urban science

Review

Urban Green Spaces and Their Need in Cities of Rapidly Urbanizing India: A Review

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Abstract: Urbanization offers several opportunities for the growth of economic, social, and technology sectors, offering benefits to society in terms of better living and healthcare facilities, as well as employment opportunities. However, some major downsides of urbanization are overcrowding and environmental degradation. In order to realize sustainable and environmentally friendly urbanization, there is an urgent need for comprehensive land use planning and of urban settlements by giving due consideration to create and sustain urban green spaces (UGS) such as parks, gardens, roadside vegetation, etc. UGS play a vital role in reducing air pollution, mitigating climate change, and providing various ecosystem services. UGS are being deteriorated substantially due to booming urbanization in developing countries such as India. This review is focused on highlighting the many challenges in creating and maintaining UGS in the Indian context. It is a compilation of available reports on problems linked with poor land use and/or planning of urban settlements. The challenges associated with the management and maintenance of UGS are described. The poor and irregular watering of many existing UGS is one of the major issues among several others requiring immediate attention to resolve the problem of deteriorating UGS in some cities of India. As the groundwater resources are rapidly depleting because of ever increasing water demand, UGS are being dispensed with poor and irregular watering resulting in their deterioration. A list of possible solutions and prospects of UGS in cities aiming to become smart cities soon are discussed in this review. Efficient wastewater treatment and a non-potable reuse system are possible solutions for better prospects of UGS, and therefore, optimism of better cities with low to null urban heat island effect.

Keywords: urbanization; urban green spaces; climate change; wastewater management

1. Introduction

Urbanization is ongoing worldwide, especially in developing countries such as India [1–3]. About 60% of the world population will live in urban areas by 2030 [4]. As Asia and Africa currently house 90% of the world's rural population, they are urbanizing faster than any other region and are predicted to achieve urbanization rates of 56% and 64%, respectively, by 2050 [4]. The rise in urban population is expected to be high in India, China, and Nigeria, where 35% of the world urban population growth is predicted to occur during 2018–2050 [5,6]. Urbanization brings a number of benefits to the Asian countries [7,8]. By making better use of the opportunities provided by urbanization, India and other South Asian countries have the potential to transform their economies [7,9]. It is predicted that India's current urbanization rate of 0.25% will double by 2050 [10] and this rate has kept pace with the annual average economic growth of approximately 8% during the last 15 years [11]. The key reasons for increasing urbanization are ever-growing population and booming industrialization [12]. However, such unplanned urbanization is environmentally unfriendly and unsustainable leading to adverse effects on climate change.

With global climate change intensifying, climatic conditions in urban areas need to be addressed immediately [13]. Furthermore, due to excessive carbon emissions from automobiles in cities, air pollution that affects a large number of urban inhabitants globally is a major concern [14,15]. Besides rising pollution, congestion of spaces due to urban sprawl and depletion of groundwater due to its overexploitation and mismanagement are some of the other issues which need to be addressed [16–19]. Overcrowding in the metropolitan cities of India viz. Mumbai, Kolkata, Delhi, and Chennai has caused tremendous burden on the management of energy, water, and transportation as well as severely affecting the atmosphere, climate, lithosphere, biosphere, hydrosphere, as well as land and water resources [20,21].

Urbanization alters land use management which leads to the deterioration of groundwater quality and a drop in groundwater level [16,22,23]. Variations in temperature, precipitation, and evaporation also alter groundwater vulnerability through interacting with surface water, net recharge, and groundwater levels [24,25]. Therefore, understanding how urbanization and climate change may affect groundwater resources could provide deep insights for framing sustainable land use management plans.

Urban green spaces (UGS) are extremely necessary, particularly in developing countries like India and China, where air pollution levels are extremely high [26]. They play an important role in purifying air, thus improving the air quality [26] and serve as a valuable source for enabling urban agriculture, regulating the microclimate, and controlling the urban heat island phenomenon [27]. Furthermore, the UGS reduce soil erosion, noise pollution, and energy use by regulating the surface temperatures of urban canyons [28,29].

One of the prime factors for the reduced number of UGS in cities is the overpopulation of cities which results in increased scarcity of land and resources [30]. Among the UGS, the groves of trees play a significant role in carbon sequestration [31]. One of the major impacts of urbanization on the climate is that the urban area becomes significantly warmer than its surrounding rural area, usually termed as urban heat island [31]. Government initiatives, strategies and policies on UGS are necessary for the success of sustainable management plans. It requires the implementation of master plans for increasing UGS density [30], and to optimize existing ones needs to be explored [32]. Other strategies include their promotion as tourism spots involving local communities in ownership.

The way in which water resources in urban settlements are utilized does play a significant role in the preservation, development, and maintenance of UGS. While some studies have focused on how the water resource management practices in urban settlements affect the UGS cover, due attention has not been paid to the treatment and reuse of wastewater for their management. The collection of information, and insights thereof, on the change in green spaces and wastewater treatment and reuse can benefit policymakers and urban planners for environmentally friendly and long-term sustainable urban development. Therefore, the major objective of this review is to analyze the effect of management of water resources, particularly wastewater treatment and its non potable reuse in UGS. This review is also to explore the key challenges of wastewater treatment and its non potable reuse for UGS maintenance in major cities of India. It also aims to present ongoing efforts for treating and reusing wastewater in different parts of the world in an attempt to find a set of potential solutions to mitigate climate change in India.

