Herbaceous Flora Diversity Along Anthropogenic Gradient in Manipur

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Abstract: - Herbaceous flora along human-impacted landscapes in the agrestal-ruderal matrix from Manipur, North East India revealed a decrease in richness and diversity from agrestal to ruderal sites. However, the co-dominance and evenness showed the opposite trend in general. The study explored the mutual feedback mechanism between urban-rural landscapes and its impact on the composition, structure, and patterns of vegetation diversity. Studying the diversity patterns and their causes is beneficial for understanding the formation and maintenance mechanisms. This study selected four sites in NE India and conducted field research using uniform sampling methods. The composition, diversity pattern, and driving factors of vegetation were analyzed; soil phosphorus and soil reaction contributed relatively better, while soil nitrogen had a lower negative contribution. The contribution of moisture was found to be lower in distinguishing the two groups of vegetation. The increase in species richness in agrestal sites appeared to be due to the presence of r-strategists capable of rapid multiplication and dispersal, as they can make the best use of available resources.

Key-words: - Discriminant function, edaphic variables, ruderal-agrestal matrix, herbaceous flora, cluster

Received: April 23, 2024. Revised: December 29, 2024. Accepted: January 28, 2024. Published: June 12, 2025.

1 Introduction

Global biodiversity is under unprecedented threat due to human activities such as urbanization, climate change, intensification, and industrialization of land use practices in agricultural and forest areas [1], increasing the number of impermeable surfaces [2]. Nevertheless, despite dwindling species richness, agrestal sites close to rural areas may contain a variety of landscapes [3]. Considering the biodiversity crisis and global climate change, it is imperative to understand how urbanization affects species occurrence and composition.

Many studies have been carried out to explain the great diversity and identify the processes that sustain it [4]. Developing conservation plans and estimating changes in vegetation patterns require details about the distribution of plants in relation to various environmental conditions. This data provides information for assessing potential future changes and modifications [5]. Both anthropogenic and environmental factors influence the distribution of species [6]. Hence, an ecosystem's health can be gauged by the floral diversity of its plant population [7].

Understanding the relationships between species coexistence and community assembly is essential to comprehending the diversity and functionality of ecosystems. Plant communities' compositional patterns are shaped by niche partitioning and environmental filtering [8]. Low functional diversity indicates that habitat filtration and/or biotic filtering are highly important [9,10]. On the other hand, Carroll et al. [8] claim that great functional diversity is a sign of niche partitioning's significant influence on species assembly processes, which permits species cohabitation by lessening the mechanism of competitive exclusion.

The assessment of species diversity includes the variety and variability of life forms; therefore, species diversity indices that incorporate both variables aid in understanding the ecosystem's health as well as the various natural and man-made disturbances [11]. Environmental heterogeneity [12] and the severity of disturbances, both natural and man-made [13], exacerbate this complexity.

Although urban environmental conditions may change under human influence, some general characteristics of urban climate in comparison with the surroundings are known, such as increased temperature, higher pollution, lower radiation, higher precipitation, and changed water regime, etc. [14]. Thus, the vegetation in the ruderal site has severe human interference [15].

In Manipur, North East India, herbaceous flora in human-impacted landscapes in the ruderal-agrestal matrix of various settlements has not been studied previously; hence, the present investigation is undertaken to know the diversity in ruderal-agrestal sites from four settlements of Manipur, North East India.

The aim of this study is to analyze variations in terms of diversity and composition of vegetation along the urban-rural gradient, using species attributes and edaphic conditions to identify the factors responsible for filtering the species.

2 Material And Methods

The study was conducted in North East India in the ruderal-agrestal matrix of the four settlements of Manipur state ($23^o50'$-$25^o41'$ North Latitude and 93^o-$94^o47'$ East longitude), namely Imphal, Thoubal, Bishenpur, and Churachandpur, comprising a total of eight localities. The localities chosen were open, situated near pavement, and within a radius of 6 km from bus parking areas. Agrestals are plants of tilled, arable lands other than crops, whereas ruderals are plants occurring on ‘ruderal’ sites, an expression derived from Latin rudus (debris), comprising habitats having severe human interference. The vegetation was sampled at random by placing 50 quadrats of $1M^2$ size in each of the ten plots of $50\ m^2$ size. The field data on the vegetation was analyzed to obtain frequency, density, and basal cover for the sampled sites. Further, a synthetic value called Importance Value Index was derived as per Misra [16]. The diversity indices [17]; the Index of co-dominance [18] and Evenness index E [19] were computed.

Cluster analysis was employed on the Importance Value Index derived and computed from the field data using SPSS software. Cluster analysis was first applied in anthropology by Driver and Kroeber [20]. It is a statistical technique for data analysis used for pattern recognition by organizing data into groups – or clusters. The dendrogram was derived from a hierarchical agglomerative cluster analysis performed using Ward's method with squared Euclidean Distance as the distance measure for eight sites.

