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STRUCTURAL ALTERATION IN STANDING VEGETATION, SEED BANK AND SOIL FERTILITY IN THE VICINITY OF BRICK KILN INDUSTRY IN THE DRY TROPICAL NATIONAL CAPITAL REGION OF DELHI, INDIA

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ABSTRACT

Dry tropical urban ecosystems are fragile and extremely dynamic because of anthropogenic disturbances including industrialization, automation, fast population growth and distance from metropolitan centers. The brick construction industry is a thriving business that rapidly degrades the environment and threatens the regeneration capacity in Indian dry tropics. The duration of exposure and distance from the brick kiln was investigated seasonally in this study for their effects on nearby soils, seed bank (SB) and standing vegetation (SV) at Meerut. In SV, a total of 101 angiospermic plant species (63.4% alien, 40.6% American origin and 84.2% weedy herbs) were recorded over 34 families across various seasons. More than 60.4% of these species belonged to eight dominant families, with Fabaceae leading the pack, followed by Poaceae, Asteraceae, Amaranthaceae, Malvaceae, Solanaceae, and Euphorbiaceae. In contrast, a total of 29 SB flora (2 unidentified, 63% alien, 33.3% American origin and 86.2% herbs) were distributed over 16 angiospermic families, top seven most dominant with Poaceae, followed by Malvaceae, Fabaceae, Asteraceae, Amaranthaceae, Solanaceae and Euphorbiaceae. The working brick kiln (WBK) subsite, which was exposed to industrial activity, displayed higher mean aboveground biomass in the rainy season followed by winter and summer seasons and lower mean soil organic C, total N, available P, pH and moisture content. Whereas, these soil parameters were relatively rich at the agricultural land subsite (AGL) in all three seasons. which has also experienced anthropogenically less disturbance. This study showed that long-term brick kiln industrial activity had an impact on the properties of soil, as well as the structure of plant biomass and the diversity of aboveground and belowground species. This structural change in a standing vegetation and seed bank raises questions about the anthropo-potential ecosystems for adaptability in the dry tropics of India.

Keywords: Brick kiln, urban, dry tropics, species diversity, regeneration potential, soil resources.

Introduction

Anthropogenic disturbance has significant environmental and ecological consequences, including changes in atmospheric gas composition, biodiversity loss, ecosystem functions and services (Chazdon *et al.,* 2009) as well as a threat to forest regeneration capability (Esquivel *et al.*, 2008). The vegetation is removed to make space for farmlands, villages and human settlements as a result of industrialization and automation (FAO and UNEP, 2020; Neelo *et al.,* 2013). Anthropogenic factors, such as excessive use of fossil fuels, forest loss for industrialization, and rapid population increase in cities, are the primary causes of these degradations (Mukherjee *et al.,* 2016). According to previous projections, India will be 50% urban by 2050 (UN-Habitat, 2017). The demand for building bricks rises together with the global population, making the brick kiln industry a thriving business (Skinder *et al.,* 2014) that helps to meet population demands and rapid environmental damage. As a result, sections of the city near the brick kiln clusters are severely polluted in terms of air, water, and soil (Saha *et al.,* 2021). Most of the brick production (90%) is associated with South Asia (Tusher *et al.,* 2018; Weyant *et al.,* 2014), and used as building materials. Topsoil removal is a typical way of obtaining the clay required for brick manufacture in many developing nations (Rahman *et al.,* 2015). The evolution of this ancient industry of the world is recorded around 6,000-7,000 BC (Momcilovic-Petronijevic *et al.,* 2018) whereas, the Indian subcontinent has a nearly 4000-year history of creating burnt clay bricks. Several brick structures, including granaries, sewer systems, and other historic municipal infrastructure, have been excavated from the archaeological sites of the Indus Valley civilization.

As a result of this rapid yet unconstrained development, emissions from various sources are steadily growing, causing environmental distress (Elampari *et al.,* 2010; Hassan *et al.,* 2012). In the Meerut division (in six districts), there are more than 800 brick kilns in use. Although most brick kilns use a lump of low-quality coal or other solid waste material, different gaseous and particle pollutants emitted by brick kilns harm the environment (Bhanarkar *et al.,* 2002), nearby flora (Skinder *et al.,* 2014), biodiversity (Gupta and Narayan, 2010) and air (Wahid *et al.,* 2014). In comparison to the control area, the relative densities of various herbs decrease near the brick kiln (cf Fatima, 2011; Kundu and Sarkar, 1996). As a result, without causing physical harm to the plant, it may change plant development and productivity (Kumar and Thambavani, 2012). As a result, air pollution from urban and industrial regions has become a significant danger to agricultural production in areas next to these areas (Agrawal *et al.,* 2003; Sandelius *et al.,* 1995). As a result, the restoration potential of the ecosystem is hindered, especially in areas where seed dispersal from nearby seed sources is limited (Funk *et al.,* 2008).

According to research, dynamically reproducing plants and grass species dominate seed banks in urban settings (Albrecht *et al.,* 2011; Cui *et al.,* 2013). Soil seed banks serve as a record of previous vegetation and a forecast of future vegetation composition and structure in a given location (Fisher *et al.,* 2009). Weed seed banks are the principal source of weeds in cultivated areas, and they are a better predictor of management impacts in the medium and long term than aboveground vegetation (Jose-Maria and Sans, 2011). Although understory plant species are more sensitive to changes in soil chemical and physical characteristics than tree species occurring on the same sites, soil properties may have a greater impact on understory plant regeneration following disturbance than tree regeneration (Pinno and Errington, 2016). The relative importance of these multiple regeneration pathways varies by species and is expected to be impacted by the intensity of disturbance, stand age, and soil conditions (Pinno and Errington, 2016).