2. Sources of Information for the Review

Various primary as well secondary sources of information including books, databases, reports, research papers published in scholarly and academic journals have been used for investigation in this review paper. A substantial portion of research articles pertaining to this review has been gathered using Google Scholar. While searching for relevant articles in Google Scholar, several search strings such as '*urban green spaces*', '*wastewater treatment and reuse*' and '*wastewater treatment and reuse*' and '*urban green space*' were used. These search strings gave 20,200, 10,600 and 37 results, respectively. Selection of papers was pruned based on title of paper first, then keywords used, followed by reading their abstract and conclusion.

The 37 papers with phrases, wastewater and urban green spaces (UGS) were scrutinized for their contents to draw essential inferences. Many definitions, descriptions and issues concerning UGS management, several website articles and press articles were also referred for this study. Various methodologies and techniques that were adopted to interpret the results obtained in prior research has been mentioned. The intent of their choice was for relating their importance to the research problem under consideration for this review. The relationship of each of the selected papers with the other papers has been brought out as much as possible.

In addition to articles specific to wastewater and UGS, those related to urban settlements, urban population growth, effects on land surface, temperature changes, and groundwater were also referred to for contextualizing the main theme of this review, namely the role of reuse of treated wastewater in the creation and upkeep of UGS. Thus, as many as 77 articles (including four database portals) are considered in this review. The research gaps that were identified from the selected papers are put forth in this review and offered as possible solutions.

3. Identification of Key Problems

3.1. Adverse Impacts of Unplanned Urbanization

In spite of the fact that urban areas offer better opportunities and improved standard of living, several problems arise from urbanization. Overcrowding and the strain on resources, particularly water and electricity, are the immediate ones. Environmental pollution due to large quantities of waste generation and excessive automobile use leading to increased carbon emissions exacerbates climate change impacts. Moreover, the unplanned urbanization problem is ecologically unsustainable because of the many pressing issues that are afflicting the waste management process. For instance, new immigrants to cities cannot afford municipal amenities like waste disposal and sanitary functions owing to their low incomes and to being either unemployed or underemployed [27]. In developing countries, about 300 million urban residents are reported to have no sanitation access [33]. Over two-thirds of the population in these countries have no access to hygienic means of disposing excreta and wastewater [33]. Thus, untreated sewage is often directly discharged into open, natural water bodies [33]. For instance, New Delhi, a megacity in a humid sub-tropical setting, has complex patterns of urbanization in terms of its commercial, residential, mixed-use areas, and traffic intersections. For this, the major contributing factors are high population density, high density of road network, and a very high amount of traffic flow.

Unlike Delhi, the city of Pune is located in a hot, semi-arid region with village nuclei and industrial sectors. Pune is affected by a sudden recent increase in population by 10 times compared to the last century. The city is being modified from a "bicycle city" to "motorbike city". In addition, the disproportionate increase in building heights as compared to street width affects the katabatic wind. The city of Chennai, with tropical wet and very dry seasons, is affected by large concrete surfaces, runways, and high traffic load. Post-1990s, there is an unprecedented increase in traffic, large areas of exposure to hard concrete surfaces, runways, and bus parking bays. In Visakhapatnam, another tropical wet and dry climate city with its population hotspots, the central and southern business district is affected by an increase in industrialization, large reclamations of the tidal swamp for port-based industries, haphazard urbanization, and the establishment of steel plants replacing agricultural and fishing villages. Except for New Delhi with a per capita green space of 21.52 sq.m., other cities named above have only 1.4, 0.46, and 0.18 sq.m of green spaces, respectively, which are very low.

The other major impact of urbanization on landscape surfaces is the replacement of vegetated areas with artificial surfaces that are mostly impervious. These impacts modify the surface energy balance through a change in absorption and reflection of solar radiation [34]. Besides energy, the water cycle between land and atmosphere also gets altered. Impervious urban surfaces obstruct water from infiltrating the soil, and vegetation also cannot intercept water, if it is absent. Since 1970, India has been undergoing rapid urbanization [35]. The urban population rose from 109 million in 1971 to 377 million in 2011, by an 11.7% increase (from 19.9% to 31.6%) over four decades [35]. The number of cities in the country with the population exceeding one million has steadily increased from 23 in 1991, and 35 in 2001, to 53 in 2011 [33,34].

Table 1 shows the population in the 13 populous cities as of the 2018 Estimated Census which was collected from the India Environment and Population Portal [34]. The table also provides information about the geographical area, forest and tree cover, and per capita green space in these cities.

Table 1. Major cities of India with per capita green space.

