RESEARCH ARTICLE

A Score-based Method for Assessing the Importance of Urban Forest and its Ecosystem Services

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Abstract

Urban scape constitutes the manifestation of various natural and anthropic elements entangled in a specific form. However, arbitrary land-use changes during the last few decades have witnessed a significant biodiversity loss in urban areas. Over 50% of the earth's human population lives in the urban settlement, which accounts for less than 3% of the earth's urbanized area. Urban green spaces act as biodiversity refuge in urban areas. In such crucial circumstances, an urban forest can play a critical role in biodiversity conservation and management through academic green spaces. To understand and evaluate the role of the urban forest, the present study carried out on the campus of [CSIR-National Environmental Engineering Research Institute (NEERI)], Nagpur.

Furthermore, an innovative and multifaceted index named total importance value (TIV) index was developed, which used to analyze the importance of the trees present on the campus. Results revealed the presence of more than 200 plant species belonging to both native and exotic groups and their contributions to improve the urban environment in terms of the TIV index. The study also advocates the usages of TIV as a framework for the development and planning of climate-smart green cities, which is resilience to climate change.

Keywords: Green spaces, Resilience, Total importance value (TIV) index, Urban forests.

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Introduction

Urbanization is not just a 'megatrend,' it has now become a 'gigatrend,' a millennial transformation of human culture, society, economy, polity, and planetary systems. Urbanized areas cover approximately 6% of the earth's surface, yet they have extraordinarily large ecological footprints. These footprints are complex, powerful, and often have indirect effects on ecosystems (Ordóñez *et al*., 2019). Urban areas comprise more than 44% of the population in developing nations around the world. With having a majority of public living in cities, it considered that this assumption would surpass the considerable threshold in the coming years (Montgomery, 2008). India, as one of the developing countries, faces severe and complex economic, ecological, and sociological changes by rapid urbanization and population pressure (DeFries and Pandey, 2010).

Given that urbanization is now a global-scale process, a sustainable planet will depend on how our cities will grow, function, and respond to stress. Urban green spaces are familiar places of human-environment interactions providing continuous services to urban dwellers. These services are in terms of social and ecological outcomes, both intended and unintended (Cook *et al*., 2012; Fan *et al*., 2019). In the recent few years, urban green space and forest have become an emerging research topic, not only for academicians but also for municipal managers, decision-makers, and local stakeholders. Globally many policies, such as the New Urban Agenda (UN-HABITAT, 2018), now includes urban green space as one of an integral part of the policy framework. In India, many cities have a large number of green spaces and parks (Table 1). The multiple values of ecosystem services can be used to capture and identify the significance of these services for the general public of Nagpur and other emergent urban agglomerates of the country. The provisioning ecosystem services provided by urban common property resources have always supported the traditional livelihoods of local groups, and subsistence requirements of urban poor, including migrant workers in the city. Moderate climatic variations around build in established as a biodiversity spot in crowded and concrete dominated cities which ultimately contribute to enhancing the quality of human life (Botkin and

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Table 1: Green cities of India with a percentage of green cover

S. No.	*Name of the city*	*Green cover (%)*	*References*
1	Gandhinagar	53.90	Singh (2012)
2	Chandigarh	35.70	Action plan (2016)
3	Pune	28.50	Bhaskar (2012)
4	Ahmedabad	24 .00	Padmanaban (2016)
5	Bhopal	22.00	Singh (2012)
6	Nagpur	12.80	Khadri *et al*. (2014)
7	Delhi	11.90	Singh (2012)
8	Kolkata	07.30	Padmanaban (2016)
9	Bangalore	06.85	FSI (2013)
10	Hyderabad	05.00	FSI (2013)

Beveridge, 1997; Long and Nair, 1999; Aminzadeh and Khansefid, 2010; Chaudhry and Tewari, 2010; Nagendra and Gopal, 2010; Vogt *et al*., 2015; Fan *et al*., 2019).

Urban forest justifies the role of trees as a critical part of the urban infrastructure (Singh *et al*., 2010; Long *et al*., 2019). In denuded urban environments, trees act as a critical habitat and the last refuge of biodiversity as small green islands to support urban wildlife (Krishen, 2006). Though the urban forest is minuscule in the area, they are characterized by high levels of species richness and different microhabitat (Jim, 2002; Cornelis and Hermy, 2004; Jim and Chen, 2009; Khera *et al*., 2009; Goddard *et al*., 2010). Urban green space and avenue plantation facilitate a suitable environment to propagate non-native or exotic plant species (Richardson, 1998; Harrington *et al*., 2003; Pemberton and Liu, 2009). Non-native species mostly have some allelopathic impacts on the growth of native species (Moro and Castro, 2015). Urban areas of India are prominent sites for spreading invasive plant species along with animals (Nagendra, 2014). It is imperative to ensure a wise selection of plant species for urban green spaces along with public awareness about native plant values. Urban green can bridge the gap between nature and urban dwellers. There is an urgent need to make smart use of available land and integrate urban green spaces with urban infrastructure. Strategically planned biodiversity conservation in urban agglomerates of India will not only achieve conservation goals but also support ecological communities that provide ecosystem services for good quality of life and human well being. Urban campus forests can provide a promising solution and space to work in that direction. The present study was carried out in one of the fastest-growing cities of India, Nagpur. Emerging scenario of reduced green spaces in the city and increased exotic species motivated to explore one of the oldest and green campuses of Nagpur city CSIR-NEERI under the following objectives:

- Understanding the biodiversity of campus urban forest.
- Understanding and assessing the exotic versus native species distribution in the study area.
- Assessing the TIV of trees in the urban forest of CSIR-NEERI campus for their provisioning ecosystem values.

The present study attempts to understand the contribution of native versus exotic species in urban environments. In contrast, the TIV index can help us to assess the importance of plant species for urban green space using four critical criteria *viz*., medicinal, aesthetic, edible, and other economic values. The overall study emphasizes on the need for urban green spaces as a mandatory obligation in emerging smart cities to provide much-needed resilience to withstand changing climatic conditions.

