow to 6.50 million by the year 2025, even at the minimum scale as per the WHO norms discussed earlier, Jaipur will require to establish 5850 ha (58.50 km^2) of urban green spaces. From another perspective, overall, the people and planners will have to strive for regenerating at least 1 medium sized mature tree as desirable number per person in Jaipur, Rajasthan. There are about 1,000 bore wells drilled by Governmental agencies and an estimated 11,000 privately owned ones (Pandit et al. 2009). Over withdrawal has resulted in serious decline in water tables in Jaipur city as well as other parts of Rajasthan (Rodell et al. 2009). Thus, providing open urban spaces is necessary to facilitate the ground water recharge during monsoon.

4. Urban Domestic Gardens

In addition to urban forests, private gardens are significant habitats that improve connectivity by functioning as corridors and patches, and thus enhance the overall network size of urban green spaces. As reviewed recently (see, Goddard et al. 2010, and references cited therein), estimates of the areas of private domestic gardens in the urban environment vary from 16% (Stockholm, Sweden), through 22–27% in the UK, to 36%

(Dunedin, New Zealand). Gardens are a major component of the total green space in many UK cities, ranging from 35% in Edinburgh to 47% in Leicester. Gardens are also an important resource in many developing countries; for example, private urban patios comprise 86% of all green space in the city of Leo´n, Nicaragua.

5. Ecosystems Services and Functions of Urban Green Spaces

Trees in urban systems provide a variety of ecosystems services including biodiversity conservation, removal of atmospheric pollutants, oxygen generation, noise reduction, mitigation of urban heat island effects, microclimate regulation, stabilization of soil, ground water recharge, prevention of soil erosion, and carbon sequestration (Bolund and Hunhammar 1999).

Wildlife sanctuaries are undeniably important for biodiversity conservation tools, but research findings in Jodhpur city reinforce the idea that with a network of urban green spaces and support from local people cities can serve as de facto sanctuaries for some species. A recent El Niño Southern Oscillation (ENSO) resulted in die-off of mammals in the Kumbhalgarh Wildlife Sanctuary (KWS) in Rajasthan. This die-off coincided with the La Niña-induced drought of 2000, and two consecutive monsoon failures. Indeed, Hanuman langurs (Semnopithecus entellus) suffered a population crash of nearly 50% from 1999 to 2001 in KWS. But, langurs in Jodhpur city were buffered against drought because of the availability of urban green habitat and food (Waite et al. 2007). Even the trees in backyard provide the benefit of biodiversity conservation networks in urban ecosystems (Hillary et al. 2002). The case of Kerwa Forest Area in Bhopal is another Indian case in point. Kerwa Forest supports several threatened and endangered plant, animal, and bird species. It also plays a critical role as a carbon sink with a total storage of about 19.5 thousand tons of aboveground carbon (Dwivedi et al. 2009).

Biodiversity in urban green spaces can be large. If declines in some species are to be arrested or reversed, conservation effort will need to focus much more strongly on understanding and managing urban populations, because these might buffer some species against regional population depletion. For example, In Sheffield city, central UK, population estimates for the 77 species observed during the surveys gave a total estimate of 0.6 million breeding birds, equating to 1.18 birds per person. The size of the non-breeding population was similar at 0.57 million individuals, or 1.13 birds per person (Fuller et al. 2009).

Urban trees in the coterminous USA store 700 million tonnes of carbon ($14,300 million value) with a gross carbon sequestration rate of 22.8 million tC/yr ($460 million/year). The national average urban forest carbon storage density is 25.1 tC/ha, compared with 53.5 tC/ha in forest stands (Nowak & Crane 2002). These urban trees also remove large amounts of air pollution that consequently improve urban air quality. Pollution removal (O_3, PM_{10}, NO_2, SO_2, CO) varied among cities with total annual air pollution removal by US urban trees estimated at 711,000 metric tons ($3.8 billion value) (Nowak et al. 2006). About 4,00,000 trees planted in Canberra are estimated to have a combined energy reduction, pollution mitigation and carbon sequestration value of US$20–67 million during the period 2008–2012 in Canberra (Brack 2002). Likewise, the City of Tshwane Metropolitan Municipality in South Africa has 115,200 indigenous street trees planted during the period 2002–2008. It has been estimated that the tree planting will result in 200,492 tonnes CO_2 equivalent reduction and that 54,630 tonnes carbon will be sequestrated. The carbon dioxide reductions could be valued at more than US$ 3,000,000 (Stoffberg et al. 2010).

