

Brick kiln industry in long-term impacts biomass and diversity structure of plant communities

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Brick kiln sites in an Indian dry tropical peri-urban region, differing in the period of exposure to industrial activity and distance from the brick baking centre, were investigated seasonally for their impact on plant biomass (aboveground and belowground), diversity structure and soils. A total of 72 angiospermic plant species distributed over 25 families were recorded across different sites and seasons. The working brick kiln site, which experienced exposure to industrial activity for short term, showed highest total plant biomass (349–812 g m⁻²), and higher mean soil organic C (0.77%), total N (0.05%) and moisture content (2.75% in summer). In contrast, the abandoned brick kiln site, which witnessed long-term disturbance, had highest belowground biomass (179–253 g m⁻²) with relatively poor soil resources (mean soil organic C (0.20%), total N (0.05%)). Belowground biomass of plant communities significantly declined with increasing soil organic C and total N. Higher species diversity was found at sites with low as well as high plant biomass. Thus, this study revealed that long-term brick kiln industrial activity affected the soil characteristics, and concomitantly the structure of plant biomass (particularly the belowground), and species diversity. This structural alteration is suggestive of adaptational implications for plant communities in anthropoecosystems.

Keywords: Brick kiln, disturbance, dry tropics, peri-urban, plant biomass, species diversity.

THE conversion of primary ecosystems into anthropoecosystems as a result of human activities is most apparent in and around urbanizing landscapes¹, which account for 2% of the earth's surface². These urban landscapes have been greatly disregarded by naturalists and conservationists for reportedly attracting cosmopolitan weedy flora that threatens surrounding natural habitats³. The widespread existence of brick kilns in the rural–urban fringes of the third world cities represents one of such important centres of anthropic activities with a potential to alter the ecology of the surrounding vegetation and soil. These brick kilns

represent one of the major small-scale industries, which fulfil the growing demand of urban expansion. Indian brick kiln industry is the second largest brick producer in the world, second only to China, having more than 100,000 operating units, producing about 140 billion bricks annually. The Gangetic plain of north India accounts for 65% of the total brick production⁴. Here, the peri-urban region of Bulandshahr alone, that has been catering to the developmental needs of highly developed urban centres in its vicinity like Delhi, Noida and Meerut, has about 300 brick kilns. The study of the anthropogenic influence of this industry particularly in the National Capital Region⁵ of India assumes considerable importance, as huge chunks of agriculturally fertile lands are consumed by each brick kiln (3–4 ha), which get converted into wastelands as a result of industrial operation in the life of a brick kiln (8–12 years). These industries are also reported to normally use 4–5 million metric tonnes of coal each year⁶, indicating that these brick kilns have immense disturbance potential to cause ecological alterations.

Disturbance has been widely recognized as one of the major factors influencing variations in species diversity^{7–9} and productivity¹⁰. The disturbance generated by the brick-manufacturing process is reportedly a threat to land and environment¹¹ that adversely affects human health and vegetation¹², soils¹³ and productivity¹⁴. The brick kiln operation over the years not only covers the neighbouring area of vegetation with layers of brick dust, but also consistently dissipates heat all around. It alters the physico-chemical properties and habitats of nearby soils by destroying the top soil nutrient elements and soil biota¹⁵ which are likely to impact species diversity and biomass structure of the neighbouring plant communities.

Weeds and ruderals are often reported to invade the open and disturbed areas¹⁶, as generally observed around brick kilns. The differential biomass allocation to aboveground and belowground parts by these plants here may facilitate their adaptation and competitive ability for optimum utilization of resources. It is hypothesized that in habitats that witness adverse edaphic conditions due to long-term brick kiln industrial activity, the optimum growth of plant communities is maintained by enhanced biomass allocation to belowground parts.

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There are some studies pertaining to the pollution aspects around brick kilns^{12,13,15}. But, ecological studies on species diversity and biomass structure of the plant communities in habitats around brick kilns are lacking. The present work was designed to study: (i) the spatio-temporal dynamics of structure of plant biomass (aboveground and belowground) and diversity in habitats around brick kilns differing in the intensity of disturbance, and (ii) plant biomass relations with soil and species diversity.