City	Population in Millions	Population Density (km^{-2})	Geographical Area (km^2)	Green Cover % (in km^2; 2017)	Per Capita Green Space (m^2; 2018)
Delhi	28.50	12,591	1484.00	20.00 (296.80)	**10.41**
Mumbai	23.50	20,482	603.00	36.48 (220.00)	**9.36**
Kolkata	15.20	24,400	1380.00	7.30 (100.74)	6.61
Bangalore	13.90	4381	2196.00	2.09 (46.03)	3.31
Hyderabad	11.57	18,480	650.00	1.66 (10.79)	0.93
Chennai	9.88	14,350	1189.00	15.00 (178.35)	**18.05**
Ahmedabad	8.41	9900	464.00	17.00 (78.88)	**9.38**
Surat	6.55	1376	326.50	11.84 (38.66)	5.90
Gandhinagar	6.33	660	649.00	54.00(188.46)	**29.77**
Jaipur	3.71	598	467.00	5.43 (24.75)	6.67
Nagpur	2.94	11,000	285.90	18.00 (51.42)	**17.49**
Mysore	1.70	6911	128.40	20.19 (25.92)	**15.25**
Chandigarh	1.05	9252	114.00	35.00(39.90)	**38.00**

Note: Figures in bold indicate the above optimal of 9 m^2 per capita green cover.

Figures 1 and 2 show India's population growth and climatic pattern based on data from the Indian government data portal [36,37]. Population growth forecasts indicate rapid global growth reaching nine billion in 2030 and migration from rural to urban areas occurring on a large scale in developing countries [33]. Such growth and migration bring in an untold number of problems in terms of urban planning and maintenance. In addition, the ordering of priorities for planned development including water and sanitation facilities faces multiple difficulties. The urbanization rates (Figure 1) in India since 1955 indicate a rise of about 35% (2019) from approximately 20% (1955) and are projected to reach 50% by 2050 [38].

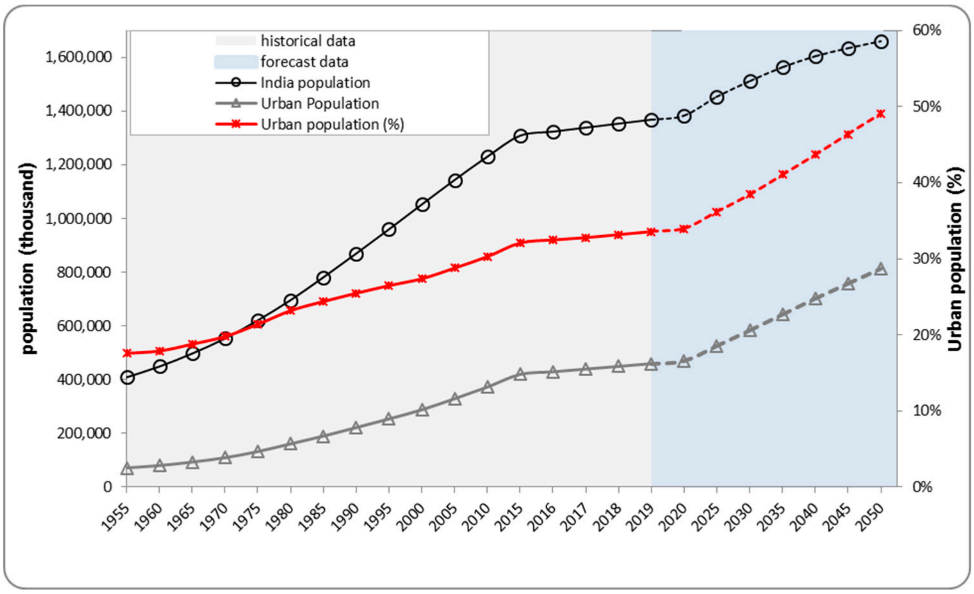

Figure 1. India's population growth and urbanization trend since 1955.

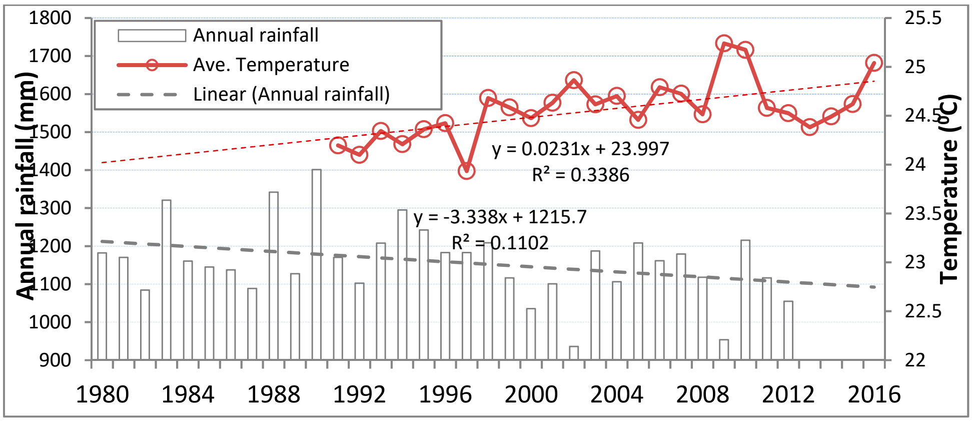

Figure 2. The pattern of annual rainfall and average temperature during the period 1980–2016. Data was collected from the India Environment Portal.

3.2. Challenges in Creating Green Spaces in Unplanned Urbanization

Rapid urbanization and industrialization in developing countries are also resulting in major problems such as air pollution and increased health risks [28]. The impact of urbanization on the climate is seen in the urban heat island effect wherein the air temperature in urban areas is considerably higher than in rural areas [28,32]. The urban heat island results in excessive use of air conditioners during summer thus accelerating the formation of urban smog [39]. Availability and the ability to grant high-in-demand, expensive but limited land area within the precincts of the cities is a complex challenge. One of the challenges of unplanned urbanization is in the implementation of master plans with areas dedicated to green space [30].

