Sequential restoration of urban green space in tropical dry forest region: Kulish Smriti Van, Jaipur Rajasthan, India

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Contents

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Abstract

Creating functional urban green spaces is necessary for ecological, economic and social sustainability of urban systems. Full range of benefits of urban green spaces, however, can only be realized with the developing or enriching the vegetation with native pool of species. Yet, this reality has seldom been achieved. Here we provide practitioner insights on restoration and enrichment of urban green space with a large suite of indigenous vegetation in a tropical dry region of India. These insights are based on experiential knowledge and long-term observations as daily visitors to Karpoor Chand Kulish Smriti Van in Jaipur, Rajasthan during 2007 - 2014. The interventions such as protection, fencing and cattle exclusion in an old urban sand dune plantation and adjacent degraded tropical dry forest fragment have initiated large-scale colonization and natural regeneration of native species. In addition to a variety of tools and interventions that have been applied for the holistic restoration of the green space, we also provide a photographic case study about ecological surprise in this urban green space with wider relevance to green space restoration. A word of clarification is also in order, as it is often easier to miss the global relevance of local practitioner insights. We, therefore, wish to caution that while insights we provide are rooted in a locality, its focus is neither narrow nor local. These insights have a wider global relevance from the perspective of novel and holistic international research priorities for urban green spaces. These lessons are also vital for evidence-based urban forest management by linking science to policy and action. Understanding and anticipating these ecological surprises is critically important to avoid unexpected negative ecological outcomes. The lessons are also useful for creation, restoration and management of self-sustaining multifunctional urban forests, parks, gardens, and greenspaces.

Keywords: International research agenda; Natural regeneration; Practitioner insights; Seed dispersal; Tropical dry forest restoration; Urban greenspaces.

1. Introduction

Creating functional urban green spaces is necessary for ecological, economic and social sustainability of urban systems. Full range of benefits of urban green spaces, however, can only be realized with the development of new green spaces, or enrichment of existing vegetation, with native pool of species. Yet, this reality has seldom been achieved. In this article we provide practitioner insights on restoration and enrichment of urban green space in a tropical dry region of Rajasthan, India. In doing so, we also describe an ecological surprise realized during the restoration. "Ecological surprises" are defined as unexpected outcome of interventions in the natural environment [1-3]. As practitioners and researchers we often make assumptions and set hypotheses about what is likely or unlikely to happen as a result of specific management intervention on the ground. Consequently, an ecological surprise is said to occur when what is found is outside the range of our assumptions. Such surprise can lead to a fundamental shift in our understanding of ecological systems [1,4]. While ecological surprises have been found in many ecosystems, there are not many insights from urban forests and green spaces. Here we provide practitioner insights and a photographic case study of ecological surprise in an urban green space in a tropical dry region of India. Observations for the case study were collected first during our management interventions and later through long-term observations as daily visitors to green space for the last 7 years during 2007 - 2014. Understanding and anticipating these ecological surprises is critically important both to avoid unexpected negative outcomes and to improve management of urban green spaces towards the desired outcome [5,6].

In the next section we briefly describe the study area and place the green space in wider context of the city of Jaipur (section 2). We then provide our practitioner insights and management interventions that yielded ecological surprise (section 3). Subsequently, we discuss why our observations on natural regeneration of Neem (*Azadirachta indica*) in urban green space are unique (section 4). In the next section we present a variety of tools and interventions that have been applied for the holistic restoration of the green space (section 5). Finally, we conclude and invite scientists and practitioners to invest their energy and time in designing and implementing strategies of green space development, management and restoration that also rely on natural seed dispersal and colonization to create multifunctional green spaces (section 6).