Study Area and Climate

Nagpur is the thirteenth biggest urban agglomeration in India and the third biggest city in Maharashtra. It is located in the central part on the edge of the Deccan plateau of India, at a mean elevation of 310-meter amsl covering an area of 217.56 km^2. The climate of the city is typically hot, dry, and tropical weather type with an average rainfall of 1000 mm. Nagpur is an affluent wetland district of Maharashtra state, contributing significantly to the state wetland area. Nagpur is girdled by tropical dry deciduous forest, which engulfs most alluring flora and fauna and has been heralded as the "tiger capital of India." Nagpur enjoys the privilege of being termed as the richest and greenest city with latent potential, a hub of health care industry in the state. The city is specked with natural as well as artificial lakes and the biggest being Futala lake (0.26 km^2), others are, Ambazari, Gandhisagar, Naik, Lendi, Sonegaon, Telankhedi, Pardi, Khadan, Gorewada, Tilhara, Sakkardara, Naik *talab,* Raghuji *talab,* Sukravari *talab,* Baradri *talab*, and Dhobi *talab.* Nagpur falls in the drainage basins of river Nag, Kanhan, Pohara, and Pili that transverse the city in west to east direction. The natural area in the city consists of water bodies, croplands, fallow land, wasteland, urban forests, campus forests, parks, etc. Nagpur considered to be one of the livable cities of India, and land use pattern in Nagpur shows 69% of the area under development. Out of the total developed area, 45% is residential, 6% under commercial and industrial use, 41% of the land is under public use, and 8% of land under parks and gardens in the city. Nagpur is one of the greenest cities of India that has 18% of its area under forests and plantations, 17% under cultivation, and 2% underwater bodies (Sinha, 2013). In the city, seminary hills, Gorewada biodiversity park, Ambazari garden, and surroundings of Futala lake are some large green spaces that harbor plants, avifauna, macrofauna, mesofauna, mammal, and reptile diversity. Our study area, NEERI campus, Nagpur is one of the oldest CSIR research and development institute of India has 43 acres of urban forest (Fig. 1). NEERI campus forests are rich in a plant (both angiosperm and lower plant groups), avifauna, reptiles, mammals, and macrofauna.

Materials and Methods

For a comprehensive assessment of plant diversity, two baseline inventories conducted in the year 2007-08 (Gupta *et al*., 2008) and 2014-15. Primary data were collected, scrutinized, and refined using the least count method following standard protocols (Misra, 1972). Species identified using regional floral literature and books (Krishen, 2006). For ease of documentation, the whole campus forest divided into two zones. Zone I includes research divisions, eastern colony, and guest house, whereas

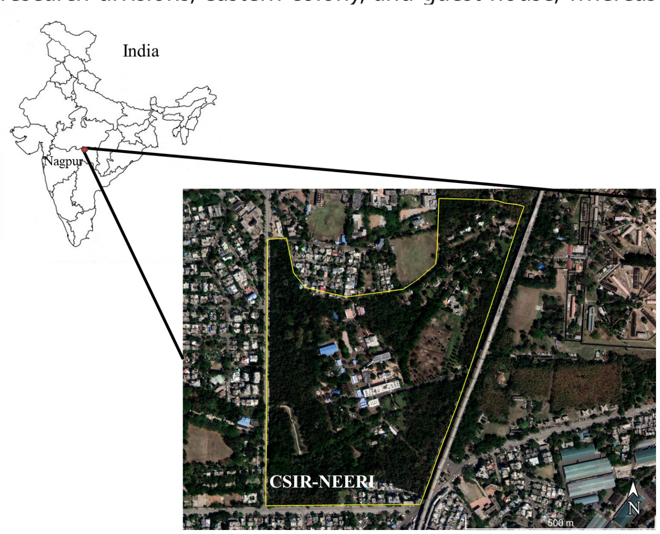

Fig. 1: Map showing NEERI campus urban forest, Nagpur, Maharashtra, India

zone II includes areas nearby gate number 1 and 2. The plant species present on the campus were identified and documented regularly. Based on the plant structure and their origin, identified plant species were classified into four categories, such as trees, shrubs, herbs, and others (grasses, climber, and lianas) along with native or exotic groups. Additionally, a score based matrix was developed to assign scores to identified trees based on different ecosystem services provided (medicinal, aesthetical, edible, timber, Non Timber Forest Products (NTFP's), fodder, etc.). The potential uses of plants based on literature review (LR), expert opinion (EA), direct observations (DO), and informal interviews (II) (Table 2). Indigenously developed interactive portal NEERI biodiversity portal also helped to identify and giving appropriate scores to the trees.

Assessment and Scoring Criteria

After reviewing different indices and approaches for importance assessment of floral diversity, we have tried to develop a score based matrix that would help to understand the importance of trees in an urbanscape, under five different categories of significant provisioning ecosystem services by the tree (Table 3). The score based matrix also comprised of four sections discussed below.

Medicinal Values

Based on four sub-criteria *viz*., lifecycle, the abundance of the tree species, medicinal use, and commercial value therapeutic scores given to the trees species. Based on their lifecycle and their occurrence, plants were classified into perennial and

Table 2: Scoring criteria to assess the TIV of trees in CSIR-NEERI urban campus forests

Criteria	*Weightage*	*Values*	*Background of scoring*
Medicinal	Lifecycle	Annual (1)/ perennial (2)	DO[a]; EA[b]
	Availability of species in identified the forest patches	Rare (1)/ abundant (2)	DO; EA
	Medicinal usage	Medicinal uses mentioned in the literature (1) and uses observed/described by local peoples with score (2)	II[c]; LR[d]; DO
	Commercial applications in market	Low (1)/ high (2)	DO; II
Aesthetical	Lifecycle	Annual (1)/ perennial (2)	DO; EA
	Availability of species in identified the forest patches	Rare (1)/ abundant (2)	DO; EA
	Flowering	Non-flowering (1)/ attractive and high flower bunch (2)	DO; EA; LR
	Canopy cover/crown cover	Lesser canopy (≥ 30%) (1)/ more canopy cover (≤ 30%) (2)	DO; EA; LR
Edible	Lifecycle	Annual (1)/ perennial (2)	DO; EA
	Availability of species in identified the forest patches	Rare (1)/ abundant(2)	DO; EA
	Commercial uses in market	Low (1)/ high (2)	DO; II
	Edible value	Trees which do not have any edible value for human scored (1) and trees which are having edible value used by human scored (2)	LR; EA
Others scores to tree species	Fodder value	Low value (1)/ high value (2)	LR; EA
	Timber value	Low value (1)/ high value (2)	LR; EA
	NTFP value	Low value (1)/ high value (2)	LR; EA
	Origin	Low value (1)/ high value (2)	LR; EA

a = Direct observation (DO); b = Expert view (EA); c = Informal interviews (II); d = Literature review (LR)

Table 3: Categories and TIV percentage used to evaluate the ecosystem services provided by the trees

Categories	*TIV percentage*	*Significant provisioning ecosystem services by tree*
A	81-100	Very significant
B	61-80	Significant
C	41-60	Moderately significant
D	21-40	Less significant
E	0-20	Least significant

annual, rare, and abundant. Medicinal properties or utilization of locals confirmed through informal interviews and secondary literature (Table 4a).