Ecological studies are lacking on the species diversity, impact on soil characteristics, and biomass structure of plant communities in and around the brick kiln. This study aimed to investigate the spatio-temporal dynamics of plant communities above and below-ground surrounding brick kilns (standing vegetation and soil seed bank flora) as a function of disturbance intensity, plant above-ground biomass, and disturbance relationships with soil and site condition.

Materials and Methods

Study area

As India's urban population is growing, bricks will become one of the most essential building materials. Meerut is situated in the western part of Uttar Pradesh (between 28°57' and 29°02' N latitude and 77°40' and 77°45' E longitude) in the upper Doab of the Ganges and Jamuna rivers, at an elevation of 237.4 m above the mean sea level. More than 800 brick kilns are in operation in the six districts of the Meerut division. Majority of them use a lump of low-quality coal or other solid waste materials, resulting in the production of SOx, NOx, COx, and PM, as well as a variety of other organic pollutants. These brick kilns discharge harmful substances that impair the soil, vegetation, amenity and legacy of the area. A typical brick kiln in Indo-Gangetic plains requires 12,000 tonnes of soil and 600 tonnes of coal every year to produce roughly 4 million bricks (personal communication with brick operator). More than hundreds of people have been hired to actively operate the brick kiln industry. Among the employed laborers are local residents and migrants from Bihar and Bengal. Two permanent subsites working brick kiln (WBK) and agricultural land (AGL) at the brick kiln site were chosen for the current study due to known variable disturbance and intensity. A hectare of land was set aside in each of the subsites for the current investigation. Locals claim that this brick kiln has been producing bricks for at least four to five decades and is still working. WBK subsite had hard, compact and deeper soils with an uneven layer of brick dust and fractured brick fragments on the surface. The AGL subsite is located approximately 100 meters radial (except north) from BK where seasonal crops (wheat and paddy) are grown alternately. However, April-June is the busiest month for brick production. As this industry continues to contaminate the air, soil, land, and groundwater in Meerut, the expanding trend of brick manufacture exposes the unseen influence on the environment. The climate of the research area is semi-arid, with high dryness, a scorching hot summer (44.5°C), and a frigid winter (2.5°C). The average maximum and lowest temperatures were 38.18°C in May and 7.75°C in January, respectively. The relative humidity ranged from 9 to 100 % daily. The annual mean rainfall (2016-20) was 784.8 mm, with the majority of it falling during the monsoon season (Jul-Oct).

Standing vegetation plant sampling

The floristic study of the brick kiln site was conducted every month from February 2019 to October 2020. Gaur (1999); Sharma (1980) and the flora of Duthie (1960) were used to identify plant species. In all three seasons, 10 random quadrats (each measuring 50cm × 50cm) were laid at the brick kiln site for phytosociological study of aboveground vegetation. The collected plant species were identified and dried for 48 hours at 80°C before being weighed to determine their aboveground biomass. The relative important value index (RIVI) of a species was plotted against the species sequence to generate dominance-diversity curves.

Soil seed bank sampling

The soil seed bank samples were collected in the summer (March) and winter (October) of 2019 when plants had already grown and distributed their seeds. In each season, 10 soil samples (each measuring 25cm×25cm) were collected, 5 from the top layer (0-5 cm) and 5 from the bottom layer (5-10 cm). Under a shade house with a transparent roof and fiber walls, all soil samples were homogenized in earthen pots (size 29 cm top diameter, 25 cm bottom diameter, and 9 cm depth). A total of 20 soil samples were collected, air-dried, and sieved using a 2 mm sieve to remove vegetal fragments, stones and gravel throughout this study. These earthen pots were watered regularly for eleven months to explore the late seedling emergent too (Thompson and Grime, 1979). Before being removed, the seedlings were allowed to develop to the point where they could be identified. The dominance-diversity curves of seed bank flora were prepared by plotting the relative density (RD) of species against the species sequence.

Statistical analysis

Similarity Coefficient

Sorenson similarity coefficient (Southwood, 1978) was estimated according to the following formula to calculate the similarity among the standing vegetation and soil seed bank at the brick kiln site.

$$SC = \frac{2\,jN}{2N + bN}$$

aN = total number of species in a vegetation ‘a’

bN = total number of species in a vegetation ‘b’

jN = the number of common species in both vegetation.

Species diversity

In standing vegetation, dominance-diversity curves were created by plotting species relative importance value index (RIVI) against species sequence (highest to lowest RIVI), whereas, species relative density (RD) was plotted against species sequence (highest to lowest RD) in soil seed bank (Whittaker, 1972).

Using seven diversity indices (D_1-D_7), β diversity of each research site across seasons was estimated. S = Total number of species in the community, N = total sum of important attributes of all species, n = number of plants of each species, Pi = Proportion S (species in the family) made up of the i^{th} species, N_{max} = importance attributes of the most important species, ln = Natural logarithm, H'= Shannon-Weaver diversity index, D = Species biodiversity (higher means more diverse) was calculated by using relative density (RD) of the seed bank and RIVI of standing vegetation.