Study area

The study area of Bulandshahr (28°24'N lat. and 77°51'E long.) in western part of Uttar Pradesh, is located in the upper Doab of the Ganges and Jamuna rivers at an altitude of ca. 180 m above msl. Three study sites in brick kiln industrial area varying in the intensity of disturbance were selected for the present study. They were: (i) abandoned brick kiln (ABK), (ii) working brick kiln (WBK) and (iii) intervening brick kiln (IBK) sites. ABK was located around an abandoned brick kiln. This site witnessed active brick baking operations for 12 years between 1988 and 2000, and was abandoned in 2001. Its shallow soils (10–15 cm deep) were covered with brick dust (~4 cm deep) and broken pieces of half-burnt and over-burnt bricks beneath. The second site, WBK, at a radial distance of 600 m from ABK, experienced active brick-baking operations since 2001. Its soils were relatively hard, compact and deeper (130–140 cm) with irregular accumulation of brick dust and broken brick pieces (in small quantity) over the surface. The third site, IBK lay equidistant from these two sites, which exhibited 110–120 cm deep soils but without any broken pieces of bricks, although a thin layer of brick dust (1–2 cm) was recorded. Brick manufacturing is a seasonal activity and remains active from January to June. However, the peak season of brick production is April–June. An area of 1 ha was marked in each of the three sites for the present study.

The climate of the study area is semi-arid having three seasons, rainy (July–October), winter (November–February) and summer (March–June). The monthly mean minimum temperature ranged from 7.4°C (January) to 29.8°C (June), and the mean maximum from 16.8°C (January) to 39.7°C (June) (2001–05). Annual mean rainfall (2001–2005) was 548 mm.

Materials and methods

Floristic survey of the study sites was done at monthly intervals from January 2003 to December 2004. The plant species were identified according to Gaur¹⁷ and Sharma¹⁸. At each site in each of the three seasons, 25 monoliths to the depth of 20 cm were randomly extracted with the help of soil corer (inner diameter 22.6 cm), in the months of

October 2003, February 2004 and June 2004. The extracted monoliths were washed within 24 h of their extraction and the plant material was collected on a 0.5 mm sieve. It was separated into different species as far as possible. All plant individuals were fractioned into aboveground and belowground plant parts, which included both live and standing dead parts. All plant parts were dried for 48 h at 80°C and weighed. The biomass data of unidentified species, and the broken/unidentified belowground plant parts that could not be linked to the aboveground parts were placed under miscellaneous category. Aboveground (AGB), belowground (BGB) and total biomass (TB) of each plant species were calculated (g m^{-2}). The biomass data of all species present at a site including the biomass data of miscellaneous components were pooled to get the total AGB, BGB and TB at that site.

Dominance–diversity curves were prepared by plotting relative dominance (in terms of AGB, BGB and TB) of a species against the species sequence. Species diversity of the study sites was estimated according to the following formulae using total biomass data of the species.

Species count (number of species that occurred in monoliths sampled across a study site)

$$\text{Shannon-index } (H')^{19} = -\sum p_i \ln p_i,$$

$$\text{Evenness}^{20} = \frac{H'}{\ln S},$$

$$\text{Simpson index}^{21} = \sum p_i^2,$$

where S is the total number of species, N the total sum of relative dominance of all species, i.e. 100, p_i the proportional dominance of i th species (n_i/N), n_i the relative dominance of each species, and N_{\max} is the relative dominance of the most dominant species.

Six representative surface soil samples (0–10 cm) were randomly collected from each study site in October 2003, February 2004 and June 2004. The soil samples were air-dried and sieved (2 mm). The soil moisture content, pH, total organic carbon (Walkley and Black method) and total nitrogen (microkjeldahl's method) of each soil sample were estimated according to Piper²². Available phosphorus, exchangeable calcium and potassium were estimated according to Allen *et al.*²³. Soil data were analysed by one-way ANOVA, and the site means were compared applying *post hoc* Tukey's HSD test at $P \leq 0.05$ by using SPSS 16.00.