The Urban Heat Island is a phenomenon whereby temperatures in urban areas are warmer than the surrounding rural countryside, often by several degrees. As urban green spaces and urban forests increase, evapotranspiration rate increases .Thus, a common measure to mitigate urban heat island effect is to increase urban green spaces. Studies on microclimate formation through built-up morphology and urban shade trees have clearly established the importance of urban trees in alleviating the heat island effect in a hot and humid summer (Shashua-Bar et al. 2010).

As noted earlier, Beijing has one of the best urban forests. A recent study showed that the forest ecosystems of Beijing could intercept approximately 1.43 billion m^3 of annual rainfall and 277.82 million m^3 of soil water under ideal conditions, and supply 286.67 million m^3 of fresh water. The total economic value of water conservation provided by Beijing's forests was US$ 0.63 billion, and the economic benefit per hectare was equal to US$ 688 (Biao et al. 2010). Further, a study in 2002 suggests that trees in the central part of Beijing removed 1261.4 tons of pollutants from the air. The air pollutant that was most reduced was PM_{10} (particulate matters with an aerodynamic diameter smaller than 10 μm), the reduction amounted to 772 tons. In addition, the carbon dioxide (CO_2) stored in biomass form by the urban forest amounted to about 0.2 million tons (Yang et al. 2005).

6. Economic and Social Perspective

Urban forests and trees also serve various economic and social purposes. Research from around the world indicates that property owners value the urban forest by the premium they pay to live in neighborhoods urban green spaces and public parks. For instance, according to the most influential study on the subject, just one kilometer increase in the distance to the nearest forested area leads to an average 5.9 percent decrease in the market price of the dwelling. Dwellings with a view onto forests are on average 4.9 percent more expensive than dwellings with otherwise similar characteristics (Tyrvainen & Miettinen 2000). In densely-populated areas this effect is even more pronounced. For example, view of green spaces and proximity to water bodies raised housing price in China, contributing notably at 7.1% and 13.2%, respectively (Jim & Chen 2006). Study on effects of neighbourhood parks on the transaction price of high-rise private residential units in Hong Kong indicated that neighbourhood parks could lift price by 16.88%, including 14.93% for availability and 1.95% for view. Comparing with other landscape elements, neighbourhood parks induced the heaviest investment intention in home-buying behaviour (Jim & Chen 2010).

Urban shade trees offer significant benefits in reducing building air-conditioning demand and improving urban air quality by reducing smog. The savings associated with these benefits vary by climate region and can be up to $200 per tree. The cost of planting trees and maintaining them can vary from $10 to $500 per tree (Akbari 2002). Studies on benefit-cost ratios suggest residents may receive back $1.85 and $1.52 in annual benefits for every $1 invested in management through aesthetic and other benefits (McPherson & Simpson 2002). Further, a five-city study in USA suggests that although these cities spent $13–65 annually per tree, benefits ranged from $31 to $89 per tree. For every dollar invested in management, benefits returned annually ranged from $1.37 to $3.09 (McPherson et al. 2005).

The recreational and aesthetic use value of urban forests, parks/gardens and other urban green spaces are well documented in European countries and USA particularly. Urban woodland in Europe attracts thousands of recreational visits per hectare annually (Konijnendijk 2003). In Europe, majority of recreational use of urban woodland takes place in areas not more than 1 to 2 km from inhabitant's homes (Hornsten 2000). Urban open green spaces play an important role in offering town-dwellers a more stress free environment, irrespective of sex, age or socio-economic background. The more time people spend outdoors in urban open green spaces, the less they are affected by stress and related complaints (Grahn and Stigsdotter 2003). Tree planting and management activities also cause strengthening of community bonds and keeping crime rates low (Kuo 2003).

7. Linking Knowledge to Action: Lessons for Jaipur

As our review has demonstrated, there are several lessons for policy, practice and research in order to develop new urban green spaces, enhancing the management effectiveness of existing green spaces, financial innovations to generate resources for sustainable management of green spaces, and local monitoring and local enforcement for effective governance of urban forests.