Species richness indices

D_1, Species count (Number of species/area in the present study the no. of species that occurred in quadrants sampled).

D_2, Margalef index (Clifford and Stephenson, 1975)

$$D_2 = \frac{S - 1}{\ln N}$$

D_3, Menhinick index (Whittaker, 1977)

$$D_3 = \frac{S}{\sqrt{N}}$$

Information statistic indices

D_4, Shannon-Weaver diversity index H\` (1963)

$$D_4 = \sum_{i=1}^{s} pi \ln pi$$

D_5, Evenness (Pielou, 1966)

$$D_5 = \frac{D_4}{\ln S}$$

D_6, Berger-Parker index (1970)

$$D_6 = \frac{N_{max}}{N}$$

D_7, Simpson’s diversity index (1949)

$$D_7 = \Sigma\, pi^{2}$$

β diversity

Diversity was calculated by dividing the total number of species at a study site by the average number of species per sample (Whittaker, 1972).

Soil analysis

Six random surface soil samples (0-10 cm) were periodically taken from the brick kiln site (three from each subsite- WBK and AGL) during all three seasons *viz.* winter, summer and rainy. These soil samples were dried in open air and sieved (2 mm). The soil moisture content was determined on a dry weight basis. Soil pH, EC and salinity were determined by a Biogen digital ‘water & soil analysis kit’- Cat No. BGS-297 and product series no. 102299. Piper's method, (1944) was used to calculate the organic carbon (Walkley and Black method) and total nitrogen (microkjeldahl's method) of each soil sample. Exchangeable Na, K and Ca were extracted with 1 M Ammonium acetate solution at pH 7 and concentrations determined by flame photometer by Allen *et al.* (1986). Available phosphorus was estimated, according to Olsen *et al.* (1954).

Results

Floristic composition of SV and SB

A total of 101 angiospermic plant species distributed over 34 families were recorded in standing vegetation across three seasons at the brick kiln study site. The top seven dominant families accounted for 71.8% in winter, 74.4% in summer, and 55% in the rainy season respectively. Fabaceae with 14 species was the largest family followed by Poaceae (13), Asteraceae (10), Amaranthaceae (9), Malvaceae (7), Solanaceae (5), and Euphorbiaceae (3) together accounting for 60.4% of the total recorded flora. The number of species was highest in the rainy season (60) and lower in the winter and summer seasons (39) each (Table 1).

Table 1 : Phytosociological characteristics in different seasons at Brick-kiln site in Indian dry tropics. D: Mean density (no. of individuals m^{-2}), B: Mean Biomass (gm^{-2}) and above-ground flora having > 70% RIVI.

Plant species	Winter			Summer			Rainy		
	D	**B**	**RIVI**	**D**	**B**	**RIVI**	**D**	**B**	**RIVI**
Achyranthes aspera L.	7	32.5	10.6	3	12.7	3.3	6	28.6	4.7
Alternanthera philoxeroides (Mart.) Griseb.	10	2.4	3.02	-	-	-	-	-	-
Alternanthera pungens Kunth	-	-	-	3	12.7	3.3	2	9.8	1.6
Alternanthera sessilis (L.) R.Br. ex DC.	-	-	-	8	2.4	3.3	1	1.4	0.9
Anisomeles indica (L.) Kuntze	-	-	-	2	24.4	2.4	3	42.6	2.7
Boerhavia diffusa L.	1	6.7	0.5	4	18.8	4.6	2	30.8	1.4
Cannabis sativa L.	11	8	6.3	3	17.6	3.0	1	58.2	1.1
Chenopodium album L.	13	4.5	5.1	2	17.3	3.5	-	-	-
Cleome viscosa L.	-	-	-	2	10.5	2.2	2	22.2	2.1
Croton bonplandianus Baill.	4	14.1	2.8	10	7.3	8.3	1	3.3	0.6
Cynodon dactylon (L.) Pers.	29	3.2	9.4	14	5.7	8.3	8	7.0	2.9
Cyperus compressus L	-	-	-			-	39	1.6	7.3
Dactyloctenium aegyptium (L.) Willd.	2	2.3	0.6	1	13.9	1.0	36	7.6	11.0
Dichanthium annulatum (Forssk.) Stapf	1	14.7	1.1	4	11.1	2.9	-	-	-
Dicliptera paniculata (Forssk.) I. Darbysh.	-	-	-	-	-	-	3	23.0	2.0
Digitaria sanguinalis (L.) Scop.	-	-	-	-	-	-	48	3.5	10.4
Echinochloa colonum (L.) Link	-	-	-	-	-	-	3	7.0	1.3
Eleusine indica (L.) Gaertn.	-	-	-	3	2	1.8	10	7.6	3.0
Erigeron bonariensis L.	-	-	-	1	50.2	2.9	-	-	-
Euphorbia hirta L.	10	0.7	2.3	11	2.1	6.1	8	1.6	2.3
Gamochaeta pensylvanica (Willd.) Cabrera	8	1.4	2.7	-	-	-	-	-	-
Launaea procumbens (Roxb.) Ramayya & Rajagopal	-	-	-	6	2.8	2.8	-	-	-
Mesosphaerum suaveolens (L.) Kuntze	-	-	-	1	75.5	3.7	2	13.5	1.6
Oxalis corniculata L.	80	0.9	13.9	-	-	-	-	-	-
Parthenium hysterophorus L.	48	1.0	10.1	7	5.0	5.2	5	13.6	2.9
Rumex dentatus L.	6	7.1	3.0	-	-	-	-	-	-
Scoparia dulcis L.	-	-	-	2	23.8	2.7			
Senna occidentalis (L.) Link.	1	0.7	0.4	2	15.9	3.4	2	58.9	2.3
Sida acuta Burm.f.	2	1.5	1.6	2	8.7	2.3	2	13.1	1.9
Taraxacum mongolicum Hand.-Mazz.	2	30.7	3.3						
Tribulus terrestris L.	-	-	-	-	-	-	2	36.7	1.8
Urochloa ramosa (L.) T.Q. Nguyen	-	-	-	-	-	-	14	3.9	4.1
Urena lobata L.	1	16.1	0.9	1	18.4	1.4	3	74.6	4.0
Others (*)			22.5 (18)			21.7 (22)			26.2 (23)
Total number of species			39			39			60