Aesthetical Values

Based on four sub-criteria *viz.,* lifecycle, abundance, flowering, and canopy cover the aesthetic importance of trees assessed. Lifecycle and abundance were scored based on annual and perennial, whereas the abundance by low and high. Flowering and canopy cover properties of a tree add aesthetics beauty, creates environment wellbeing, and attract various pollinators. Trees with dense canopy cover add exquisiteness to their surroundings by adding color to an area, softening harsh lines of buildings, screening unsightly views, and contributing to the character of their environment. Henceforth it will become one of the important factors on which aesthetics scores depend (Table 4b).

Edible Values

Edible scores of trees based on four important criteria *viz.,* lifecycle, abundance, the commercial value in market, and palatability. The above three sub-criteria are related to an edible score like lifecycle will determine when the fruiting will happen, how abundant it is, and it is driven by the market-based economy or not. An edibility rating is more for plant species that offer year-round fruits for human consumption than those who do not. However, it is important that plants with no nutritive value to people might provide food to birds, apes, and other pollinators or seed dispersals so, they have some value or other. Their score bases technique shown in (Table 4c).

Other Values

Fodder value is an important parameter since livestock get nutrition and important feed from it. Though, in urban areas, not many tree leaves are lopped for fodder. Still here having fodder values that indicate trees have some significant economic and social value. Timber value was also to understand how trees play a vital role in sequestering carbon and how urban forests can be efficient carbon sinks. NTFP values of the trees reflected the products like gum, honey, and bark. While one of most factors origin (native *vs*. alien) also contributed in assigning importance to the tree species (Table 4d).

Table 4a: Medicinal score matrix for four species of trees

Tree species	*Annual = 1 Perennial = 2*	*Rare = 1 Abundant = 2*	*Mentioned in only literature = 1 Mentioned by local informant and literature both = 2*	*Low commercial value = 1 High commercial value = 2*	*Total medicinal score*
MI	1	2	2	2	7
ZM	1	2	2	2	7
BR	1	1	1	1	4
HI	1	1	1	1	4

Table 4b: Aesthetical score matrix for four species of trees

Tree species	*Annual = 1 Perennial = 2*	*Rare = 1 Abundant = 2*	*Low flower = 1 High flower = 2*	*Low canopy = 1 High canopy = 2*	*Total aesthetical score*
MI	1	2	2	2	7
ZM	1	2	1	2	6
BR	1	1	1	1	4
HI	1	1	1	1	4

Table 4c: Edible score matrix for four species of trees

Tree species	*Annual = 1 Perennial = 2*	*Rare = 1 Abundance = 2*	*Non-edible = 1 Edible = 2*	*No commercial value = 1/ High = 2*	*Total edible score*
MI	1	2	2	2	7
ZM	1	2	2	2	7
BR	1	1	1	1	4
HI	1	1	1	1	4

Table 4d: Other value score matrix for four species of trees

Tree species	*Fodder value Low = 1 High = 2*	*Timer value Low = 1 High = 2*	*NTFP value Low = 1 High = 2*	*Exotic = 1 Native = 2*	*Total other score*
MI	1	2	2	2	7
ZM	2	1	2	2	7
BR	1	1	1	1	4
HI	1	1	1	2	5

Overall Scoring for provisioning Ecosystem using Total Importance Value (TIV)

The TIV index originally developed to equate the importance of trees within the same geographical area. Generally, it is based on four supporting criteria of a tree. Under each criterion, four different weightage categories with specific values are assigned for precise assessment of tree characters. Assigning the values is based on direct observation, expert view, informal interviews, and extensive review of literature, thereby creating individual criteria score and further overall TIV score. The sum of the importance values for all uses further expressed as the relative percentage (maximum possible score). A score of four suggested minimal potential use, while a maximum of eight suggested the species with higher economic value/benefits. Thus, TIV in the equation below was taken as a measure of the potential importance of the plant under 24-criteria. It could be calculated using the following equation:

$$TIV = (U1 + U2 + U3 + U4) \quad (1)$$

$$TIV\ \% = \quad (2)$$

Where: U1 = medicinal value; U2 = aesthetical value; U3 = edible value; U4 = other value.

A maximum value eight for all four applications provides an overall maximum value of 32, which would produce a TIV (100%) for the plant species. All values incorporated in the mathematical framework provided us TIV based on TIV percentage. Cumulative score matrix of four species of the tree shown in Table 4e. TIV is a tool for organizing, analyzing, and presenting results of the holistic importance of a tree species in an urban environment.

Results and Discussions

Plant Diversity in Urban Forest

Documentation carried out in 2007-08 revealed the presence of 135 vascular plants which belong to 16 monocots, 119 dicots. Overall plant taxa included grasses of 4 types, herbs of 55 types, 30 types of shrubs, and 46 trees species (Gupta *et al.*, 2008). Whereas the assessment carried out in the year 2014-15, suggests the rise of plant species from 135 to 200 (Fig. 2). Increased species diversity in the urban forest was a combination of both native and non-native origin. In India spread of non-native plants has been both ecologically and human-mediated. With the introduction of alien species in urban environments, native plants face particular challenges, i.e., altered disturbance, habitat fragmentation, and increased chances for invasion (Kang *et al.*, 2019). However, humans fail to control plant invasion because of many times, aesthetics, and immediate usefulness. Despite this fact, urban forests act as an island for native and valuable species of plants. This fact would be more apparent with the present investigation, which revealed the presence of 78% of native species and only 22% non-native species of plant (Fig. 3).