Results

Floristic composition

A total of 72 angiospermic plant species distributed over 25 families were recorded across different sites and

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Table 1. Seasonal changes in relative dominance of top four dominants (in terms of total biomass) at three different sites in a brick kiln area in Indian dry tropics

Species name	Rainy season			Winter season			Summer season		
	ABK	IBK	WBK	ABK	IBK	WBK	ABK	IBK	WBK
<i>Achyranthes aspera</i> L.	14.4	14.1	8.4	0.6	15.2	–	1.1	8.8	2.9
	5.1	5.7	4.4	0.2	3.7	–	1.9	3.2	3.4
	11.5	12.1	7.6	0.4	11.2	–	1.3	7.3	3.0
<i>Boerhavia diffusa</i> L.	–	–	–	13.0	–	–	3.6	3.5	1.9
	–	–	–	7.6	–	–	7.2	3.3	3.3
	–	–	–	10.6	–	–	4.6	3.5	2.2
<i>Cassia obtusifolia</i> L.	–	17.6	14.9	–	–	–	–	–	–
	–	5.5	8.7	–	–	–	–	–	–
	–	14.7	13.6	–	–	–	–	–	–
<i>Chenopodium murale</i> L.	3.9	3.7	1.5	0.9	21.3	1.0	1.3	19.6	29.2
	1.4	2.7	0.6	0.2	13.4	0.8	0.9	14.3	18.3
	3.1	3.5	1.3	0.6	18.5	1.0	1.2	18.2	26.8
<i>Cynodon dactylon</i> (L.) Persoon	1.7	7.2	4.3	–	6.2	1.5	0.5	4.9	0.8
	2.4	18.2	14.7	–	21.4	10.3	1.4	14.3	3.2
	1.9	9.8	6.5	–	11.5	4.2	0.7	7.4	1.4
<i>Dactyloctenium aegyptium</i> (L.) P. Beauv.	12.7	11.2	3.6	–	1.3	–	0.4	1.3	0.6
	13.9	20.1	6.7	–	2.4	–	0.4	1.2	0.7
	13.1	13.4	4.3	–	1.7	–	0.4	1.2	0.7
<i>Gnaphalium luteo-album</i> L.	–	–	–	3.2	–	–	–	–	–
	–	–	–	0.1	–	–	–	–	–
	–	–	–	1.8	–	–	–	–	–
<i>Malva sylvestris</i> L.	–	–	–	–	6.6	35.5	–	–	–
	–	–	–	–	6.3	21.0	–	–	–
	–	–	–	–	6.5	31.0	–	–	–
	–	–	–	–	8.2	1.4	–	0.9	2.7
<i>Parthenium hysterophorus</i> L.	1.2	8.6	10.3	1.4	14.9	19.6	0.9	27.5	38.7
	0.7	6.6	4.3	0.3	9.4	4.2	0.7	20.0	35.1
	1.1	8.1	9.1	0.9	13.0	14.9	0.9	25.5	37.9
<i>Paspalidium flavidum</i> (Retz.) A. Camus	7.5	2.6	2.8	–	–	–	–	–	–
	10.2	2.8	6.8	–	–	–	–	–	–
	8.4	2.6	3.6	–	–	–	–	–	–
<i>Rumex dentatus</i> L.	–	–	–	0.3	2.1	8.8	–	–	–
	–	–	–	0.0	3.3	17.4	–	–	–
	–	–	–	0.2	2.5	11.5	–	–	–
<i>Saccharum munja</i> Roxb.	29.4	–	–	70.2	–	–	76.8	–	–
	29.9	–	–	76.2	–	–	57.8	–	–
	29.6	–	–	72.9	–	–	71.9	–	–
<i>Senebiera didyma</i> (L.) Persoon	–	–	–	0.4	4.4	9.7	–	–	–
	–	–	–	0.1	3.3	4.9	–	–	–
	–	–	–	0.3	4.0	8.2	–	–	–
<i>Sida acuta</i> Burm. F.	1.2	12.3	13.3	–	–	1.5	2.5	9.7	4.4
	1.3	7.4	10.0	–	–	1.1	3.2	19.9	11.0
	1.2	11.1	12.6	–	–	1.4	2.7	12.4	5.8
<i>Sida rhombifolia</i> L.	1.5	8.9	6.1	3.7	1.7	–	2.1	9.1	6.5
	0.7	3.1	5.3	0.8	4.7	–	3.9	8.6	8.0
	1.3	7.5	5.9	2.4	2.8	–	2.6	9.0	6.9
<i>Urena lobata</i> L.	2.1	–	–	–	–	–	5.0	–	–
	1.2	–	–	–	–	–	3.2	–	–
	1.8	–	–	–	–	–	4.5	–	–
Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	15.4	8.0	7.3	11.5	11.8	9.5	14.2	5.7	6.2
	4.7	1.9	1.5	5.2	4.1	3.0	3.7	1.5	1.4
Other species	24.2	13.7	34.8	6.4	26.4	22.3	5.8	15.6	14.9
	17.9	20.0	31.2	2.9	20.4	30.7	5.1	9.5	10.7
	22.2	15.3	34.0	4.8	24.3	24.9	5.6	14.0	14.0
No. of other species	15	12	11	7	12	10	8	4	6
Total AGB (g m ⁻²)	539.2	608.9	641.3	307.4	198.7	240.9	515.5	416.7	464.0
Total BGB (g m ⁻²)	239.7	194.8	171.0	252.7	107.0	108.3	178.6	146.9	132.9
Total biomass (g m ⁻²)	778.9	803.7	812.4	560.1	305.7	349.2	694.0	563.7	596.9