*Value in the parenthesis ( ) indicates the number of species.

On the other hand, a total of 29 angiospermic flora (27 identified and 2 unidentified) were recorded in soil seed bank (SSB and WSB) which spread over 16 families. The top seven most dominant families were Poaceae (4), Malvaceae (3), Fabaceae (2), Asteraceae (2), Amaranthaceae (2), Solanaceae (2), and Euphorbiaceae (2) which accounted for 17 species (58.62%) of total SB flora (29) in our study (Table 2). A much lower number of flora were recorded in SB vegetation (29) compared to that in standing vegetation (101). The number of flora in standing vegetation in all three seasons (39-60) was generally more than three times the no. of flora in their corresponding SBs (11-21). It was noteworthy that all dominant angiospermic families were common to both SV and SB vegetation. *Phalaris minor* and *Melia azedarach*, these two plant species that were only reported in SB flora.

Table 2 : Mean density (no. of individuals m^{-2}), in summer and winter seed bank at Brick-kiln site in dry tropical tropics in Meerut, India.

S.No.	Plant name	Family	SSB	WSB
1.	*Achyranthes aspera* L.	Amaranthaceae	11	-
2.	*Bonnaya ciliata* (Colsm.) Spreng	Linderniaceae	10	-
3.	*Cannabis sativa* L.	Cannabaceae	-	3
4.	*Chenopodium album* L.	Amaranthaceae	-	5
5.	*Corchorus olitorius* L.	Malvaceae	2	-
6.	*Croton bonplandianus* Baill.	Euphorbiaceae	6	-
7.	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	18	-
8.	*Digitaria sanguinalis* (L.) Scop.	Poaceae	75	109
9.	*Eucalyptus globulus* Labill.	Myrtaceae	18	-
10	*Euphorbia hirta* L.	Euphorbiaceae	72	2
11	*Gamochaeta pensylvanica* (Willd.) Cabrera	Asteraceae	-	30
12	*Juncus bufonius* L.	Juncaceae	-	2
13	*Lysimachia arvensis* (L.) U.Manns & Anderb.	Primulaceae	2	2
14	*Melia azedarach* L.	Meliaceae	3	-
15	*Melilotus indicus* (L.) All.	Fabaceae	-	2
16	*Nicotiana plumbaginifolia* Viv	Solanaceae	19	-
17	*Oldenlandia corymbosa* L.	Rubiaceae	19	-
18	*Oxalis corniculata* L.	Oxalidaceae	13	-
19	*Parthenium hysterophorus* L.	Asteraceae	19	-
20	*Phalaris minor* Retz.	Poaceae	-	3
21	*Phyllanthus amarus* Schumach. & Thonn.	Phyllanthaceae	-	2
22	*Senna occidentalis* (L.) Link.	Fabaceae	5	-
23	*Sida acuta* Burm.f.	Malvaceae	-	5
24	*Sida rhombifolia* L.	Malvaceae	-	2
25	*Solanum villosum* Mill.	Solanaceae	-	2
26	*Torenia crustacea* (L.) Cham. & Schltdl.	Linderniaceae	90	-
27	*Urochloa ramosa* (L.) T.Q. Nguyen	Poaceae	754	-
28	UN 1	-	5	-
29	UN 2	-	-	2
	Seed density of identified species		1137 (19)	165(11)
	Seed density of unidentified species		5 (1)	2 (1)
	Total Seed density (seeds m^{-2})		1144 (21)	167(11)

*Value in the parenthesis ( ) indicates the number of species.

Species dominance in standing vegetation and soil seed banks in different seasons

In standing vegetation at the BK site, none of the plant species were lying under the top five dominants in all three seasons. *Parthenium hysterophorus* and *Cynodon dactylon* were more evident in the summer and winter seasons, but *Achyranthes aspera* was more pronounced in the winter and rainy seasons. *Oxalis corniculata* was the most abundant in winter, followed by *Achyranthes aspera, Parthenium hysterophorus, Cynodon dactylon,* and *Cannabis sativa*, which together accounted for 50.3 % of the total biomass of the season. However, *Cynodon dactylon* was the most dominant in the summer season followed by *Croton bonplandianus, Euphorbia hirta, Parthenium hysterophorus* and *Boerhavia diffusa,* which together accounted for 32 % of aboveground plant biomass (Table 1). During dry seasons, *Parthenium hysterophorus,* an exotic invasive weed, occupied sub-dominant status (Winter and Summer). During the rainy season, grasses competed for top supremacy with *Dactyloctenium aegyptium* and *Digitaria sanguinalis* leading the way, followed by *Cyperus compressus, Achyranthes aspera* and *Urochloa ramosa*. During the rainy season, the top five most prevalent species collectively accounted for 37.6% of total aboveground biomass. The RIVI and biomass data of standing vegetation species considered at the BK site in different seasons influenced the dominance order of a species.