One possible reason for the widespread presence of native species in an urban forest might be due to the favorable microclimatic conditions which support the fast regeneration of native species. However, most abundantly found non-native species in the forest of NEERI is Subabool (*Leucaena leucocephala), which* belongs to subfamily *Mimosoideae* and family *Fabaceae*. Other non-native species present in the campus are *Peltophorum pterocarpum, Annona squamosa, and Plumeria alba*. Most of the native species having high aesthetic

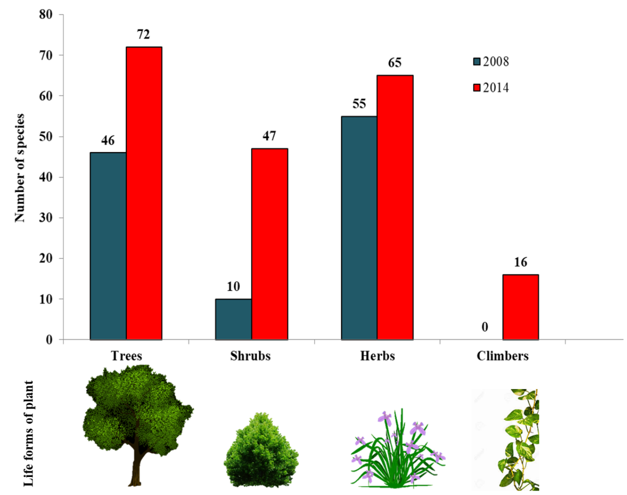

Fig. 2: Species documented in 2007-08 and 2014-15 at NEERI campus urban forest, Nagpur, Maharashtra, India

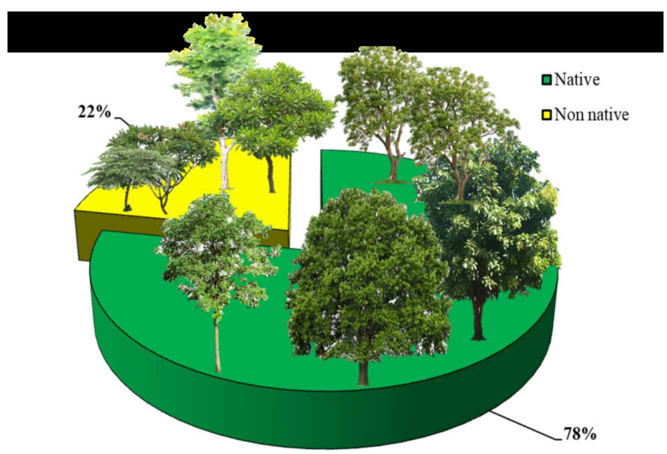

Fig. 3: Native and non-native tree species in NEERI campus urban forest, Nagpur, Maharashtra, India

Table 4e: Cumulative score matrix of TIV percentage for four species of trees

Tree species	*Total medicinal score*	*Total aesthetic score*	*Total edible score*	*Total other score*	*Cumulative TIV*	*TIV percentage*
MI	7	7	7	7	28	87.50
ZM	7	6	7	7	27	84.30
BR	4	4	4	4	16	50.00
HI	4	4	4	5	17	53.12

TIV = Total importance value; MI = *Mangnifera indica* L.; ZM = *Ziziphus mauritiana*; BR = *Beaucarne recurvate*; HI = *Holoptelea integrifolia* value and preferred in gardens and along the roadside, but non-native species like *Leucaena leucocephala* having less soil holding capacity and tend to fall often during heavy rains and storms. Among the native species of the plants, *Mangifera indica, Ziziphus maurtiana, and Tamarindus indicus* are the prominent tree species of the campus and add value regarding the variety of pollinators and avifaunal elements.

TIV of Tree Species in Urban Forest

The result revealed a TIV percentage of 74 trees (Table 5), *Beaucarnea recurvata* with 50% being the least scorer in TIV, whereas the *Mangifera indica* L. with 87.5% being the top scorer species (Figs 4 and 5). *Beaucarnea recurvate is a non-native species single palm-like plant belongs to family Asparagaceae. It is an evergreen perennial plant with a noticeable expanded caudex. It generally has lower fodder and aesthetical values*. TIV of trees reflects fodder, medicinal, aesthetic, economic, and edible and fuelwood trees present on campus. The higher TIV value of trees indicates the biomass potential of the urban forest. Mango (*Mangifera indica*) belonging to family *Anacardiaceae* is abundantly present in the NEERI campus depicted by higher TIV percentage, i.e., 87% and diversity too. The nutrient value of mango fruit is high in dietary fiber, citric acid, polyphenols, and carotenoid making it is a superfruit (Fowomola, 2010). Neem (*Azadirachta indica*), with its more comprehensive applicability and high medicinal properties, shows a higher TIV percentage (84.4%). In the case of some other species of plants like *Ziziphus mauritiana,* the medicinal and other values like timber, fuel, and