Regarding the creation of UGS, the two critical inputs are the availability of land areas and adequate water supply to maintain the existing green spaces or new ones planned. Firstly, cities face the challenge of the surge of rural migrants who tend to occupy any free space and not easily dislodge once anchored. Secondly, cities need to cater to the civic amenities of water, electricity, and road access for migrants. These factors might severely hinder the much-needed creation of parks, lawns or avenue gardens for greening the city environs.

3.3. Challenges with the Creation of Green Spaces

UGS are an important component that directly affects climate and water resources for sustainable development [40]. Designing interventions which support planning at the landscape level with a better understanding of the future spatial configurations of urban landscapes is a crucial step planning authorities need to take [41]. In India, there are pockets of green cover in urban areas such as neighborhood parks, roadside plants, and trees [42]. However, the problem is that of maintenance [43]. Impervious urban surfaces impact local climate very differently from that of vegetated countryside areas [44]. This is because of inefficient rainwater retention and storage which lead to more runoff thereby reducing the availability of water for plants. These autotrophs, in turn, would have helped ease the microclimate through evapotranspiration.

The main maintenance-related problem of UGS is that of irregular watering. With the growing populations in the haphazardly urbanizing cities, the water scarcity can be alarming and can be a great detriment for maintaining the green spaces. In Figure 4, the months during which the shortages can be severe are depicted; and in Figure 3, the projected water demand in India in relation to the available resources. Without an overemphasis, the reuse of wastewater is central to the sustained availability of water.

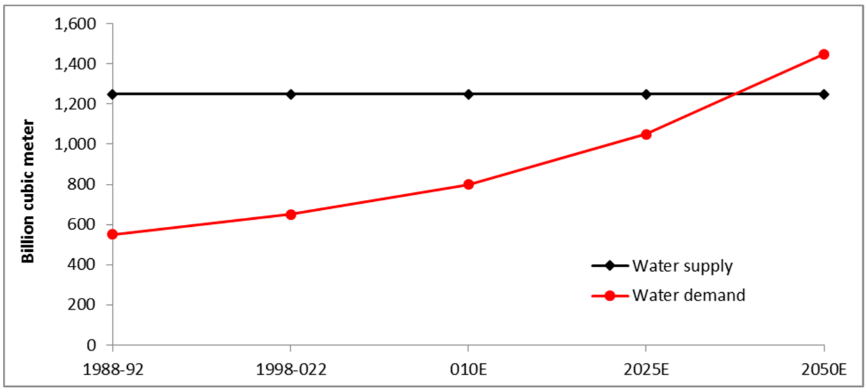

Figure 3. As the urban population in India is rapidly increasing, the demand for water is predicted to exceed the estimated (E) available supply by 2050. Data on water supply and demand collected from the portal of standing sub-committee of the Ministry of Water Resources.

Increasing immigration into cities creates severe pressure on the water. For example, Pune City is experiencing a surge of external population in search of economic opportunities [45]. Consequently, there is a rapidly increasing demand for land and water. This is also affecting other habitats of the city, including the UGS. The encroachment of hill slopes, riverbeds, barren and fallow land by slums have led to the degradation of both these habitats. Also, the artificial plantations of exotic species result in degradation of the local habitat and disturb the local biodiversity [45].

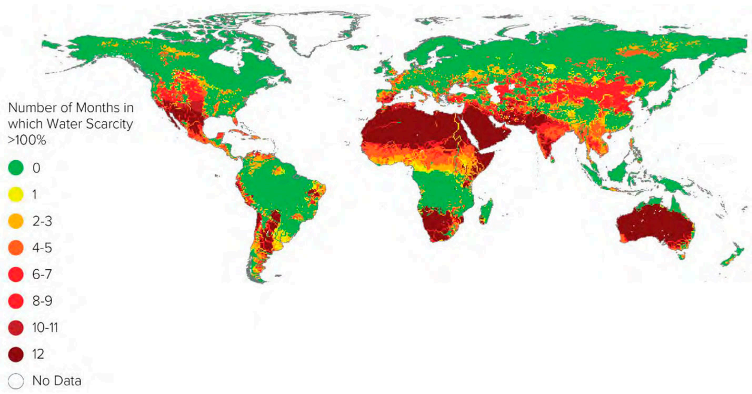

Figure 4. The number of months per year where water scarcity exceeds 100% during the period 1996–2005 [46].

A 10-year data based analyses of land cover changes of Pune City suggests that the built-up area has grown substantially to 43.01 sq.km., an increase from 30.86% in 1999 to 48.50% in 2009 [45]. Correspondingly, there is a decrease from 36.20% in 1999 to 21.80% in 2009 in the barren and fallow land area due to encroachment [45]. Both sparse and dense vegetation has decreased by 5.58 and 1.66 sq. km., respectively [45]. From these reports, it can be clearly seen that rapid urbanization due to exponential increase of population in an urban center such as Pune leads to various environmental issues.