The dominance order of the soil seed banks (summer and winter) species varied with the relative density (RD) at the BK site. These two seed banks were dominated by annual native grasses *Digitaria sanguinalis* and *Urochloa ramosa* at the Brick kiln site. In the winter soil seed bank, *Digitaria sanguinalis* was the top dominant followed by the alien species *Gamochaeta pensylvanica*, *Chenopodium album,* and *Sida acuta,* which together accounted for 90.3% of the total relative density of the site (Table 2). *Digitaria sanguinalis* dominance was more pronounced in Winter (alone accounted for 66.1%) than in the summer (alone accounted for 6.6%) seed bank. In SSB, *Urochloa ramosa* was the top dominant followed by *Torenia crustacea,* *Digitaria sanguinalis* and *Euphorbia hirta,* together with sharing 86.6% of the total relative density of the site.

Variation in plant aboveground biomass

Across various seasons, aboveground mean biomass ranged from 244.4 to 544.2 gm^{-2} (Fig.1). The highest community biomass was recorded in the rainy season. The seasonal plant biomass (AGB) of the study site showed this trend: rainy > summer > winter. Maximum biomass allocation to aboveground was recorded in rainy which was almost 2 times higher than in the winter season.

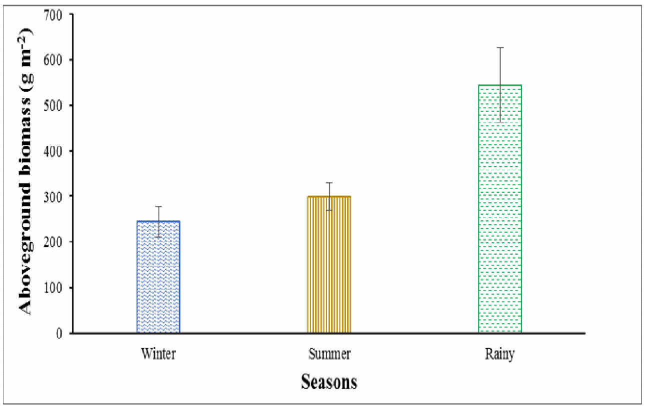


Fig. 1 : Aboveground biomass (mean ± S.E.) in different seasons at Brickkiln site in a dry tropical urban region.

Species nativity and life form analysis

Herbs dominated in both standing vegetation (SV) and seed bank (SB) flora, it represented three times more in SV comparison to SB. Trees were also found in both vegetation types, but the SV tree flora was nearly 5 times that of the SB tree flora. Shrub and climber species were absent in the SB vegetation of the Brick kin site (Table 3).

Table 3 : Life form analysis of plant taxa in standing and soil seed bank flora at Brick-kiln site in a dry tropical region of Meerut, India.

S. No.	Life form	Number of plant species	
		Standing vegetation	Seed Bank
1	Tree	11	2
2	Shrub	3	-
3	Climber	2	-
4	Herb	85	25
5	Unknown (UK)	-	2
	Total number of species	101	29

The recorded angiospermic flora at the BK site, in terms of nativity, came across ten different bio-geographic zones in the present study (Table 4). Exotic plants, from the American continent alone accounted for (40.6% in SV and 33.3% in SB). Only 36.4% of the native species were found in SV and 37% in SB.

Table 4 : Nativity analysis of standing and seed bank flora (identified) at brick kiln site in a dry tropical anthropic region in India.

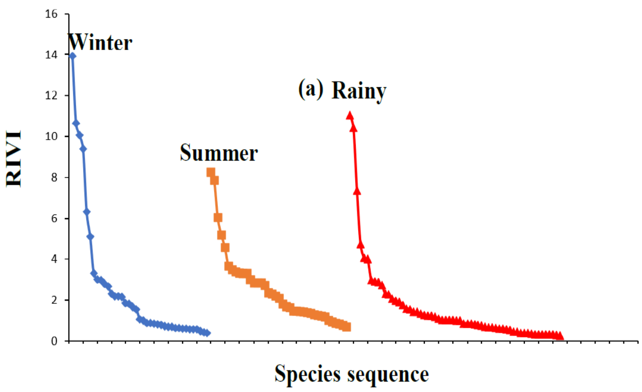
S. No.	Nativity	Standing vegetation	Seed Bank
1	India	37	10
2	Tropical America	27	5
3	South America	10	2
4	Africa	8	1
5	Asia	6	2
6	Europe	6	4
7	North America	4	2
8	Australia	1	1
9	Asia, Africa	1	-
10	Eurasia, Africa	1	-
	Total	**101**	**27**

*India category includes all those plants whose origin is in India as well as in any other country/continent at the same time.