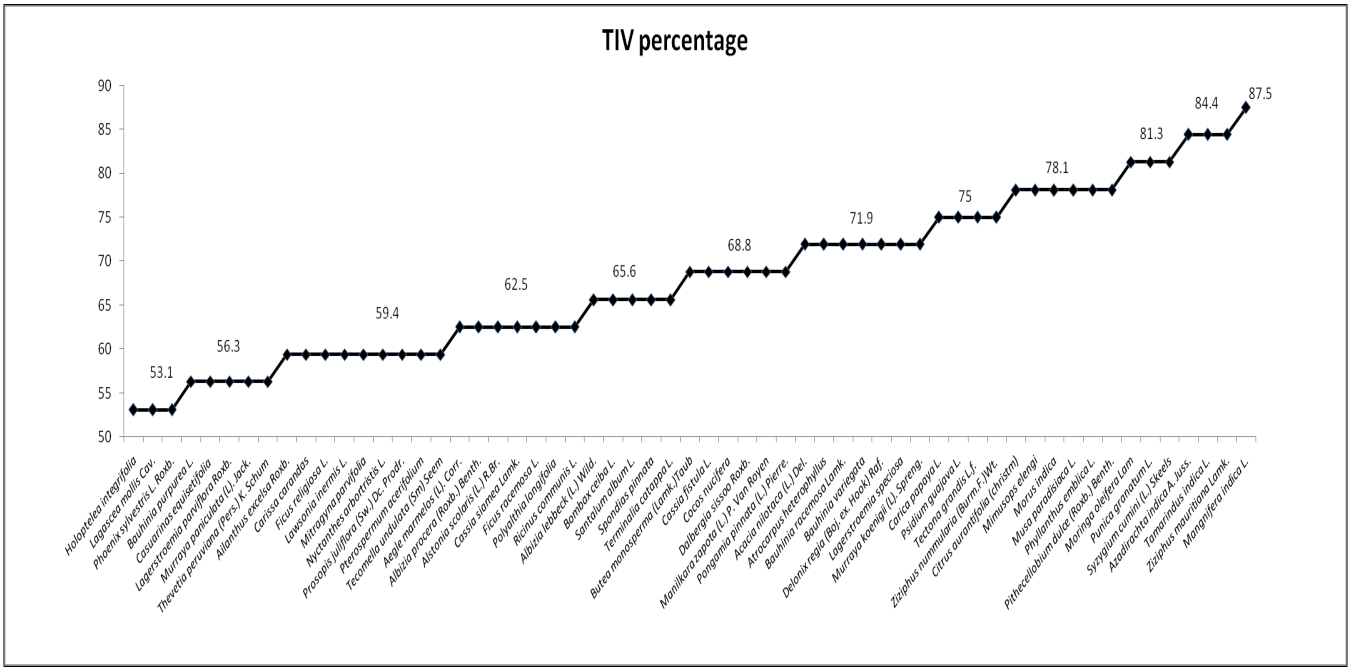

Fig. 4: TIV index of native tree species present in NEERI campus urban forest, Nagpur, Maharashtra, India

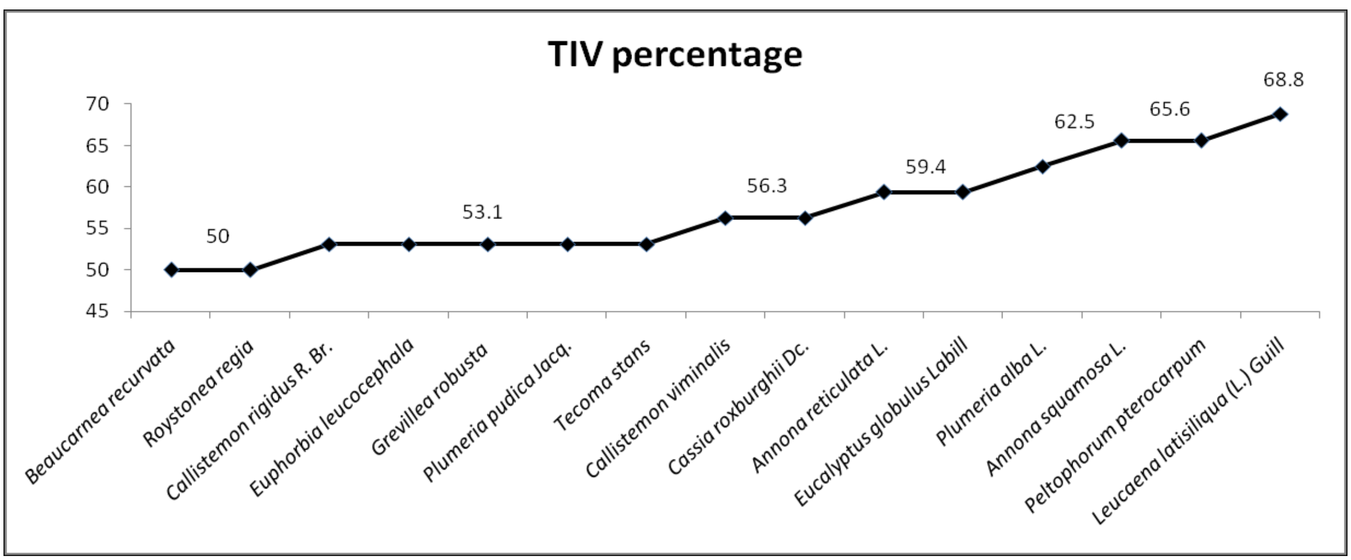

Fig. 5: TIV index non-native tree species in NEERI campus urban forest, Nagpur, Maharashtra, India