It is now well-established that we need to coherently manage terrestrial, ecological, physical and socio-economic components of urban ecological systems (Pickett et al 2001, Wu 2008), and without urban green spaces a sustainable city can not be designed (Chiesura 2004). Interesting finding that urban tree cover is highest in cities that developed in naturally forested areas (Nowak et al. 1996) provides new insight to develop urban forests in Jaipur. One of the most useful strategies for enhancing the urban green spaces in Jaipur would be to protect and develop adjoining forest lands—in accordance with Forest (Conservation) Act, 1980, and after carrying out appropriate Environmental Impact Assessment—by investing in sequential restoration and enrichment of local biodiversity. We can significantly reduce the potential extinction debt for a city by maximizing the proportion of native forest vegetation in the landscape. Indeed, in some cases, the urban remnants may be all that is left of particular species or ecosystems (Hahs et al. 2009). Forest area, now named as Karpoor Chandra Kulish Samriti Van, situated along the JLN Marg is a case in point. The available records show that the area is rich in flora and avian fauna and acts as green lung for a portion of Jaipur (Dubey and Pandey 1993). Recent efforts by Forest Department and Jaipur Development Authority have further enriched the area.

In the face of rapid urbanization of Jaipur city, developing forest lands as urban green spaces and botanical gardens would be a prudent conservation strategy. Indeed, this could be a vital tool to solve the challenge of forest land encroachments in urban proximity. Around the world, evidence is mounting that urban society is bound to further domesticate the natural systems and accordingly shape landscapes and ecosystems for human welfare (Kareiva et al. 2007). Tropical wildlands—particularly urban natural systems—and their biodiversity will survive in perpetuity only through their integration into human society (Janzen 1998 & 1999; Pandey 2003, Pinheiro et al. 2006, Ward et al. 2010). Thus, it would be prudent to implement this strategy by establishing multifunctional botanical gardens as urban green spaces in forest lands around Jaipur. This strategy would not only be useful for in situ conservation of biodiversity in small forest fragments that remain around Jaipur, it will also provide multifunctional urban reserves.

The next lesson relates to financial innovations for generating the resource to manage the urban green spaces sustainably. People appreciate that urban green spaces serve important social, psychological, health, aesthetic, ecological and economic functions. However, these functions are frequently taken for granted, both by the public and city authorities. Studies in cities of India suggest willingness of visitors to pay the entry fees provided these green spaces, gardens, urban forests and protected areas are managed sustainably (Chaudhry and Tewari 2010a, b, Hadker et al. 1997). Most public parks and gardens in China, a developing country like ours, levy a modest entrance fee and residents are accustomed to paying such charges (Jim and Wendy 2009). A nominal gate fee is being charged in some urban parks/gardens of Indian cities such as Hyderabad, Bangalore and inhabitants are happily paying it for their daily strolls, recreational purposes and jogging exercises. Thus, we may have to draw on two financial mechanisms to generate regular resources for managing urban green spaces: first, between 5 to 7% of the total municipal and development authority budget allocations are required for reasonable implementation of public green space policies; second, system of appropriate user fees and facilities rental is required to be established to supplement—and not to substitute—the budget allocation noted above.

Private domestic gardens provide significant habitats and enhance the overall functional size of green space network by functioning as corridors and patches. Thus, regulatory framework of public policy for future urbanization of Jaipur should build strong incentives to encourage development of private domestic gardens with a preponderance of local tree species.

From the perspective of biodiversity, the golden rule is: larger the urban forests, richer the biodiversity. Number of floral and faunal species often increase with increasing size of urban green spaces. Thus, maintaining larger greenspaces with high structural diversity may be effective in maintaining plant and bird diversity in urban systems (Khera et al. 2009).

On the technical and governance issues following suggestions may be useful for creating multifunctional landscapes to enhance urban resilience and human well-being:
(i) strengthening the network of urban green spaces through linkages between various components ; (ii) sequential restoration of existing urban forests and developing them into a multifunctional ecosystem; (iii) developing connectivity, as far as possible, among backyard habitats, urban domestic gardens, and public parks; (iv) integrating urban forest planning into regular master plans and urban development projects; (vi) maintenance of species diversity and spatial heterogeneity by planting three-tier vegetation (herbs, shrubs and trees): no more than 30% from one family, no more than 20% from one genus, and no more than 10% from one species (vii) designing and implementing the programme for local monitoring and local enforcement of locally-made rules for the management of urban forests.