A word of clarification shall be in order here. It is often easier to miss the global relevance of local practitioner insights. We, therefore, wish to caution here that while insights we provide are rooted in a locality, its focus is neither narrow nor local. These insights have a wider global relevance from the perspective of holistic international research priorities currently being promoted for urban green spaces [7-14]. Our case study is also strongly linked to the international literature from the standpoint of what contemporary research is missing (e.g. importance of natural regeneration in urban green spaces). Indeed, not withstanding a few studies, there is

a surprising paucity of research on natural regeneration in tropical urban green spaces[15-23]. These learning are also vital for evidence-based urban forest management by linking science to policy and action[9,24-28]. Finally, as we shall discuss later, our case study has implication for international research and practice on urban green spaces.

2. Study area at Kulish Smrit Van, Jaipur, India

Karpoor Chand Kulish Smriti Van (26°52'16"N 75°48'50"E) is an important urban green space of Jaipur, the capital city of Rajasthan and the largest urban centre in western India. Population of the city was 0.16 million in 1901; it has grown to 3.6 million in 2014. The total urbanisable geographical area is now estimated to be 1464 km^2. This expansion has resulted in shrinkage of green spaces in Jaipur [29-31]. In 2003, green space per 1000 persons was merely 1.01 ha[31]. Planning by local authorities envisages a 5-year goal to have 20 per cent tree coverage in the district, by planting 10 million trees in both rural and urban areas of the district [32].

The deficiency in green spaces jeopardizes the sustainability of urban systems. A recent study shows that 13.12 per cent of the total area of city falls in moderate and 0.97 per cent in high urban heat island potential zone [33]. Concentration of respirable suspended particulate matter in residential, commercial and industrial areas of the city are more than the prescribed air quality norms [34]. As per the existing land use analysis, the current area under parks and open spaces is about 5.43 km^2 which works out to be 1.60 m^2 per person. An opportunity is available to enrich and develop the available 75 km^2 forests in surrounding hills as urban green spaces [35]. As a part of this strategy, old sand dune plantations of *Acacia tortilis* (now known as *Vachellia tortilis*) and adjacent degraded tropical dry forests were sequentially converted in to urban green space, named as Karpoor Chand Kulish Smriti Van, in the year 2005 over an area of 43.7 ha (Fig. 1).

Figure 1: Google Earth image of the Kulish Smriti Van, Jaipur, Rajasthan

3. The restoration intervention and ecological surprises

Management interventions aimed at converting the old Acacia plantations and adjacent degraded tropical dry forest fragments into a green space included protection, enrichment planting, arrangements for periodic irrigation and in some patches, application of geotextile to stabilize sand dune, and planting of about 100 species of medicinal herbs, shrubs and trees from the regional species pool. Details of restoration interventions are presented in Table 1.

Enrichment planting of medicinal plants beneath existing old *Acacia* trees after soil preparation unexpectedly promoted autogenic natural regeneration of *Azadirachta indica* through seed dispersal by frugivorous birds. As the area is free from trampling and compaction due to cattle exclusion, seeds deposited by birds could germinate easily. Further survival in this dry tropical region was ensured by periodic irrigation to medicinal plants that also supplied water to *Azadirachta indica* seedlings. With better humus and soil seed bank development over the last 7 years, the regeneration is visible over a large area now.

Table 1. Restoration interventions, outcome and ecological surprises in urban green space, Jaipur, India

No.	Restoration intervention	Expected outcome	Prominent ecological surprises and outcomes
1.	Protection, strong fencing and cattle exclusion in an old urban sand dune plantation and degraded tropical dry forest fragment	(i) Reduction in depletive factors operating in the green space, particularly repeated grazing by feral livestock. (ii) Prevention of encroachment (iii) Protection to planted saplings. (iii) Enhanced growth of existing vegetation in sand dunes and forest fragments. (iv) Resprouting of coppice growth from dormant rootstock of a large number of tropical dry forest species. (v) Build-up of humus and soil seed bank further contributing to natural regeneration.	Ecological trajectories as expected.
2.	Protection against fire and illicit wood collection by residents	(i) Protection to remnant vegetation and promoting the growth of biomass in existing vegetation. (ii) Resprouting of dormant rootstock of shrubs and trees.	Ecological trajectories as expected.
3.	Beneath existing old *Vachellia tortilis* (syn. *Acacia tortilis*) trees, soil preparation and enrichment planting of medicinal herbs, shrubs and woody climbers such as *Aloe*	(i) Restoration of local species through planting. (ii) Enhanced availability of medicinal plants to Ayurveda practitioners. (iii) Regular visitors and morning	Plantation of medicinal species unexpectedly promoted autogenic natural regeneration of *Azadirachta indica* through seed dispersal by