Table 5: TIV of trees in CSIR-NEERI urban campus forests

S. No.	*Scientific name*	*Family*	*M*	*A*	*E*	*O*	*TIV*	*TIV percentage*
1.	*Acacia nilotica* (L.) Del.	Mimosaceae	5	6	5	7	23	71.9
2.	*Aegle marmelos* (L). Corr.	Rutaceae	4	5	5	6	20	62.5
3.	*Ailanthus excels* Roxb.	Simaroubiaceae	4	4	4	7	19	59.4
4.	*Albizia lebbeck* (L.) Wild.	Mimosaceae	5	5	5	6	21	65.6
5.	*Albizia procera* (Roxb.) Benth.	Mimosaceae	5	5	5	5	20	62.5
6.	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	5	6	4	5	20	62.5
7.	*Annona reticulate* L.	Annonaceae	6	4	4	5	19	59.4
8.	*Annona squamosa* L.	Annonaceae	6	4	6	5	21	65.6
9.	*Atrocarpus heterophyllus*	Moraceae	6	5	6	6	23	71.9
10.	*Azadirachta indica* A. Juss.	Meliaceae	7	7	7	6	27	84.4
11.	*Bauhinia purpurea* L.	Caesalpiniaceae	4	5	4	5	18	56.3
12.	*Bauhinia racemosa* Lamk.	Caesalpiniaceae	5	7	6	5	23	71.9
13.	*Bauhinia variegate*	Caesalpiniaceae	5	7	6	5	23	71.9
14.	*Beaucarnea recurvata*	Asparagaceae	4	4	4	4	16	50.0
15.	*Bombax ceiba* L.	Malvaceae	4	5	5	7	21	65.6
16.	*Butea monosperma* (Lamk.) Taub.	Fabaceae	6	5	4	7	22	68.8
17.	*Callistemon rigidus* R. Br.	Myrtaceae	4	5	4	4	17	53.1
18.	*Callistemon viminalis*	Myrtaceae	4	6	4	4	18	56.3
19.	*Carica papaya* L.	Caricaceae	7	5	7	5	24	75.0
20.	*Carissa carandas*	Apocynaceae	4	3	6	6	19	59.4
21.	*Cassia fistula* L.	Caesalpiniaceae	6	6	4	6	22	68.8
22.	*Cassia roxburghii* Dc.	Caesalpiniaceae	4	6	4	4	18	56.3
23.	*Cassia siamea* Lamk.	Caesalpiniaceae	4	6	4	6	20	62.5
24.	*Casuarina equisetifolia*	Casuarinaceae	4	4	4	6	18	56.3
25.	*Citrus aurantifolia* (Christm.)	Rutaceae	7	5	7	6	25	78.1
26.	*Cocos nucifera*	Arecaceae	6	4	6	6	22	68.8
27.	*Dalbergia sissoo* Roxb.	Fabaceae	5	6	5	6	22	68.8
28.	*Delonix regia* (Boj. ex. Hook) Raf.	Caesalpiniaceae	5	7	5	6	23	71.9
29.	*Eucalyptus globules* Labill	Myrtaceae	6	4	4	5	19	59.4
30.	*Euphorbia leucocephala*	Euphorbiaceae	4	5	4	4	17	53.1
31.	*Ficus racemosa* L.	Moraceae	6	5	4	5	20	62.5
32.	*Ficus religiosa* L.	Moraceae	5	5	4	5	19	59.4
33.	*Grevillea robusta*	Proteaceae	4	5	4	4	17	53.1
34.	*Holoptelea integrifolia*	Ulmaceae	4	4	4	5	17	53.1
35.	*Lagascea mollis* Cav.	Asteraceae	4	4	4	5	17	53.1
36.	*Lagerstroemia parviflora* Roxb.	Lynthraceae	4	5	4	5	18	56.3
37.	*Lagerstroemia speciosa*	Lynthraceae	6	6	5	6	23	71.9
38.	*Lawsonia inermis* L.	Lynthraceae	6	4	4	5	19	59.4
39.	*Leucaena latisiliqua* (L.) Guill	Mimosaceae	5	6	5	6	22	68.8
40.	*Mangifera indica* L.	Anacardiaceae	7	7	7	7	28	87.5
41.	*Manilkara zapota* (L.) P. Van Royen	Sapotaceae	6	4	6	6	22	68.8
42.	*Mimusops elengi*	Sapotaceae	7	5	6	7	25	78.1
43.	*Mitragyna parvifolia*	Rubiaceae	5	5	4	5	19	59.4
44.	*Moringa oleifera* Lam.	Moringaceae	7	6	7	6	26	81.3

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45.	*Morus indica*	Moraceae	6	5	7	7	25	78.1
46.	*Murraya koenigii* (L). Spreng.	Rutaceae	7	5	5	6	23	71.9
47.	*Murraya paniculata* (L). Jack.	Rutaceae	5	4	4	5	18	56.3
48.	*Musa paradisiacal* L.	Musaceae	7	5	7	6	25	78.1
49.	*Nyctanthes arbortristis* L.	Oleaceae	4	5	4	6	19	59.4
50.	*Peltophorum pterocarpum*	Fabaceae	5	7	5	4	21	65.6
51.	*Phoenix sylvestris* L. Roxb.	Arecaceae	4	4	4	5	17	53.1
52.	*Phyllanthus emblica* L.	Euphorbiaceae	7	6	7	5	25	78.1
53.	*Pithecellobium dulce* (Roxb.) Benth.	Mimosaceae	6	6	7	6	25	78.1
54.	*Plumeria alba* L.	Apocynaceae	5	6	5	4	20	62.5
55.	*Plumeria pudica* Jacq.	Apocynaceae	4	5	4	4	17	53.1
56.	*Polyalthia longifolia*	Annonaceae	5	5	5	5	20	62.5
57.	*Pongamia pinnata* (L.) Pierre.	Fabaceae	6	5	4	7	22	68.8
58.	*Prosopis juliflora* (Sw.) Dc. Prodr.	Fabaceae (Mimmocidae)	4	4	4	7	19	59.4
59.	*Psidium guajava* L.	Myrtaceae	7	4	7	6	24	75.0
60.	*Pterospermum acerifolium*	Steruliaceae	4	5	4	6	19	59.4
61.	*Punica granatum* L.	Punicaceae	7	6	7	6	26	81.3
62.	*Ricinus communis* L.	Euphorbiaceae	6	4	4	6	20	62.5
63.	*Roystonea regia*	Arecaceae	4	4	4	4	16	50.0
64.	*Santalum album* L.	Santalaceae	6	4	4	7	21	65.6
65.	*Spondias pinnata*	Anacardiaceae	5	4	5	7	21	65.6
66.	*Syzygium cumini* (L.) Skeels	Myrtaceae	7	6	7	6	26	81.3
67.	*Tamarindus indica* L.	Caesalpiniaceae	7	6	7	7	27	84.4
68.	*Tecoma stans*	Bignoniaceae	4	5	4	4	17	53.1
69.	*Tecomella undulata* (Sm)	Bignoniaceae	4	5	4	6	19	59.4
70.	*Tectona grandis* L.	Verbnaceae	7	6	5	6	24	75.0
71.	*Terminalia catappa* L.	Combretaceae	2	7	6	6	21	65.6
72.	*Thevetia peruviana* (Pers.) K.	Apocynaceae	4	5	4	5	18	56.3
73.	*Ziziphus mauritiana* Lamk.	Rhamnaceae	7	6	7	7	27	84.4
74.	*Ziziphus nummularia* (Burm. F.) Wt.	Rhamnaceae	7	5	5	7	24	75.0

M = Medicinal value; A = Aesthetic value; E = Edible value; O = Other values

fodder value are relatively high, making species fall under high TIV ranking plants (84.4%).

Overall non-native species is having a small range of the TIV values 50–68.8%, which shows lesser importance of tree which are non-native and alien in origin. Some studies in India showed that with the increase in exotic plant population, native bird diversity in Delhi city declined. Bangalore city also faces a similar scenario, where 80% of the trees in city parks are exotic in nature (Nagendra *et al*., 2014). For instance, if non-native species would occupy significant urban green spaces of cities, the traditional knowledge related to native species is going to perish with time. If people are unaware of the importance of native plants, they may not be able to conserve and protect them (McKinney, 2006; Dearborn and Kark, 2010; Moro and Castro, 2015).