Dominance and diversity structure

D-D curve of SV in different seasons showed a tendency to the geometrical pattern of resource share in the initial segment of the curve and lognormal pattern of resource share toward the lower end, i.e., after five species, indicative of equitable share of resources by tailender species (Fig.2a). The equitable resource among species is more pronounced in summer and rainy season compared to the winter season, where two equally top dominants were *Cynodon dactylon* and *Croton bonplandianus* in summer and *Dactyloctenium aegyptium*, *Digitaria sanguinalis* in the rainy season. In winter top dominant was *Oxalis corniculata* followed by *Achyranthes aspera*, *Parthenium hysterophorus,* and *Cynodon dactylon.*

On the other hand, the seed bank exhibited a geometrical pattern of resources in SSB with a distinct dominant *Urochloa ramosa* in the summer seed bank. It was *Digitaria sanguinalis* that exhibited distinct dominance in the winter seed bank (Fig.2b).



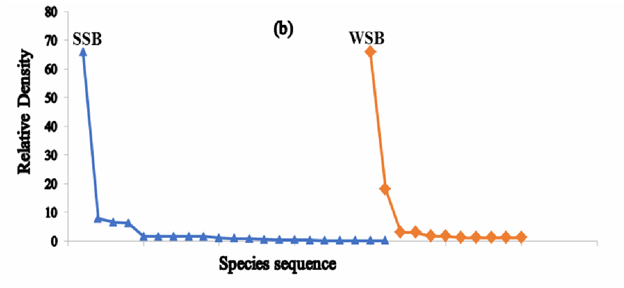


Fig. 2 : Dominance-diversity curve of standing vegetation (a) and seed bank (b) in a dry tropical urban ecosystem in India.

Similarity analysis

The analysis of the similarity of SV and SB at the brick kiln site indicated that no SV in any season had > 50% similarity (Sorenson index > 0.50) with any SB vegetation studied. Standing vegetation and seed bank of the study site also showed varying scales of inter-site SV and SB similarity. A higher similarity (0.37) was recorded between RSV and SSB and a lower similarity (0.13) was recorded between SSV and SSB seasons (Table 5).

Table 5 : Similarity coefficient (Sorenson Index) of standing and seed bank vegetation at brick kiln site in dry tropical urban region of Meerut, India.

S.No.	Seasons	SSB	WSB
1	WSV	0.3	0.32
2	SSV	0.23	0.13
3	RSV	0.37	0.14

Season code:

RSV- Rainy standing vegetation; SSB-Summer seed bank; and WSB-Winter seed bank;

WSV- Winter standing vegetation; SSV- Summer standing vegetation.

Diversity indices

The SV showed higher species diversity than the soil SB flora at the BK site. The seven diversity indices ranked the site diversity (SV and SB) in a different way (Table 6). Margalef index (D_2) and Menhinick (D_3) were found to be maximum in the aboveground flora in comparison to underground vegetation. The information statistic indices (Shannon- D_4 and evenness- D_5) were recorded as the maximum value in standing vegetation (Shannon 3.39; evenness 0.89), and lower in the soil seed bank (Shannon 1.33; evenness 0.49). Dominance measures (Berger Parker- D_6 and Simpson- D_7) showed higher values for SB showing lower diversity. The highest value of dominance concentration (D_7) in SB (0.54) followed by SV (0.5).

Table 6 : Diversity estimates of the Standing vegetation and seed bank at brick kiln site using different diversity indices.

Diversity indices	Standing vegetation	Soil seed bank
D_1 (Species count)	101	29
D_2 (Margalef)	9.78	2.4
D_3 (Menhinick)	4.6	0.74
D_4 (Shannon-index)	3.39	1.33
D_5 (Evenness, Pielou)	0.89	0.49
D_6 (Berger Parker)	0.36	0.66
D_7 (Simpson)	0.05	0.54
β Diversity	4.22	3.9

Soil characteristics

Soil samples were neutral to slightly basic (7.03-7.8) at both the subsites (WBK and AGL) in the Winter and Summer seasons but it varied from slightly acidic to basic (6.7-7.7) in the Rainy season (Table 7). WBK and AGL soils showed higher soil moisture content in the rainy season as compared to the winter and summer seasons. It was lowest (1.39%) at WBK subsite in summer. Soil organic carbon, total N, and available P at AGL subsite were significantly higher than WBK subsite in all three seasons except for the organic carbon and available P in the rainy season. The ranges of exchangeable Na, K and Ca (means of all three seasons) at AGL subsite were significantly higher than WBK subsites. However, the soil C: N ratio and EC were significantly higher at WBK subsite in all three seasons. Salinity was only found in summer and rainy soil samples; it was higher in the summer season than in the rainy season.

Table 7 : Seasonal soil characteristics (Mean ± SE) across two subsites (n=3) at varying distances from working brick kiln (WBK) and agriculture land (AGL).