	vera, Withania tetraphylla, *Rauvolfia serpentina, Asparagus racemosus, Abrus Precatorius, Cissus quadrangularis, Cocculus hirsutus, Adhatoda zeylanica*, *Barleria prionitis* etc.	walkers have access to Ayurvedic treatment during weekends. The green space is now visited by about 1200 persons every day for morning physical exercise and walking. A large number of young people visit throughout the day.	frugivorous birds such as Red-vented Bulbul (*Pycnonotus cafer*). In addition, with humus and soil seed bank accumulation over the last 7 years, natural regeneration of many species is visible over a much larger area. Prominent species are wind-dispersed tree species *Holoptelia integrifolia*, *Ailanthus exelsa, Acacia senegal,* and naturalized exotic *Leucaena leucocephala* and *Vachellia tortilis* in scattered patches and microsites.
4.	Periodic irrigation of the patches during dry months where medicinal species have been planted	Enhanced survival of medicinal plants and other introduced species in a water-limited tropical dry environment.	Enhanced survival of naturally regenerated *Azadirachta indica* and other seedlings
5.	Sequential stabilization of urban sand dunes using hard-plastic mesh (grid made of extruded polystyrene / Geotextiles)	Stabilization of reactivating urban sand dunes	Autogenic regeneration of *Azadirachta indica* and other species through seed dispersed by birds in grids acting as germination niches (microsites)
6.	Planting of saplings of several species including late-successional, animal-dispersed tree species in small numbers (founder trees from regional species pool, often referred as 'framework species')	Supplementing the local species pool that may not come quickly through seed dispersal or sprouting. These are expected to act as seed source for natural colonization in future.	About 2000 planted saplings are surviving: *Butea monosperma*, *Madhuca indica*, *Lannea coromandeliaca, Bombax ceiba, Albizia lebbeck, Aegle marmelos, Termina liabellerica, Pongamia pinnata, Cassia fistula, Cordia dichotoma, Syzygium cuminii, Gmelina arborea, Tecomella undulata, Sterculia urens, Sapindus laurifolius*, *Phyllanthus emblica, Capparis decidua, Manilkara hexandra, Caesalpinia bonduc etc.*
7.	Planting of vegetative stakes	Development of 'instant trees' of the species that are able to come up through vegetative cuttings.	As expected, satisfactory sprouting and growth is visible in *Ficus benghalensis, Ficus*

			religiosa and *Boswellia serrata*.
8.	Creation of tree islands; protecting the soil beneath large *Vachellia tortilis* trees and planting of ornamental shrubs in islands	"Tree islands" serve as "recruitment foci" and facilitate tree recruitment to a similar degree as restoration through intensive plantations.	Ecological trajectories as expected.
9.	Assisted natural regeneration by weed removal around germinated and developing seedlings, retention of old trees and snags to facilitate seed rain, retention of leaf litter, woody debris and necromass to facilitate humus build-up, encouraging coppicing by providing effective protection against grazing and fire	Natural regeneration of several species through seeds in seed bank, seed dispersal by birds, and resprouting of many local species of tropical dry forest species from dormant rootstock.	Ecological trajectories as expected.
10.	Periodic de-silting of urban drain passing through green space, storage of muddy sludge on open drain-banks and direct seeding of early successional species	Helps in greening of these ugly nallahs of our cities. Autogenic regeneration due to long-term protection. It is also a phytoremediation strategy.	Ecological trajectories as expected, but now that early-successional species have developed, direct sowing of late successional large-seeded species such as *Terminalia arjuna*, *Syzygium cuminii*, *Syzygium heyneanum*, *Phoenix silvestris*, *Derris indica* syn. *Pongamia pinnata*, and small-seeded species *Ficus racemosa* syn. *Ficus glomerata* etc. can be attempted.
11.	Continued protection against fire by permitting manual grass cutting	Grass removal ensures that dry fuel is not built-up within the green space. Harvested grass is used as fodder for livestock. It also supports livelihoods of families that harvest and sell in local market.	Ecological trajectories as expected.
12.	Continued protection and management of green space	Self-sustaining multifunctional urban green space that serves ecological, economic and social functions.	As expected.