Importance of CSIR-NEERI Urban Forest

Urban land use severely affects biodiversity patterns, and cities are important drivers of climate change due to the large emission of greenhouse gases. As urban forests are part of natural systems, *in situ* conservation plays a significant role (Nautiyal, 2010). Many Educational and research institutions in India have green spaces, and the large area could contribute to conserving biodiversity with minimal effort (Nautiyal, 2011). CSIR-NEERI is one of the Institutions in the field of environmental engineering, having a campus of 43 hectares with rich and diverse plant species having high medicinal and economic values (Plates 1 and 2). Availability of the favorable growth factors and lesser interferences from colony residents and workers has led to the constant increase in a number of the diverse plant species from the year 2007-08 to 2014-15 and is still on a steady increase.

Practical Approaches of the Study

Urban trees contribute valuable provisioning ecosystem services *viz*., clean air, buffer microclimatic variations, and lower noise levels; regulate and filter water flow (Boland and Hunhammar, 1999; Chiesura, 2004). Quantifying the role of

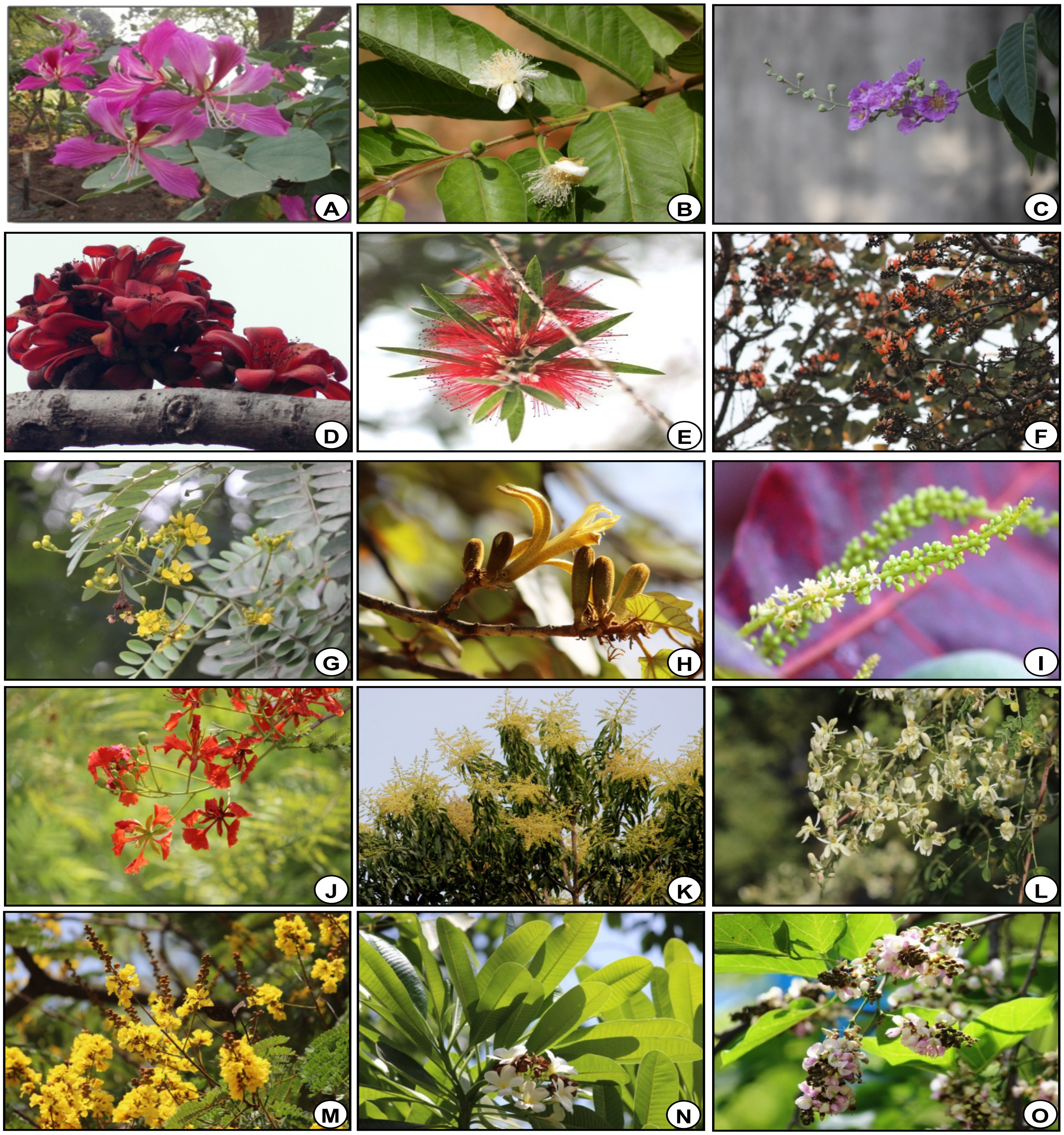

Plate 1: Diversity of Trees in NEERI Urban Forests, Nagpur, India: A. *Bauhnia varigata* (Kachnar); B. *Psidium guayava* (common guava); C. *Ligerstromia speciosa* (Jarul); D. *Bombax ceiba* (Semal); E. *Callistmon viminalis* (Bottle brush); F. *Butea monosperma* (Palash); G. *Cassia samea* (Kasod); H. *Pterospermum acerifolia* (Kanak champa); I. *Terminalia cattapa* (Desi badam); J. *Delonix regia* (Gulmohar); K. *Mangifera indica* (Mango); L. *Moringa olerifera* (Drumstick); M. *Peltophorum pterocarpum* (Copperpod); N. *Plumeria alba* (Fragpani); O. *Pongamia pinnata* (Karanj)