3.4. Problems of Urban Water Supply and Sanitation

One other major and complex challenge is water supply to all the sub-divisions in the urban setting. It is quite a day-to-day encounter in most cities in the underdeveloped or developing countries to reach treated, potable water to the last house in the block. Low water levels of many sources during the summer season also hamper the water supply leading to inadequate volumes in many cities. The migrants usurping water by competing with the regular and accounted households creates a lot of pressure on civic authorities. According to Gill et al. [44], one of the distinctive biophysical features of urban areas compared to surrounding rural areas includes the urban heat island resulting from altered energy exchange. Another feature is the modified hydrology such as increased surface runoff of rainwater. These changes partly result from the altered surface cover of urban areas. Urban areas with less vegetation experience lesser evaporative cooling. Surface runoff increases with increase in surface sealing. The global climate change is certain to intensify these features. Data on annual rainfall and average temperature during the period 1980–2016 in India are presented to emphasize the point that the average rainfall pan-India is quite significant though varying inter-annually.

Urban sanitation systems must be of high hygienic standards to prevent the spread of diseases [47]. The World Bank predicts that over the next two decades, the greatest challenge in achieving adequate water and sanitation level would be the implementation of low-cost, rapid and efficient sewage treatment technology [47]. At the same time, this treatment option must "permit selective reuse of treated effluents for agricultural and industrial purposes" [47]. In addition, the recovery of nutrient and water resources is necessary for reuse in UGS creation and agricultural production to ease the overall user-demand for water resources. With increasing population and economic growth, it is evident that treatment and safe disposal of wastewater is essential for preserving public health and reducing intolerable levels of environmental degradation. In addition, adequate wastewater management is also required for preventing contamination of water bodies for preserving the sources of clean water.

4. Solution Strategies

4.1. Provisioning and Creation of Urban Green Spaces

For urban development to be sustainable, it must be environmentally, socially, and economically beneficial. In this context, UGS are an important component of sustainable development [40]. The environmental benefits through green spaces include mitigation of climate change by sequestering carbon emissions and reduction in air pollution [48]. Economic benefits include an appreciation of real estate value [49]. Social benefits include job creation, recreation zones, and better health [50]. Plants provide important ecosystem functions such as shading and cooling through evapotranspiration.

Growing plants in open areas free from concrete pavements and other locations of cities is a desirable step forward to cut down on the impact on climate. This is because impervious urban surfaces differ significantly from those of vegetated countryside areas in terms of being cooler [44]. According to Bonan [51] and Gill et al. [44], "This less effective rainwater interception and storage generates more runoff and reduces evapotranspiration in urban areas." Urban green spaces can synergistically add up in mitigating climate change by sequestering sizable volumes of carbon emissions. Citing Greater Manchester as a case study site, Gill et al. [44] recognize the important roles the green infrastructure—the green space network—plays in adapting for climate change. They highlighted that their model study, on surface temperature and surface runoff in relation to the green infrastructure, calls for an adaptation strategy to climate change in the urban environment.

4.2. Water Management for Urban Green Spaces

Green space is a much sought-after facility even in chaotic, traffic busy urban sites. In order that the green spaces are healthy and enabled for growing normally, regular supplement of water, nutrients, periodic de-weeding, pruning, spraying and replacing may be essential. Among these, the vital and frequent requirement is water. As highlighted earlier, this finite resource is becoming deficit, largely due to population growth and injudicious allocation of natural supplies as well as due to a lot of mismanagement. Groundwater is one of the natural resources essential for the upkeep of biodiversity. However, the escalating urbanization trend and climate change have a severe effect on groundwater availability. As groundwater resources are getting depleted rapidly, it is crucial to recycle wastewater, purify, and reuse for various purposes including drinking and, most importantly, for regular watering and irrigation of UGS such as parks and gardens.

The domestic wastewater that is generated daily in millions of liters (MLD) is a resource that is both easy to collect and reuse in urban areas. One of the strategies for the maintenance of UGS is regular irrigation. The major irrigation methods of roadside plants in India are flooding of the plant areas from a pipeline mounted to trucks. In the parks, flood irrigation, sprinkler irrigation, as well as drip irrigation are in practice. Drip irrigation is an efficient, water-saving technology that reduces losses from evapotranspiration [52]. Suitable treatment of several 100-million liters of wastewater generated daily across the cities is not yet considered for use in urban green space programs.

4.3. Wastewater Treatment and Use for Urban Green Spaces

In developing countries, there is still a persisting aversion to reuse treated wastewater. However, this cannot go on, or as Jhansi and Mishra [33] highlight, "cannot be assumed that the current low percentage of the coverage of wastewater treatment in these countries will increase in the future unless a new, innovative strategy is adopted and affordable wastewater treatment options are used." According to them [33], "a key component in any strategy aimed at increasing the coverage of wastewater treatment should be the application of appropriate wastewater treatment technologies that are effective, simple to operate, and low cost in investment and especially in operation and maintenance". Further, there is a need for appropriate technology processes that are very eco-friendly by being energy efficient and able to facilitate efforts to mitigate the effects of climate change. The appropriate technology unit processes are listed by Jhansi and Mishra [33] are as follows:

- Preliminary treatment by rotating micro screens
- Vortex grit chambers
- Lagoons treatment (anaerobic, facultative and polishing), including recent developments in improving lagoons performance
- Anaerobic treatment processes viz. anaerobic lagoons, up flow anaerobic sludge blanket reactors, anaerobic filters and anaerobic piston reactor
- Physicochemical processes such as chemically enhanced primary treatment
- Constructed wetlands
- Stabilization reservoirs for wastewater reuse and other purposes
- Overland flow
- Infiltration-percolation
- Septic tanks
- Submarine and large rivers outfalls

From the processes and various technical details listed above, it is possible that various treatment combinations can be set up including sand filtration and dissolved air floatation together.