Spontaneous or autogenic regeneration of *Azadirachta indica*, beneath old *Acacia* trees, through bird-dispersed seeds, after protection was initiated in 2005, is a common occurrence now at Kulish Smriti Van. There are about 100 such patches in this 43.7 ha of urban green restoration area (Fig. 2 to 3). In addition, degraded areas that earlier supported tropical dry forests, by virtue of their remarkable resilience,

have regenerated both through resprouting of dormant root-stock as well as natural seed dispersal, direct sowing, germination and establishment process[36].

In water-limited tropical dry forests, early stages of plants benefit from growing in close proximity to others that mitigate extreme conditions, improve nutrient availability, and protect against grazing, trampling and herbivory. This facilitation by nurse-plants has implications for urban forest restoration through direct seeding and the establishment of desired species, mimicking the natural phenomenon.

Figure 2: Natural regeneration of *Azadirachta indica* seedlings under an old *Acacia* tree along with planted medicinal shrubs

4. Importance of *Neem* in multifuntional green spaces

This case study on the ecological surprises in urban systems is unique as it provides a hope for the future that multifunctional green spaces can be developed and enriched by mimicking nature in tropical dry regions. *Azadirachta indica* trees are important because of a variety of valuable products and services they provide. Our results are also exciting because of the surprise that natural regeneration through seed dispersal by birds in an intensely contested urban world is a reality. To the best of our knowledge, this is the first long-term study of natural regeneration and establishment of *Azadirachta indica* through bird-dispersed seeds in urban green spaces.

Azadirachta indica has been planted in urban systems since the days of the earliest cities in antiquity. For instance, Neem leaves were found in the settlement of Mohandjodaro, a city as old as 2000 BC [37]. Neem is one of the most frequently grown trees in urban parks, gardens, streets and green spaces in India [38-42] and Nepal [43]. Even in countries where Neem is an exotic species, it is one of the frequently occurring tree in urban systems [44, 45].

The popularity of Neem is the result of ecological, economic and social importance of the species that only few can compete globally [46-48]. The air pollution tolerance index of *Azadirachta indica* is good compared to many other species [40, 49-53]. It is thus one of the best trees for green belts to mitigate noise and air pollution [40, 54, 55]. While its dust collection potential is less compared to many other species [56], leaves of Neem can nevertheless retain up to 178 mg cm^2 [57]. Potential of emission of volatile organic compounds and ozone forming potential of *Azadirachta indica* are moderate compared to many other species [58].

Neem is also one of the important species for phytoremediation of heavy metals [59, 60]. The species can also be grown with municipal wastewater irrigation [60, 61] and industrial wastewater of textile industries in arid region [62, 63]. It is not surprising, then, that the suitability of Neem for urban greening even in hot arid regions [64, 65], gave rise to one of the most famous Neem plantation, probably the world's largest, on 10 km^2 area in the Plains of Arafat, in Saudi Arabia. Here 50,000 trees have been planted to provide shade to the millions of pilgrims who camp there annually for Haj [65].

5. Other holistic restoration interventions and their outcome

In addition to ecological surprises we described above several other tools have been used for ecological restoration of the green space at Kulish Smriti Van, Jaipur. These interventions have resulted into self-sustaining multifunctional urban green space that serves ecological, economic and social functions.