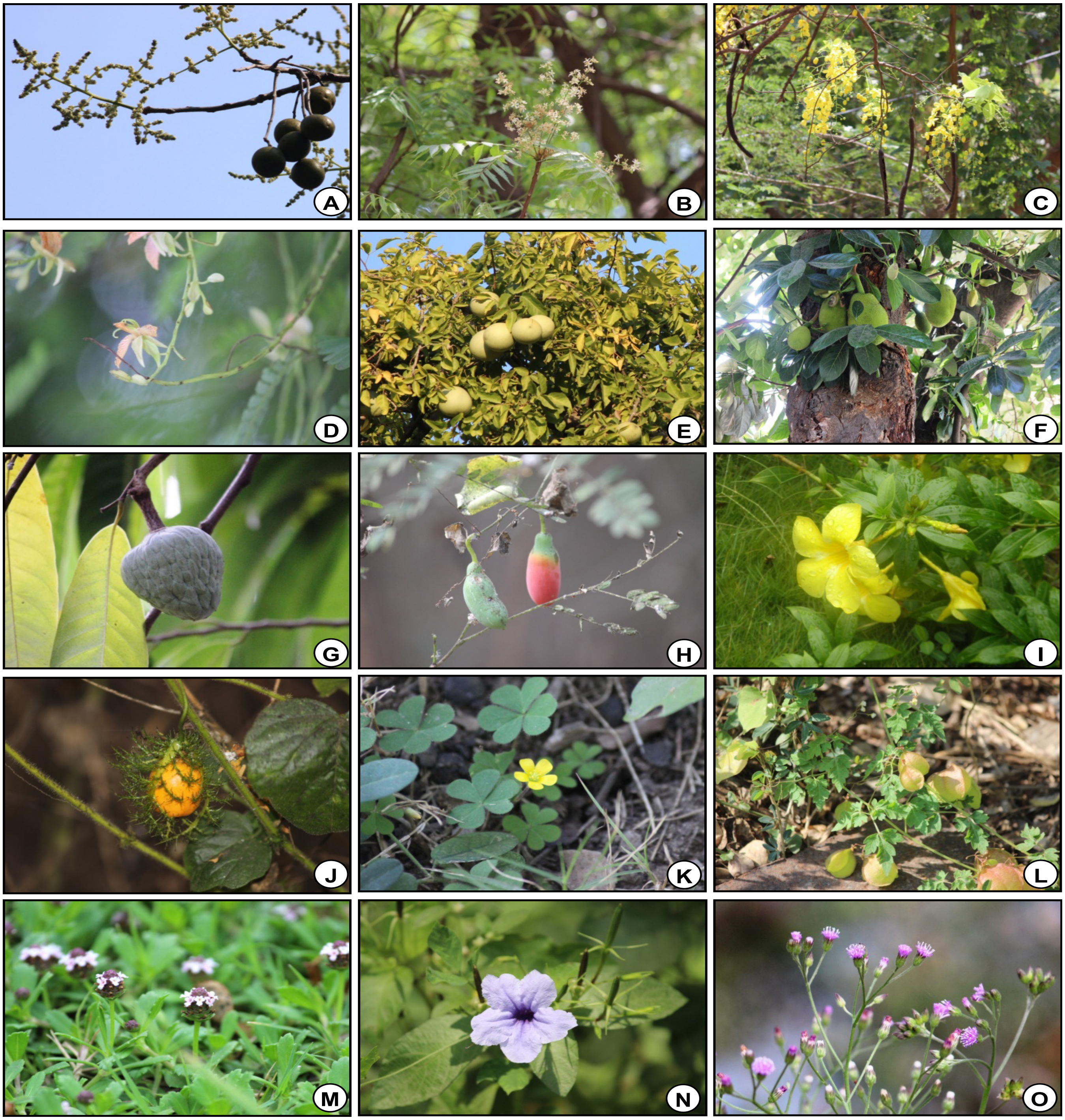

Plate 2: Diversity of Medicinal plant and Herb species in NEERI Urban Forests, Nagpur, India. A. *Spondias pinnata* (Ambada); B. *Azardirachta indica* (Neem); C. *Cassia fistula* (Amaltas); D. *Tamarindus indica* (Imli); E. *Aegle marmelous* (Bel); F. *Artocarpous heterophyllus* (Jackfruit); G. *Annona reticulate* (Ramphal); H. *Coccinia indica* (Kundru); I. *Allamanda cathartica* L. (Allamanda); J. *Passiflora foetida* (Passion flower); K. *Oxalis corniculta* (Amrul); L. *Cardiospermum halicacabum* (Baloon plant); M. *Phyla nodiflora* L. (Frog fruit); N. *Ruellia tuberosa* L. (Minnieroot); O. *Vernonia cineria* (Little ironweed)

urban trees in terms of importance would help the upcoming researcher, academician, urban planner, and stakeholders in a number of ways. It could be used in the selection and planting of tree species in greenbelt, ecological corridors, aesthetics plantations. It is also useful in decision making for a planner for the development of urban infrastructures. For example, in a city for construction of the proposed flyover, a wise selection of location could be made if TIV value is considered, resulting in a lower rate of felling of higher TIV valued trees. TIV could be Useful in replantation and regeneration of degraded patches of vegetation in urban areas. United Nations (UN), through sustainable development goals (SDG), is trying to make all cities socially inclusive, economically productive, environmentally sustainable, secure, and resilient to climate change. Urban SDG targets ensure safe air and water quality for all; integrate reductions in greenhouse gas emissions, efficient land and resource use, and climate and disaster resilience into investments and standards. The above goals cannot be achieved without increasing and managing urban green spaces. Thus, there is an urgent need to describe and understand the benefits of urban forests and green ecosystems, integrate the value of ecosystem services into the simulation of the urban system. Developed TIV index would positively help in the planning and management of the urban green spaces. This approach can be applied and used widely to conservation, management, and arrest the exploitation of existing forest patches. However, there are some limitations of the index, such as restricted criteria and lacks details on endemism, rare, endangered, and threatened (RET) species and International Union for Conservation of Nature (IUCN) red list species.

Conclusion

In the vague of rapid urbanization, urban planners and policymakers required to know how natural resources can be strategically developed and managed sustainably to meet the needs of the urban population. This includes understanding and documenting urban green spaces, what has been lost in the last few decades, what can be restored, and how? In Indian cities, only a few large spaces with green cover are left because of the lesser availability of land, improper land use, and excessive development of infrastructure. The findings of the study have positively indicated the increase in plant diversity from 2007-08 to 2014-15 in the campus of CSIR-NEERI. The abundance of native species also suggests that the NEERI campus offered a calm and suitable microclimatic environment for native species to flourish. Furthermore, TIV would act multifaceted tool for knowing the importance of trees in urbanscape. The overall study stresses the importance of urban forest and the role of academic institutions in their better management. Inside the concrete environment, these green spaces act as islands and can be a great refuge for plants and animals. Thus urban forest needs to be integrated and emphasized more because no city can be a smart city unless it has natural spaces to enhance livability.

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