Dominance values of these species if found at other sites (irrespective of their ranks) are also shown. For each species the first value from the top represents its relative dominance in terms of aboveground biomass (AGB), second belowground (BGB) and third its total biomass (TB). Site codes – ABK: abandoned; IBK: intervening; WBK: working brick kiln sites.

seasons in the brick kiln study area. Poaceae with 12 species was the largest family followed by Asteraceae (7), Leguminosae (6), Amaranthaceae (6) and Malvaceae (5), together accounting for 50% of the total recorded flora. The number of species was highest at all sites in rainy season and lowest in summer. While winter season witnessed emergence of much comparable number of species (30–33) at the three sites, it varied in rainy (26–35) and summer (16–26) seasons.

Species dominants across sites and seasons

At ABK site, perennial plant *Saccharum munja* was the leading dominant in all three seasons. Its dominance was more pronounced in summer and winter seasons, where its total biomass alone accounted for >71% of the plant biomass at this site (Table 1). The other two sites (IBK and WBK) were dominated by the exotic invasive weed *Parthenium hysterophorus* in dry months. In summer, it was the top dominant followed by *Chenopodium murale*, which together accounted for 44% of the total plant biomass at IBK and 65% at WBK. In winter, however, *P. hysterophorus* occupied sub-dominant status, and the top dominants varied. *Chenopodium murale* dominated at IBK and *Malva sylvestris* at WBK. In rainy season, there was a relatively close contest for the top dominance among species, especially at IBK and WBK sites, where *Cassia obtusifolia* topped in terms of AGB and TB.

The dominance order of a species varied with the biomass data of species considered in terms of its AGB, BGB or TB, as evident at IBK site in summer and WBK in winter. In terms of AGB at IBK in summer, *P. hysterophorus* and *Chenopodium murale* were the top two dominants but in terms of BGB, *Sida acuta* replaced *Chenopodium murale* as the sub-dominant (Table 1). In terms of TB, however, the decreasing order of species dominance was *P. hysterophorus*, *Chenopodium murale* and *S. acuta*.

Variation in plant biomass distribution

Across all sites and seasons, total biomass ranged from 306 to 812 g m⁻² (Table 1). Highest community biomass was recorded in rainy season. Whereas highest AGB and TB were found at WBK, the highest BGB was recorded for ABK site. The seasonal plant biomass of the study sites (AGB and TB) showed a similar trend: rainy > summer > winter. The variation in plant biomass (AGB and TB) at a site with the change of season was observed to be minimum at ABK and maximum at IBK sites. Inter-site variation of biomass in a season (TB) was minimum in rainy season and maximum in winter season.

The plant communities at ABK allocated larger percentage of TB to belowground parts compared to that by those at IBK and WBK sites (Figure 1). Belowground

biomass allocation by plant communities at these three sites in summer was much comparable (22–26%), whereas it was much variable in winter and rainy seasons. Maximum biomass allocation to belowground was recorded in winter which was much higher at ABK (45%), compared to WBK (31%) and IBK (35%).