5.1. Greening of stormwater drain-banks: Urban storm-water drains are often used for drainage of filth and sewage [61, 66]. While the practice is harmful, unlawful and

irresponsible act of municipalities, it is nevertheless a reality in India and many other countries [67-74]. Periodic de-silting generates muddy sludge that is stored on open drain-banks. Direct seeding of early successional species on sludge/muddy silt has helped in greening of these ugly nallahs within the green space. It is also a phytoremediation strategy[75-77].

In Kulish Smriti Van, seed sowing of quick growing vegetation such as *Ricinus communis* and *Amaranthus* sp. has helped in spontaneous regeneration of woody species through seeds dispersed by winds and birds. Autogenic regeneration of wind-dispersed local species *Holoptelia integrifolia*, *Bombax malabaricum*, and naturalized non-native species *Leucaena leucocephala* has started. Planting of *Dendrocalamus strictus* has also been successful (Fig. 3).

Now that early-successional species have developed, direct sowing of late successional large-seeded species such as *Terminalia arjuna*, *Syzygium cuminii*, *Syzygium heyneanum*, *Phoenix silvestris*, *Derris indica* syn. *Pongamia pinnata*, and small-seeded species *Ficus racemosa* syn. *Ficus glomerata* can be attempted [35, 36, 78, 79].

Figure 3: Greening of stormwater drain-banks as a phytoremediation and beautification strategy.

5.2. Shade, weed reduction, and regeneration: In many patches of the green space planted species such as *Caesalpinia bonduc* provide shady areas for autogenic regeneration. The absence of weeds due to shade contributed by the canopy of tree, and humus build-up from necromass over the sandy soil together ensure better moisture in water-limited tropical dry region, and contribute to good germination (Fig. 4).

Decaying leaf litter, debris and necromass also provide nutrients and act as a thick mulch and thus conserves moisture for longer duration[80-85]. Several species of shrubs and trees are regenerating in shady areas in Kulish Smriti, Van that may later require opening canopy as many of these species are light-demanders.

Figure 4: Regeneration of species in shady areas that promote vigorous germination in tropical dry regions

5.3. Development of soil seed bank: Soil seed bank is vital for natural regeneration in tropical dry forests[86-90]. Good seed bank can develop only when remnant forests are present in the vicinity, and the area is protected against fire, grazing, soil trampling and compaction [91-98]. However, not all species found as remnants are represented in seed bank. Many suffer from heavy seed predation and loss due to pathogens. Seed bank often contains large number of seeds of invasive species that quickly germinate and outcompete the desired species [86, 87, 99-103]. Further, even when moisture conditions become favourable many of the native species do not germinate as they may either remain dormant or may have lost the viability due to longer periods of drought. For these reasons external seed addition through natural seed dispersal, direct seeding or planting of target/desired species may be necessary to initiate the succession [36]. The soil seed bank in Kulish Smriti Van is slowly becoming species-rich as is evident from regeneration of local species across the green space.

5.4. Resprouting from dormant root-stock: Resprouting or coppicing is essentially a survival strategy of vegetation in a variety of tropical forests worldwide[104-106]. Degraded tropical forest fragments near urban systems and elsewhere that earlier supported good forests can quickly regenerate through resprouting of dormant root-stock (bud bank) in persistent niche[107-115]. About 50 such species are regenerating in Kulish Smriti Van, in Jaipur, Rajasthan including rare species of trees and shrubs such as *Commiphora wightii*, *Ehretia laevis*, *Maerua arenaria*, *Rhus mysorensis*, *Anogeissus pendula*, *Diospyros montana* among others. Because of the profuse capability of sprouting, there is often a tendency for trees to be multiple-stemmed in tropical dry forests[116] (Fig. 5).

Figure 5: Resprouting of *Anogeissus pendula, Ehretia laevis* and *Commiphora wightii* from the dormant root stock

Resprouting is believed to be a survival strategy to chronic disturbance [117]. The phenomenon is seen sometimes even in the species known for their grand size, such as some *Madhuca indica* trees in Rajasthan. In the early years of resprouting, shoot singling, i.e., retaining the leading stem and removing others, may be helpful in supporting the growth of trees.