4.4. Carbon Sequestration

In the carbon sequestration process, Carbon dioxide (CO_2) and other forms of carbon are stored [31]. The capture of CO_2 from the atmosphere through biological, chemical, and physical processes mitigates global warming [31]. Other benefits provided by carbon sequestration helps in mitigating the effect of greenhouse gases in the atmosphere [31]. During the photosynthetic process, plants/trees convert water and carbon dioxide into oxygen and sugar molecules. A part of the sugar gets stored, while most of it gets used for many other purposes such as energy, growth, reproduction, and structure-upkeep [31].

4.4.1. Carbon Sequestration Potential

All plant species contribute to carbon sequestration in varying quantities depending on the availability of water, inorganic nutrients, and adequate sunlight. According to Misni et al. [53] in their paper "Carbon Sequestration Through Urban Green Reserve and Open Space", the tree species that have the highest carbon sequestration potential include *Khaya senegalensis* (Khaya), *Alstonia angustiloba* (Pulai), *Pterocarpus indicus* (Angsana), *Sandoricum koetjape* (Sentul), *Mimusops elengi* (Tanjung), and *Samanea saman* (Hujan-hujan). According to Chandrashekhar [54], "A study in Varanasi found that native species like fig (*Ficus carica*), banyan (*Ficus benghalensis*), mango (*Mangifera indica*), and Ashoka (*Saraca asoca*), with their large thick leaves, withstood air pollution better and were more suited to planting in that urban area." According to Bhalla and Bhattacharya [55], all India-urban tree cover area is 16.40% of the total urban area. With a green cover of approximately 20% of the urban area, the Municipal Corporation of Delhi has a record of 18,000 parks that is further planned to be increased to 33% in coming years. According to the study by Terakunpisut et al. [56], tropical rain forests have the greatest carbon sequestration potential (137.73 ton C/ha) followed by dry evergreen forest (70.29 ton C/ha) and mixed deciduous forest (48.14 ton C/ha).

4.4.2. Main Plants Grown in Indian Cities and Their Carbon Sequestration Potential

Depending on the locations, the plant species (Table 2) grown in major cities of India vary, quite widely. These are the percentages of green spaces and the common/local names of the main plants grown in major cities of India according to the Gujarat Forest Department report [57].

Table 2. Green spaces and plant species grown in some major cities of India.

City	Green Space (%)	Major Plant Species
New Delhi	11.90	Banyan tree, Peepal tree, Bael, Jamun, Ber, Arjun
Mumbai	6.20	Bhendi tree, Banyan trees, Tamarind tree, Coconut palm, Paral tree, Padauk trees, Mahogany tree, Cajuput tree, Baobab tree, Star Apple, Baobab tree, Peltophorum tree, Gulmohar tree
Chennai	7.50	Sansiveria, Dieffenbachia, Dracaena, Spider plant, Earth star, Money plant, Pothos, Syngonium
Hyderabad	1.66	Bougainvillea, Neerium, Adeneum, Lantana, Euphorbia russelia
Bengaluru	2.96	Australian wattle, Butterfly tree, Red silk-cotton tree, Popcorn bush cedar, Coconut palm, Gulmohur, Indian cork tree, Indian elm, Teak, Silver oak, Orange champak
Kolkata	7.30	Neem, Peepal, Banyan, Radhachura, Krishnachura, Tamarind, Coconut, Betelnut tree
Pune	1.40	Cadamb, Tetu, Awala, Chandan, Tamhan, Muchkund, Cadamb, Kanchan, Putranjiva, Semla Kanchan, Kapila, Murudsheng Ritha, Undi
Panaji	10.00	Coconut, Teak, Sal, Cashew, Mango, Jackfruit tree

Panaji City in the state of Goa is one of the cities chosen for the Smart Cities Mission initiated by the Government of India. In Goa state, the total forest cover is 60.21% with an area of 2229 sq. km. as per the 2017 Forest Survey of India (FSI) report [58]. The state's forest cover has increased by 5% between 2015 and 2018 due to the increase in mangroves [59]. In Panaji city, the approximate green space area is 80 hectares. The city aims to be clean, environmentally friendly, and ecologically sustainable with a focus on improving the urban infrastructure facilities and tourist infrastructure, along with conserving the natural elements and heritage structures by adopting eco-friendly alternatives and techniques.