Soil characteristics	WBK			AGL		
	W	S	R	W	S	R
Moisture content (%)	8.52 ± 0.438	1.39 ± 0.243	15.12 ± 0.248	12.0 ± 0.611	4.39 ± 0.302	18.15 ± 0.303
pH	7.4 ± 0.153	7.03 ± 0.067	6.7 ± 0.384	7.8 ± 0.088	7.7 ± 0.120	7.7 ± 0.033
EC (mS)	0.06 ± 0.003	0.82 ± 0.388	0.16 ± 0.12	0.04 ± 0	0.46 ± 0.165	0.08 ± 0.009
Salinity (ppt)	0	0.4 ± 0.252	0.003 ± 0.003	0	0.17 ± 0.120	0
Phosphorus (mg/g)	0.013 ± 0.002	0.026 ± 0.002	0.022 ± 0.004	0.028 ± 0.004	0.037 ± 0.013	0.015 ± 0.004
Na (mg/g)	0.065 ± 0.026	0.067 ± 0.026	0.063 ± 0.025	0.073 ± 0.001	0.1 ± 0.025	0.066 ± 0.001
K (mg/g)	0.094 ± 0.019	0.096 ± 0.019	0.090 ± 0.018	0.126 ± 0.001	0.168 ± 0.059	0.116 ± 0.001
Ca (mg/g)	0.353 ± 0.056	0.358 ± 0.057	0.351 ± 0.055	0.794 ± 0.029	0.817 ± 0.031	0.784 ± 0.029
Organic Carbon (%)	0.34 ± 0.044	0.43 ± 0.088	0.43 ± 0.120	0.37 ± 0.055	0.63 ± 0.033	0.4 ± 0.1
Total Nitrogen (%)	0.06 ± 0.007	0.09 ± 0.012	0.07 ± 0.007	0.08 ± 0.004	0.17 ± 0.012	0.09 ± 0.007
C: N ratio	6.07 ± 1.26	4.86 ± 0.92	6.94 ± 2.27	2.80 ± 1.05	3.81 ± 0.096	4.67 ± 0.33

Discussion

High population pressure and human intrusion are threatening indigenous plant diversity and fragmenting grazing ecosystems in the dry tropical urban region of Meerut, India. The vegetation is mosaic and largely distinct from that in natural ecosystems because of alterations in resource availability, stress intensity, and disturbance as reported by Gupta and Narayan (2006; 2010; 2011 and Yadav, 2023) for such disturbed ecosystems *viz.* around the brick kiln, in Indian dry tropics. The number of species recorded in the current study was higher than the 87 angiospermic species reported by Gupta and Narayan (2010) at the brick kiln site in the dry tropical region, of Bulandshahr, India. However, the present study also revealed a heavy scale of intrusion by the alien plants into not only standing vegetation (63.6%) but also in seed banks (63%) across the anthropic sites in urban regions in the Indian dry tropics which is likely to alter the standing vegetation floristic structure with a larger abundance of alien flora. Invasive plants are alien species that have the greatest negative impact on biodiversity and ecosystem functioning (Nentwig *et al.,* 2018; Rumlerova *et al.,* 2016 and Vila *et al.,* 2010). Local adaptation of plant traits, particularly those associated with seeds and seedlings, could play a key role in the process of establishment in the new locality (Kudoh *et al.,* 2007; Tognetti *et al.,* 2019). As per the previous study, between 5 and 20% of the alien species are considered to be problematic (Lockwood *et al.,* 2013; Vila *et al.,* 2010) and the impacts of these few are larger and more persistent (McGeoch *et al.,* 2016).

In this study, fourteen plant species are common in the phytosociological study in all three seasons and are mostly aliens of American (7) and African origin (2). Eight plant species (6 aliens and 2 natives) were similar in the seed bank and standing vegetation at the BK site indicating a significant possible role of anthropogenic activities in the urban regions of Indian dry tropics, evinced by the largest proportion of grasses and herbs dominated by exotics, especially of American origin (Agrawal and Narayan, 2017; Yadav and Narayan, 2023 and Yadav, 2023). *Achyranthes aspera, Croton bonplandianus, Euphorbia hirta, Dactyloctenium aegyptium, Parthenium hysterophorus, Senna occidentalis*, *Sida acuta,* and *Sida rhombifolia,* were more evident in all three seasons in standing vegetation as well as in seed banks. Among these, those related to reproduction are repeatedly suggested as important determinants of the success of invasive species (Moravcova *et al.,* 2010; Pysek and Richardson, 2007 and Pysek *et al.,* 2015). Only two herbaceous species are native (*Dactyloctenium aegyptium* and *Sida rhombifolia*) and the other six species are of American alien elements. The relative densities of diverse herbs decline in the vicinity of the brick kiln as compared to control (cf Fatima, 2011; Kundu and Sarkar, 1996). But alien species through successful naturalization may cause homogenization of floristic structures in Indian dry tropical urban environments. BK site has witnessed a close contest among the seasonal weeds for top dominance, indicating ecological opportunities generated here for the arrival and establishment of several species in SV and soil SB (Gupta and Narayan, 2010; Yadav, 2023). This is important for alien species, as it affects their responses to the novel conditions encountered in their new ranges, as well as for native species, by affecting how they respond to the novel conditions created by the alien species (Gioria *et al.,* 2012). Such habitats characterized by persistent disturbance, such as brick dust accumulation over soil and plant surface, and heat released to neighboring areas around brick kilns, appear to become susceptible to invasion by non-native species (Sharma *et al.,* 2005). This is perceptible from the increasing tendency of the exotic invasive weed *Parthenium hysterophorus* to occupy the top dominant status, particularly at BK sites (Gupta and Narayan, 2010; Yadav and Narayan, 2023). Its dominance at the BK site assumed greater prominence in the dry months of summer and winter, as elucidated by the steepness of dominance-diversity curves, particularly in the initial segment of the winter season.