5.5. Promoting natural regeneration under nurse-trees: Facilitation is a widely observed phenomenon in plant communities worldwide[118-126]. This has been used as a restoration strategy in a variety of contexts[118]. Tropical secondary dry forest may be best restored by underplanting late-successional species within whatever existing vegetation we have. As native leguminous trees are rare in mature dry forests, naturalized non-native species such as *Leucaena leucocephala* and *Vachellia tortilis* can act as nurse trees. For example, fast growth and quick natural regeneration of *Leucaena leucocephala* provides green cover, reduces fire damage to native species, enriches the soil by supplying humus and nutrients such as nitrogen and organic contents, thereby facilitating the recruitment of native species. The care that now needs to be taken in some patches of Kulish Smriti Van is to reduce the density of stands, so that seeds deposited by seed-dispersing birds that have germinated in the shade are now able to grow (Fig. 6). We may also treat the area with direct seeding of native large-seeded late-successional species.

Figure 6: Natural regeneration through seeds available in the soil seed bank

5.6. Conserving woody debris and necromass: Litter, woody debris and necromass is an important habitat element for many organisms such as saproxylic beetles and fungi in tropical forests[80, 82, 83, 127-132]. It also facilitates restoration by supplying humus and nutrients through decomposition, conserving moisture and physically providing microsites for seed deposition, germination and sapling development. In a large number of patches in Kulish Smriti Van this strategy has supported natural regeneration of several local species.

Figure 7: Woody debris and necromass

5.7. Instant trees through vegetative cuttings: Planting of large-sized cuttings can produce "instant trees" in tropical dry forests[109, 133-141]. For example, in Kulish Smriti Van, planting of *Boswellia serrata*, *Bombax ceiba*, *Ficus religiosa*, *Ficus benghalensis*, and *Garuga pinnata* just before the onset of monsoon gave excellent results (Fig. 8). This method provides instant green cover in a short period and trees reach beyond browsing height making protection easier and less costly. Sprouted branches in these cuttings can mimic the remnant trees that facilitate tropical forest restoration by providing perch to seed-dispersing birds in the restoration area.

Figure 8: Stake planting of *Boswellia serrata* and *Ficus benghalensis*

5.8. Protecting natural lianas and climbers: Lianas (woody vines) play an important role in forest regeneration, species diversity and ecosystem-level processes in the tropical forests [142]. They are an important component across the range of tropical dry forests globally[143-154].

In the urban green space at Kulish Smriti Van, there are several species of these medicinally important woody vines (Fig. 9) such as *Tinospora cordifoila, Leptadenia reticulata*, *Pergularia daemia*, *Cocculus pendulus*, *Caesalpinia bonduc*, *Abrus precatorius*, *Asperagus racemosus*, *Celastrus paniculatus*, and seasonal climbers such as *Gloriosa superba* and *Coccinia grandis*.

Figure 9: Lianas and woody climbers play an important ecological role in tropical dry forests

5.9. Applied nucleation, tree-islands and recruitment-foci: An alternative approach to large-scale plantations for restoration is to plant tree islands as nuclei to simulate the nucleation model of succession and accelerate natural recovery[155]. These tree-islands act as recruitment foci and facilitate tropical dry forest restoration. Planting tree islands facilitates tree recruitment to a similar degree as restoration

through intensive plantations[155-160]. Likewise, if large remnant trees from earlier planting are present, they develop fertile islands that enhance urban biodiversity. In Kulish Smriti Van, this phenomenon is clearly discernible (Fig. 10): undisturbed soil beneath large trees is enriched by decaying humus of fallen leaves and twigs. Birds visiting these trees and associated woody-climbers for fruits and forage bring seeds along and an autogenic regeneration chain starts, becoming complex over time, and thus improving and expanding the regeneration-niche further.