Finally, as noted above, although enough is known to initiate a systematic urban green space development programme in Jaipur to facilitate its development as a world-class city, we recognize that urban forests in India are least studied as far as species selection, planting methods, pollution control, carbon storage, energy/soil/water conservation aspects are concerned. As this review demonstrates, virtually no comprehensive study on the governance of urban green spaces in Jaipur have been performed. Accordingly, in addition to the actions proposed above, we also identify several issues for further research to fill critical gaps in our knowledge about the urban green spaces of Jaipur. Research is needed to get a better understanding of the urban forest in Jaipur and other cities of Rajasthan. Research that quantifies the spatial extent, species diversity across different urban land-use, growth and mortality, urban tree biomass, diameter distribution of urban trees across various species, present carbon storage and rate of carbon sequestration by urban trees and urban forest, pollution mitigation potential, and hydrological functions of urban forests is urgently required.

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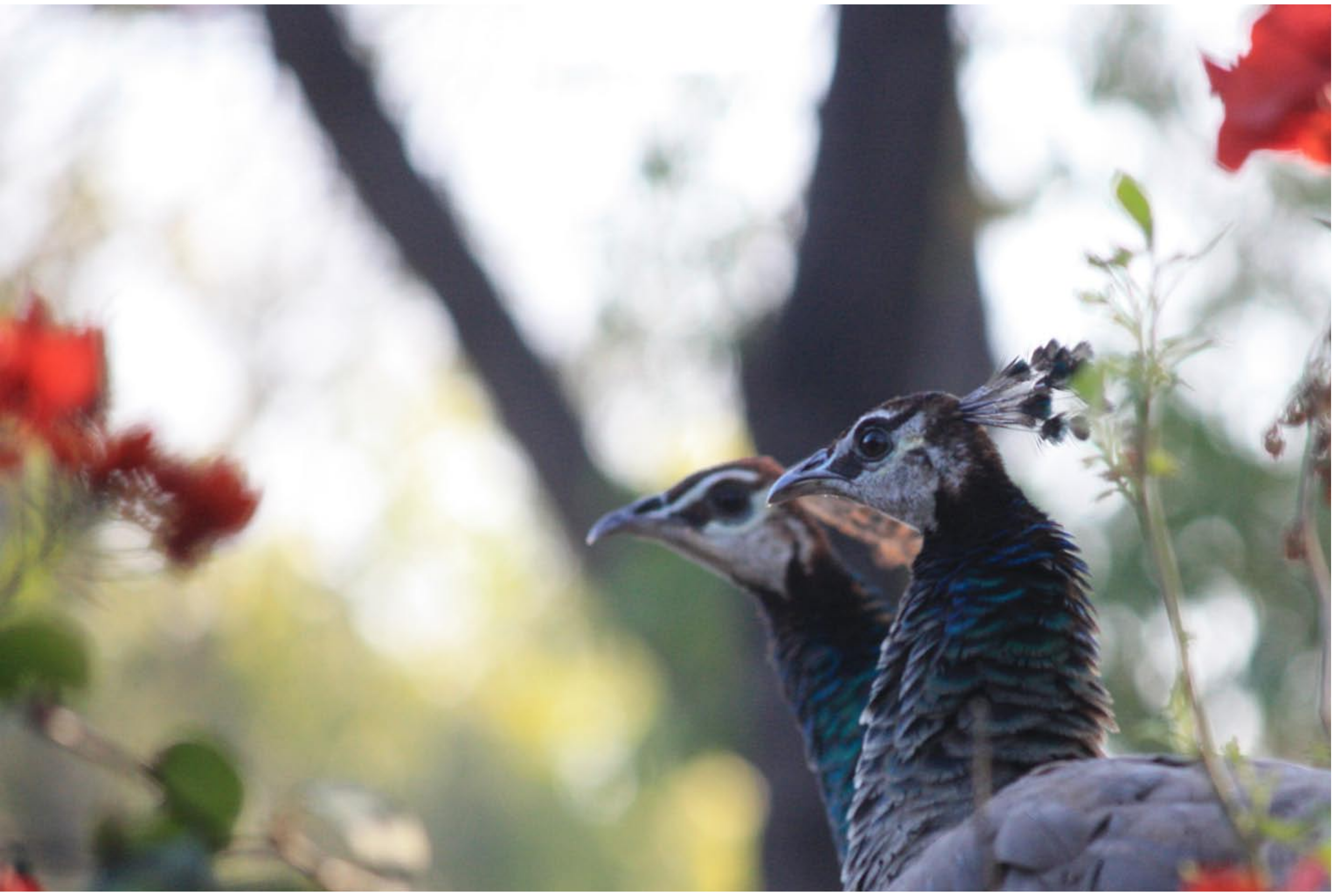

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"An ounce of practice is worth more than tons of preaching."

-Mahatma Gandhi

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