Dominance and diversity structure

The ABK site in different seasons showed a distinct geometrical pattern of resource share among species, as evinced by the initial segment of dominance–diversity curves (Figure 2). The steepness of the curves was more pronounced in summer and winter. This trend of steepness of curves in the initial segment was markedly reduced at WBK and IBK sites. Amongst the seasons, a much-enhanced equitable share of resources, as indicated by lognormal tendency of the curves, was observed for rainy season. Species diversity at the study sites varied with season (Table 2). The range of diversity variation was maximum at ABK and minimum at IBK. ABK showed lower diversity compared to WBK and IBK. The rainy season showed generally higher species diversity at all sites. Across all sites and seasons, the highest species diversity and evenness were recorded at WBK in rainy season (Shannon 2.78; evenness 0.93), and lowest at ABK in winter season (Shannon 0.98; evenness 0.35).

Soil characteristics

The soils of the study sites were neutral to slightly basic (Table 3). WBK and IBK soils showed higher soil moisture content, organic C, total N, C : N ratio, available P, exchangeable K and Ca compared to ABK soils. Soil organic carbon and C : N ratio at ABK site were signifi-

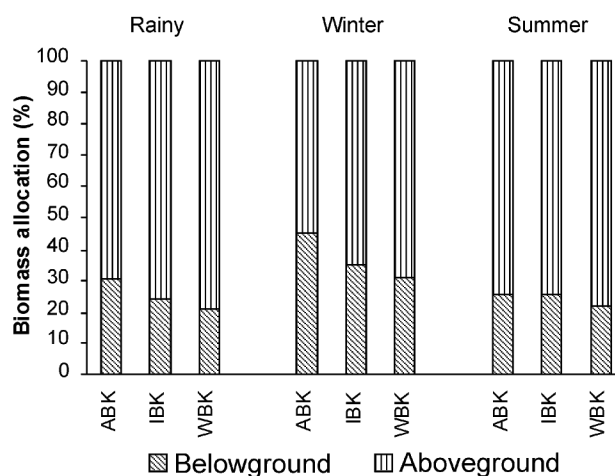


Figure 1. Biomass allocation to aboveground and belowground parts by plant communities in different seasons at three sites in a brick kiln area. Site codes: ABK: abandoned; IBK: intervening; WBK: working brick kiln sites.

Table 2. Seasonal changes in diversity estimates of the vegetation at three different sites in a brick kiln area in Indian dry tropics

Season/site	Species count	Shannon index	Evenness	Simpson index
Rainy				
Abandoned brick kiln	25	2.38	0.74	0.15
Intervening brick kiln	21	2.54	0.83	0.10
Working brick kiln	20	2.78	0.93	0.07
Winter				
Abandoned brick kiln	16	0.98	0.35	0.61
Intervening brick kiln	21	2.53	0.83	0.10
Working brick kiln	17	2.22	0.78	0.16
Summer				
Abandoned brick kiln	18	1.20	0.41	0.56
Intervening brick kiln	12	2.14	0.86	0.15
Working brick kiln	14	1.84	0.70	0.24

Table 3. Soil characteristics (mean \pm SE) of three different sites in a brick kiln area. Except summer moisture content values ($n = 6$), all other values of soil characteristics represent the mean of three seasons (rainy, winter and summer) ($n = 18$)

Characteristics	Abandoned brick kiln	Intervening brick kiln	Working brick kiln
Summer moisture content (%)	1.53 \pm 0.28 a	2.68 \pm 0.53 b	2.75 \pm 0.55 b
pH	7.50 \pm 0.12 a	7.29 \pm 0.09 ab	7.04 \pm 0.07 b
Org C (%)	0.20 \pm 0.06 a	0.50 \pm 0.13 ab	0.77 \pm 0.17 b
Total N (%)	0.02 \pm 0.005 a	0.04 \pm 0.008 a	0.05 \pm 0.010 a
C : N ratio	8.65 \pm 0.57 a	11.78 \pm 0.80 b	15.47 \pm 0.40 c
Available P (mg/g)	0.014 \pm 0.0012 a	0.022 \pm 0.0015 b	0.016 \pm 0.0009 a
K (mg/g)	0.300 \pm 0.035 a	0.353 \pm 0.035 a	0.340 \pm 0.044 a
Ca (mg/g)	0.473 \pm 0.122 a	0.450 \pm 0.155 a	0.503 \pm 0.114 a