Figure 10: Remnant trees facilitate recruitment

5.10. Sequential stabilization of urban sand dunes using Geotextiles: Urban sand dune stabilization using hard-plastic mesh or grids made of extruded polystyrene geotextiles is essentially sequential restoration strategy in this area. Seed deposited by birds and wind in several of these regeneration niches (i.e., grids) have developed into trees (Fig. 11).

Figure 11: Sequential stabilization of sand dunes using Geotextiles

5.11. Rainwater harvesting microcatchments: In water-limited environments such as tropical dry forests, rainwater harvesting is an age-old indigenous adaptation to climate change[161, 162]. Rainwater harvesting in the form of soil manipulation and saucer-shaped structures called micro-catchments (Fig. 12) has been found to promote survival, growth, diversity and heterogeneity of vegetation[163-173]. Also, these structures ameliorate local environmental conditions and facilitate autogenic regeneration of local species. Saplings with microcatchment have better chances of establishment tropical dry forest restoration programmes.

Figure 12: Saucer-shaped micro-catchment for rainwater harvesting around seedlings

6. Conclusion and outlook for research and practice

A self-sustaining, naturally regenerating, and ecologically functional green space is the foundation for multiple ecosystem services that society may desire from urban ecosystems [174-177]. Conserving and restoring ecosystem services in cities can reduce the ecological footprints and the ecological debts of urban systems while enhancing resilience, health, and quality of life for their citizens [178]. In urban systems ecosystem functions and processes that optimally support the production of ecosystem services and goods are not yet clearly understood. There are thus several research questions that may both advance science and support the practice on the ground. These include: How does natural colonization support biological diversity of a maximum

possible set of native species in urban green spaces through seed dispersal, soil seed bank development, and natural regeneration? What kind of exotic tree plantations may promote an autogenic regeneration of local species of herbs, shrubs and trees in urban green spaces? How should we promote natural regeneration in old exotic plantations that are entrapped green islands within the urban systems? What are the integrated strategies for restoration of urban green spaces that promote multifunctionality (e.g., health benefits, biodiversity conservation, climate change adaptation, removal of atmospheric pollutants, noise reduction, microclimate regulation and mitigation of urban heat island effects, stabilization of soil, groundwater recharge, prevention of soil erosion, and carbon sequestration etc.). Should we let nature run its own course in urban green spaces, and if not, then how should we design research-informed, evidence-based interventions to guide restoration towards a desired trajectory? Currently, answers to these question are not known and thus should be rewarding to work on.

A novel research question that may also be explored is on the comparison of tropical dry forest restoration in places where, unlike the provisioning of some irrigation at Kulish Smriti Van, the restoration solely relies on the rainwater harvesting. For instances, preliminary observations at tropical dry forests in proximity to villages Sar, Kalighati and Bilochi in Jaipur district suggest that facilitation by *Euphorbia* bushes may be playing a critical and more dominant role in the regeneration of economically valuable wood-carving species *Wrightia tinctoria*. Surprisingly, this species has not been seen regenerating in Kulish Smriti Van. Also, the ecological surprise we report here in Kulish Smriti Van is not seen in regenerating forests of Sar, Kalighati and Bilochi that are subjected to livestock grazing pressure. An ongoing study may provide useful insights on the comparative perspective.

Our case study also lends support to the fact that tropical dry forests, once lost, are not lost forever, provided knowledge on ecological, economic and social issues is strategically linked to restoration action. The case of ecological surprise in urban forests and green spaces has important implications for research and practice. Mimicking this natural process (i.e., seed addition through direct seeding) in seed-limited urban soils is likely to be successful in similar other contexts. In order to encourage the autogenic regeneration, soil should remain undisturbed from trampling, sweeping, and debris cleaning. This helps in humus build-up and carbon accumulation in soils. Seeds deposited in such humus-rich soils germinate and grow successfully. For scientists it would be worthwhile to investigate the conditions under which natural regeneration can be encouraged in urban green spaces. Likewise, practitioners should invest their energy and time in drawing on the best available science to design and implement strategies that also rely on natural seed dispersal and regeneration to create multifunctional green spaces for urban sustainability.

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