In the case study conducted by Kaul et al. [60], it was found that "long-term total carbon storage ranges from 101 to 156 Mg Cha^{-1}, with the largest carbon stock in the living biomass of long rotation sal forests (82 Mg Cha^{-1}). The net annual carbon sequestration rates were achieved for fast-growing short rotation poplar (8 Mg Cha^{-1} yr^{-1}) and Eucalyptus (6 Mg Cha^{-1} yr^{-1}) plantations followed by moderate growing teak forests (2 Mg Cha^{-1} yr^{-1}) and slow growing long rotation sal forests (1 Mg Cha^{-1} yr^{-1}). Due to the fast growth rate and adaptability to a range of environments, short rotation plantations, in addition to carbon storage rapidly produce biomass for energy and contribute to reduced greenhouse gas emissions." Native trees like *Azadirachta indica* (Neem), *Tamarindus indica* (Tamarind), *Ficus religiosa* (Peepal), and *Madhuca latifolia* are considered ecologically beneficial as they have relatively high efficiency of carbon fixation; these species may be suitable for checking urban pollution and may provide a good option for maximum carbon fixation [31]. While a variety of short-term and long-lived plants/trees are grown in different cities in India, data on the carbon sequestration potential of different plants species is lacking on the whole.

5. Role of Wastewater Management in Urban Green Spaces

The UGS can enable sustainable, environmentally-friendly urbanization; and can also be highly effective in mitigating climate change [61]. However, under the present trend of urbanization in developing countries, urbanization and deforestation are occurring in parallel [62]. As urbanization increases, the problem of climate change is intensifying due to many factors, mainly, the increased carbon emissions resulting from excessive use of automobiles and deforestation for enabling new urbanization projects [45]. According to Padigala [45], "haphazard urbanization" [45] occurring in developing countries threatens vegetation, and as a result, urban settlements become a major source of greenhouse gas emissions, and at the same time, more vulnerable to global environmental change impacts [45,63]. Green areas in cities in any shape, form, function, and purpose can be created in certain open spaces, covered with either natural or planted vegetation [48] and can be public and private open spaces available for all urban users [64]. In India, there are pockets of green cover in urban areas such as neighborhood parks, roadside plants, and trees [42]. However, the problem is that of maintenance [43].

The main maintenance-related problem is that of irregular watering [32]. One main objective of this review was to also recognize the importance of planning well and ahead by taking UGS into statutory consideration to be 'smart' as in the smart city concept that was initiated during 2014. A lack therein of suitable planning and provision for UGS can be detrimental to the city's overall wellbeing and being eco-friendly. Using the available information on UGS across different parts of the world, it was also the intent of this review to list a set of possible solutions that lead to sustainable smart cities from the perspectives of being economical, environmentally friendly, and aimed at mitigating climate change impacts.

5.1. Perspectives of Green Spaces in 'Smart Cities' of India

Cities in India with populations exceeding 100,000 people can plan and implement all criteria essential for being qualified as a smart city. It is reiterated here that there are parks in all the district headquarters in India which number over 550. Also, many townships with lesser population counts possess parks, pavement, and avenue plantation. The data on these areas must be collected, pooled, and a comparative assessment of the carbon sequestration potential of all these cities, in particular, those aspiring to be smart cities in the near future. In this regard, an estimate of the green spaces available in eight Indian cities and the major types of plants grown are furnished in Table 2. Green space includes vegetated areas with trees, shrubs, and grasses. Having realized the effectiveness of vegetation in reducing air pollution, past urban forestry projects in Kuala Lumpur and Manila aimed to increase the area of planted vegetation [65].

The civic administrators in India should recognize that the benefits provided by green spaces in cities include reduced energy requirements for cooling and heating in summer and winter seasons, respectively. Green spaces significantly contribute to enhanced biodiversity of flora and fauna in cities. Fam et al. [66] highlight that the economic benefits of green open space include income generated from festivals, sporting events, and appreciation of property value. In Indian cities, systematic record keeping of all the species of plants and the area of UGS, preferably by horticulture departments is essential not only from the perspective of upholding the healthy-city status but also from showcasing the efforts in place for pollution mitigation and carbon sequestration. It is noteworthy here that some urban forestry projects received finances under carbon sequestration projects [67,68] in several cities in the United States.

The benefits of UGS are not just environmental [69]. They also encompass the provision of employment, and by cleaning and cooling, improvement of the urban air quality. Strategic tree planting following a well thought out landscaping can aid in saving energy and maintaining 'cool-comfort'. Since urban trees reduce the need for burning fossil energy, they are a cost-efficient investment for mitigation of greenhouse effects.

5.2. Treatment and Non Potable Reuse of Wastewater

Water is the world's most precious, life-sustaining resource. This valuable resource is under severe and perpetual threat due to climate change and resulting drought, explosive population growth, and more notably, wastage in many parts of India. The wastewater generated daily in millions of liters is one "cheap" resource waiting to be harnessed. It is easy to see that even if 60 to 75% is treated and reused, the hardship on water demand will be receding several folds. Reclamation and reuse of industrial and municipal wastewater are very promising to stem the water crisis across India. Jhansi and Mishra [33] have covered many details on the appropriate technologies for wastewater treatment and benefits of wastewater treatment. The natural water which is subject to purification for potable purposes is currently used in almost every city (except Mumbai, Hyderabad, New Delhi; where treated wastewater is used for maintaining greenery in some parts of the city. This is one example of treated wastewater used for maintaining the urban green spaces.).

The Water Reuse Association defines reused, recycled, or reclaimed water as "water that is used more than one time before it passes back into the natural water cycle." [33]. Recycling or reusing of treated wastewater for agricultural and landscape irrigation, industrial processes, and replenishing a groundwater basin (referred to as groundwater recharge) is the most essential requirement in India. Wastewater reuse allows communities to become less dependent on groundwater and surface water sources. This 'renewed' water can be useful by rejuvenating severely overdrawn groundwater resources [33]. Wastewater reuse can decrease the diversion of water from sensitive ecosystems. Such reuse, in particular for irrigating plants and crops, can prevent pollution by siphoning off the nutrient loads from wastewater [33].