Different letters in a row represent significant differences at $P \leq 0.05$ by applying post hoc Tukey's HSD test.

cantly lower ($P < 0.05$) than WBK site, however, the soil pH was significantly higher here.

Plant biomass, species diversity and soil inter-relations

BGB of the sites decreased significantly with increasing soil organic C ($R^2 = 0.5376$) (Figure 3) and total N ($R^2 = 0.4859$). In contrast, relatively weak relations with soil organic C were exhibited by AGB ($R^2 = 0.014$) and TB ($R^2 = 0.0938$) (not shown in figure). The relationship between species diversity and TB of the sites (Figure 4) depicted 'U' shaped curves ($R^2 = 0.7006$ for species count and $R^2 = 0.6105$ for Shannon index), explicable by quadratic polynomial relation. Higher species diversity at both low as well as high site-biomass was observed here, and diversity tended to decline at intermediate level of site-biomass.

Discussion

The present study revealed that dry tropical peri-urban areas are highly dynamic and a vegetation mosaic here²⁴

was discernible even at relatively smaller scale of study in anthropic habitats around brick kilns. This can be attributed to highly heterogeneous environment encountered in peri-urban areas for the survival of plants and their establishment²⁵. A considerable degree of spatio-temporal variation in plant biomass production and allocation pattern, species diversity and soil properties was evident from this study across various habitats differing in the intensity of disturbance. The ABK site, with longer disturbance history (12 years), showed dominance by the same perennial *S. munja* that invested greater BGB. In contrast, the WBK site, that was exposed to disturbance for short duration (2–3 years) and IBK site (at distance from active brick-baking centre), witnessed close contest among the seasonal weeds for top dominance, indicating ecological opportunities generated here for arrival and establishment of several species.

The habitats characterized by persistent disturbance, such as brick dust accumulation over soil and plant surface, and heat released to neighbouring areas around brick kilns, appear to become susceptible to invasion by the non-native species¹⁶. This is perceptible from the increasing tendency of the exotic invasive weed *P. hysterophorus* to occupy the top dominant status, particularly

at WBK and IBK sites. Its dominance at these sites assumed greater prominence in the dry months of summer and winter, as elucidated by steepness of dominance–diversity curves particularly in the initial segment. Geometrical pattern of resource share at these sites is likely due to prevalent environmental stress²⁶.

The ABK site showed lower soil moisture content and nutrients (Table 3) compared to WBK site, suggesting adverse impact of brick industrial activity in long term¹⁵. The plant communities in such disturbed habitats with poor soil resources showed growth optimization by

differentially increased BGB production for optimal resource use²⁷. Highest BGB at nutrient-poor ABK and highest AGB at relatively nutrient-rich WBK possibly indicates that limiting factor for plant growth in such habitats is soil resource as the plants respond to environmental factors that limit the acquisition of aboveground resources (e.g. light, CO₂) relative to belowground resources (e.g. nutrients, water) by shifting their resources to tissues and processes associated with gaining the resources that are limiting²⁸. Thus, the plants are thought to distribute a relatively high proportion of biomass to roots in nutrient-poor environment, such as ABK in this study, where the competition for soil resources is at a maximum²⁹.

In addition to soil nutrients, soil moisture content in dry tropical habitats appears to play a significant role in community structure. In rainy season, when the moisture in soils is generally available in plenty, the inter-site variation in TB and differential biomass allocation to belowground plant parts was found to be much reduced. The plentiful soil moisture availability after rains reduces environmental heterogeneity²⁴, as evinced by higher evenness of species (Table 2).