The geometric pattern of resource share at the site is likely due to prevalent environmental stress (Odum, 1985; Yadav, 2023) in both above and below-ground vegetation. The variation of species dominants in terms of RIVI and RD at a site indicated that the species differ in their competitive ability for acquiring above and belowground resources. The dominance order of the soil seed banks (summer and winter) species varied with the relative density (RD) at the BK site. The WBK subsite showed lower soil moisture content and nutrients compared to the AGL subsite, suggesting the adverse impact of brick industrial activity in the long term (Gupta and Narayan, 2010; Khan *et al.,* 2007). The plant communities in such disturbed habitats with poor soil resources showed growth optimization in standing vegetation and seed banks as well. Simultaneously, long-term brick kiln industrial activity had an impact on soil properties, plant biomass structure, and species diversity. This structural change is indicative of plant community adjustment consequences in anthropogenic habitats (Gupta and Narayan, 2010; Yadav, 2023).

Soil seed banks are also considered to be an important potential source for the restoration of plant communities (Bossuyt and Honnay, 2008). These two seed banks (SSB and WSB) were dominated by annual native grasses *Digitaria sanguinalis* and *Urochloa ramosa* followed by the alien species *Chenopodium album, Euphorbia hirta, Gamochaeta pensylvanica*, *Sida acuta,* and *Torenia crustacea,* at the Brick kiln site. These plant species were also reported in dry tropical urban region of Meerut (Yadav *et al.,* 2022 a, b). As a result, a wide range of invasive species, reproductive characteristics and seed banks have been investigated (Moravcova *et al.,* 2010; Pysek and Richardson, 2007). Trampling has a variety of consequences on underground vegetation, depending on the soil type, depth and moisture content, as well as the diversity and organization of the plant (Florgard, 2009; Hill and Pickering, 2009 and Yadav, 2023). Only a small amount of study has been done on the long-term effects of invasive species on ecosystem functioning, notable invasibility via seed bank alteration (Gaerter *et al.,* 2009; 2011 and Gioria *et al.,* 2011).

A considerable degree of spatio-temporal variation in plant aboveground biomass production, above and below community diversity, and soil properties were evident from this study across various habitats differing in season and the intensity of disturbance (Bhat *et al.,* 2017; Gupta and Narayan, 2010 and Mandal and Joshi, 2015). The disturbance, as in the brick kiln-impacted habitat under investigation, can be considered to be a significant event in the emergence of temporal and spatial variation in the ecosystems by altering the soil environment. According to locals, this brick kiln unit has a longer disturbance history (at least four to five decades) for producing bricks. Thus, it impacts the nearby soils, standing vegetation, crops and belowground vegetation across different seasons. According to Das (2015), the BK industry consumed the top fertile soil of the area during the last two and half decades, thus most of the agricultural lands became barren or infertile, which was also reported in this study. It was observed during the soil seed bank experiment that some seedlings in WBK samples were dying in their very early stage (before the identification) due to the lack of water and soil nutrients.

The losses of soil organic will also affect other soil functions like poorer soil structure, stability, topsoil water holding capacity, nutrient availability, and erosion (Karmakar *et al.,* 2016). A similar pattern of results was observed at the working brick subsite while nearby agricultural land is comparatively more fertile. The finding of this study revealed that the moisture content and organic carbon increased with distance, but in contrast, pH increased in the AGL subsite (Rajonee and Uddin, 2018). Organic carbon levels greater than 0.75% indicate good fertility (Ghosh *et al.,* 1983; Yassen *et al.,* 2015). Soil organic carbon levels near brick kilns (WBK) in this study are low, ranging from 0.34% to 0.63% which is similar to the findings of Bisht and Neupane (2015) and Gupta and Narayan (2010). Soil Organic Carbon is affected by soil texture due to the stabilizing properties of clay on organic matter (Ghosh *et al.,* 1983). Our result is supported by Gupta and Narayan (2010) and Kumar *et al.* (2020), the mean total nitrogen (N) status of the AGL subsite was higher (0.08-0.17%) than the WBK subsite (0.06- 0.09%).

The pH of the soil is a useful indicator of the chemical nature of the soil, with a higher pH indicating the ideal range for plant growth and a lower pH causing issues for the normal growth of the plant (Yaseen *et al.,* 2015). The pH of the soil near the brick kiln (WBK) was measured to be (6.7-7.4) throughout this study, and as the distance increased (AGL), the pH of the soil was recorded up to 7.8, indicating that the soil was slightly acidic close to the kiln and neutral to slightly basic further away which is very similar to the finding of Suwal (2018). Due to an increase in brick production, these affected areas are rapidly growing. Brick burning also destroys soil biota and topsoil nutrients, and it also modifies the physicochemical characteristics of the soil (Das, 2015). The excavation of formerly productive agricultural topsoil for brick-making has significant effects on food security (Nath *et al.,* 2018).

Conclusion

In conclusion, this study revealed that long-term brick kiln industrial activity affected the soil characteristics, concomitantly aboveground biomass and diverse structure of standing vegetation and seed bank plant communities. An altered vegetation pattern of standing and soil seed bank vegetation has adaptational implications in such stressed habitats, particularly by alien species in Indian dry tropics. The study also revealed that the seed bank vegetation was less than three times as compared to the standing vegetation, this was due to less deep, non-fertile soil of the brick kiln.

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