5.3. Outlook for Urban Green Spaces through Reuse of Treated Wastewater

The urban areas of many developing countries, including India, are growing rapidly. Thus, the adverse consequences are an ecological imbalance, if wastewater treatment and suitable sanitation systems are lacking. India has a greater opportunity under the Clean India Mission to achieve self-sufficiency in water supplies to green spaces, a variety of agricultural uses and for recharging the lost resource of precious groundwater. In doing so, the country can attain adequate sanitation which can cater to Healthy India, another pan-India Mission. The importance of reusing wastewater in a developing urban society lies in the fact that the wastewater generation usually averages 30–70 cubic meters per person per year. In this arithmetic, reprocessing of wastewater from a city with one million people would be enough to irrigate approximately 1500–3500 hectares of UGS and/or farmland. Needless to overly emphasize, a major need exists to harness this "reliable urban resource" advantageously. There is a crucial need for India's current urban development policies to address climate adaptation strategies [70,71].

Green spaces can significantly contribute to social and environmental urban sustainability, and also to the cost-effective climate adaptation and mitigation. There is an urgent need in India to realize these potentials of green spaces. Instead of making efforts to retain land as an open space, the short-term economic benefits of land conversion are more sought-after, thus leading to short sighted vision in urban planning in the country [35]. Limited efforts are underway to protect sensitive areas from excessive urban development and make adequate provisions for open spaces.

The Ministry of Urban Development, Government of India, has issued guidelines on Urban Development Plans Formulation and Implementation to protect environmentally sensitive areas from urban development to provide adequate network for open spaces. In almost all Indian cities, the public works departments (PWDs) are responsible, among other activities, for handling water supply, sewage collection and treatment/disposal, electricity supply, and road construction and maintenance. The forest and horticulture departments are mostly tasked with all aspects of green spaces in cities. While a lot needs to be advanced in wastewater handling and treatment skills and technologies, efforts to manage this year-round resource of wastewater are afoot under the smart city idea in India. Networking and cooperation between different departments is essential and to be in place. As highlighted above, there is a much larger scope for treating several more million liters of domestic sewage and ensuring the reuse of treated water for green spacing to bring many benefits.

Furthermore, urban development agencies of many metropolitan cities have framed several policies and strategies for the protection of open spaces during urban development projects. It is highly essential to develop rules and regulations to set some minimum green space per capita in major cities of India. It is also necessary to have guidelines for improving the green spaces by encouraging the maximum utilization of the available area for ecological and social needs. At present, more green spaces are being included in future urban development plans by the metropolitan development authorities. The several social and urban forestry schemes aim at improving UGS in India [35].

Wetland Option for Treated Wastewater

New and novel approaches of maximizing treated wastewater reuse as well as creation and upkeep of UGS are also to be in place [72]. In this regard, creation of wetlands through pumping in of either partially or fully treated wastewater into open areas, fallow lands and low-lying regions is a possible option [73]. It could indeed be the best means of groundwater/aquifer recharge [74]. However, with the current practices of urban planning in India, where the wastewater treatment, at best, is far minimal both in quantity and quality terms, it can become a health-hazzle and can constrain space allocation for various amenities in urban precincts [73]. Improvements of current sanitation programs and stringent practices at ground level could be very challenging [74,75]. In the near future, the outlook is weak in most Indian cities including many aspiring smart cities for creating wetlands that are economically efficient and ecologically sustainable [72,75].

6. Conclusions

In the Indian scenario, millions of urban inhabitants are still deprived of access to clean drinking water and adequate sanitation services. It is very common to see wastewater flowing in the streets in many slums and peri-urban areas of India. The insufficient quantity and substandard quality of water and sanitation services are the major causes for the spread of diseases in developing countries. A large portion of the entire population still lacks access to services such as collection and transportation of wastewater out of urban neighborhoods. Urban green spaces significantly affect the regional micro-climate. They contribute significantly to modulation of climatic extremes, improvement of the hydrological cycle, as well as plant health, etc. Creation of green spaces in urban areas requires supportive policies. Furthermore, education on the important contributions of green spaces needs to be provided on a large scale to facilitate their implementation and funding. It is highly crucial to recycle and reuse wastewater for UGS to deal with the problem of depleting groundwater resources. Furthermore, regular watering of parks, gardens, and roadside vegetation is required to maintain many of these beneficial characteristics of UGS. Irrigation of UGS can be through simple yet effective technologies such as drip irrigation. As can be recognized from the foregoing account, there is an urgent need for adequate treatment of wastewater from a larger proportion of the population. Some programs like Smart Cities and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) are aiming to provide ample job opportunities with the support of efficient service infrastructure. The missions such as Smart Cities Mission, Clean India, and Healthy India would become successful when the civic bodies prepare guidelines, implement all mandatory regulations, administer proactively and efficiently to not only create much needed UGS but also to treat and use multiple times the cheap and mega resource of wastewater to solve many problems including the reduction of carbon footprint due to urbanization.

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