The heterogeneity of vegetation structure was more prominent in dry months of winter and summer. The disturbance, as in the investigated brick kiln-impacted habitats, can be considered as major events in the creation of temporal and spatial heterogeneity in the ecosystems by modifying the soil environment. In winter, BGB allocation at different sites was substantially higher (average 37%) indicating growth strategy of plant communities to overcome the stress of dryness in forthcoming summer. Besides, belowground allocation at these sites in the order WBK < IBK < ABK indicated that subterranean allocation increased with stress. The variation of species dominants in terms of AGB, BGB and TB at a site indicated that the species differ in their competitive ability for acquiring aboveground and belowground resources.

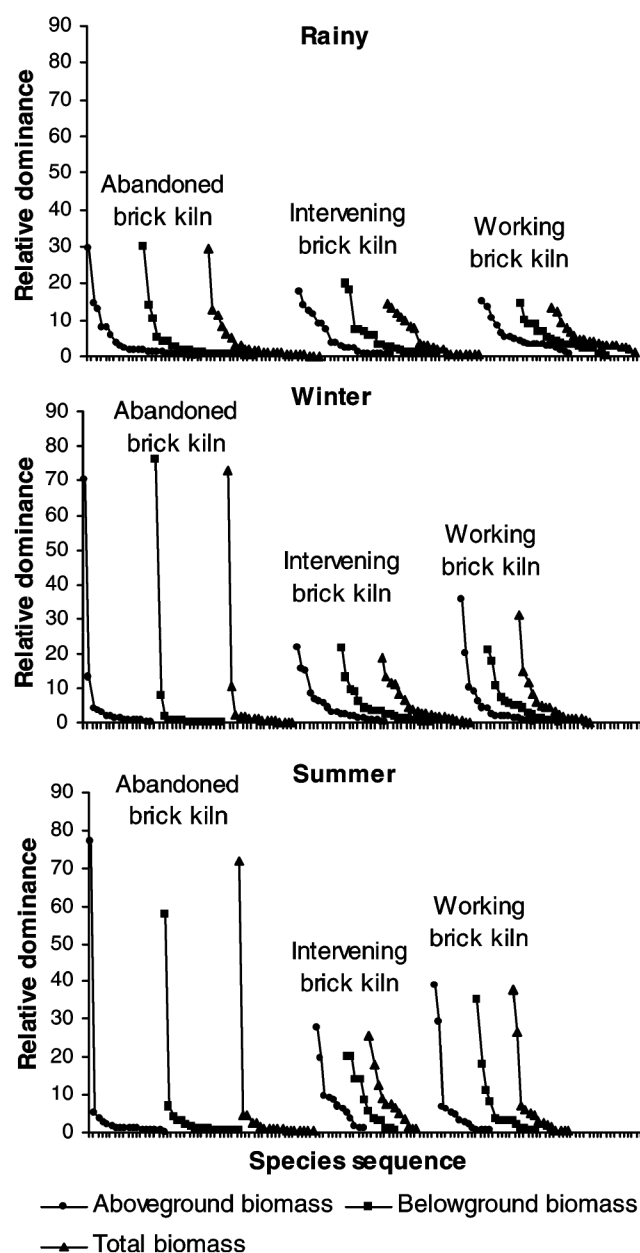


Figure 2. Dominance–diversity curves, based on relative dominance of a species (in terms of aboveground, belowground and total plant biomass) at different sites in three seasons, in a brick kiln area in Indian dry tropics.

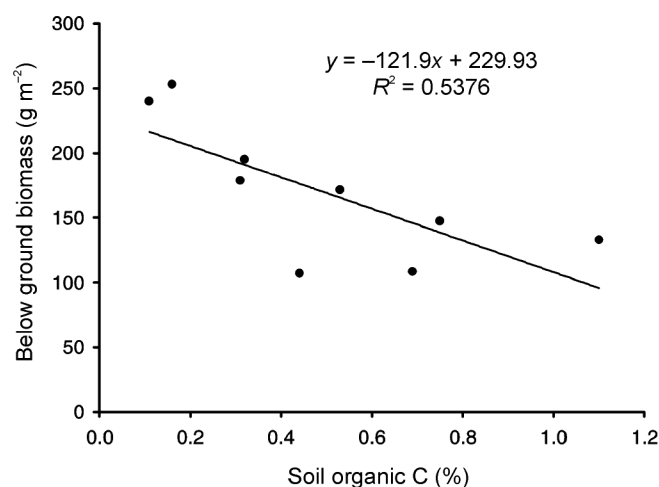


Figure 3. Relationship between belowground biomass of plant communities and soil organic C in a brick kiln area in Indian dry tropics.

Thus, the study of plant-component biomass, particularly the subterranean biomass which is difficult to work with³⁰, assumes considerable significance for assessing species dominance, especially in habitats with scarce soil resources.

In the present study that included a range of disturbed habitats, the 'U' shaped relationship between species diversity and site biomass indicated that the species diversity in disturbed habitats could be high under both low as well as high production systems. The WBK site and its neighbouring IBK site showed low site-biomass but high diversity in winter season. This season possibly represents favourable condition for the emergence of variety of winter annuals with short-life span having relatively low biomass, because of cessation of brick baking activity in the previous rainy season. The annuals that emerged here may be considered as ecological opportunists in such disturbed habitats³¹. They competed among themselves to occupy areas from where the disturbance had ceased, and there occurred a trade-off between species' ability to

compete and their ability to tolerate disturbance^{7,8}. Thus, competition at seral stages in secondary succession (the studied vegetation patches) is likely to cause high plant diversity under ecologically favourable conditions. On the other hand, increased diversity under higher production system explains the optimum utilization of resources by niche complementarity effect³². Connell⁷, and Pickett and White³³ opined that the disturbances allow the maintenance of species richness by creating a mosaic of patches.

In conclusion, this study revealed that long-term brick kiln industrial activity affected the soil characteristics, and concomitantly biomass and diversity structure of plant communities. Altered allocation pattern has adaptational implications in such stressed habitats. The study also revealed maintenance of high diversity in both low and high production systems.

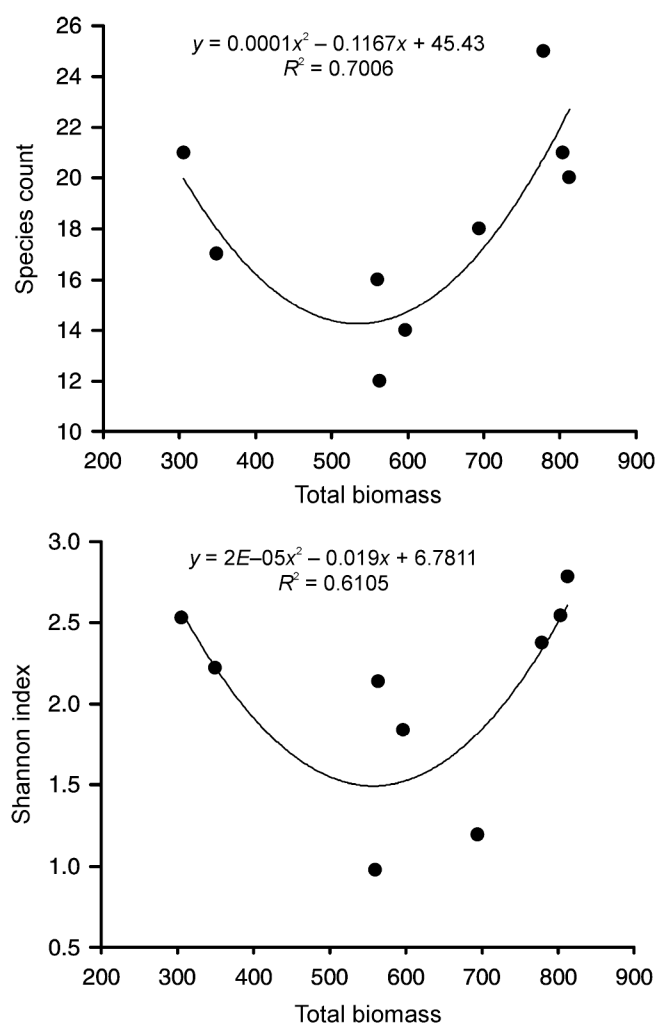


Figure 4. Relationship between species diversity and total biomass (g m^{-2}) of the study sites in a brick kiln area in Indian dry tropics.

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