For explaining the variations along an urban–rural gradient of vegetation, the sites were assessed for substrate quality. Five edaphic variables were selected to explore the driving factors that affect the composition and pattern of ruderal-agrestal vegetation diversity in NE India, based on the actual situation of the research area. The composite soil samples from 2.6 cm depth collected from different sites were analyzed as per standard methods given by Mishra [16] for Total Nitrogen, Available Phosphorous, Exchangeable Potassium, pH, and Moisture. The values obtained from the agrestal-ruderal localities were subjected to Discriminant Analysis [21]. Discriminant analysis was applied for two groups on soil attributes defined by multiple variables.

Fig 1 gives the various steps followed in the methodology for analyzing Agrestal-Ruderal Vegetation in NE India. Study area, site selection, vegetation types sampled, data collection process, computation analysis, cluster analysis, gradient data analysis, and discriminant analysis comprised the methodology steps.

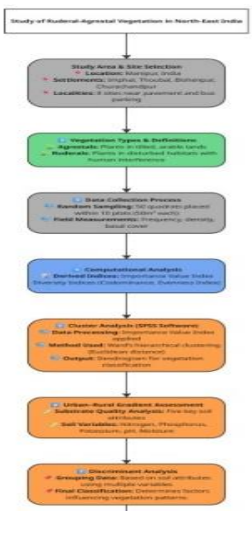
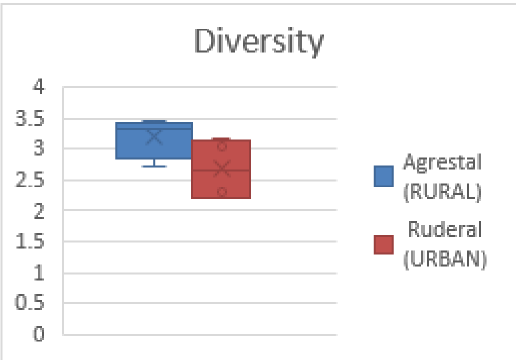
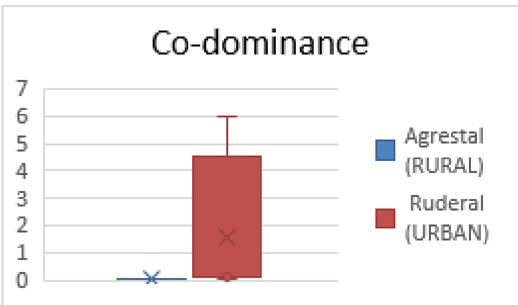


Fig 1- Steps in Methodology for Analysing Agrestal-Ruderal Vegetation in NE India

3 Results

A total number of 222 species, with 121 dicots and 99 monocot species, were obtained during the field survey from ruderal and agrestal localities of Imphal, Thoubal, Bishenpur, and Churachandpur settlements. Richness in sampled agrestal sites of species (mean±SD) recorded was 35.5±9.03, diversity 3.21±0.33, codominance as 0.05±0.02, and evenness as 0.91±0.029. Richness in ruderal sites of species (mean±SD) recorded was 16.75±2.56, diversity 2.675±0.507, codominance as 1.594±2.87, and evenness as 0.918±0.06 from agrestal localities, and 25.6±1.2, 29.7±5.2, 13.9±1.6, and 18.6±1.4 from ruderal localities of Imphal, Thoubal, Bishenpur, and Churachandpur settlements, as shown in Fig2.





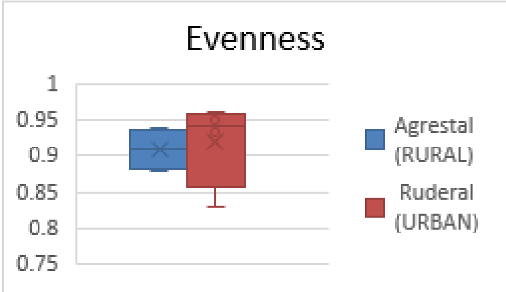


Fig 2 - Richness, Diversity, Co-dominance, and Evenness of herbaceous vegetation along the anthropogenic gradient in Manipur

Fig 2 displays the box plots of various indices at agrestal and ruderal sites, depicting the range, median, and quartiles of the data set of each site along anthropogenic gradients in four settlements of Manipur. It was observed that the richness decreases in the ruderal herbaceous flora. The index of co-dominance decreases in the agrestal localities; the same trend is displayed by the evenness index, which shows a decrease in agrestal sites, except for the Churachandpur agrestal site, where it is showing the opposite trend. The increase of E in the Churachandpur settlement seemed to be related to the co-dominance of the species out of the total species studied and their very similar nature of individuals compared to the remaining species. The number of native species was higher in agrestal localities, while that of exotics was higher in the ruderal, indicating the influence of the type of settlement on the number and growth forms of the species.

The Importance Value Index (IVI) indicates a species's relative importance within a community by quantifying its density, abundance, and dominance. It's calculated by summing the relative frequency, relative density, and relative dominance of a species in a given area. This derived synthetic index helps to classify communities by revealing the most influential species in shaping the overall structure and function of the community.

Heatmaps use color to represent data values in a two-dimensional space, in a continuous color scale in a spatial context, and visually encode to aid in the quick identification of areas of interest, with darker shades indicating higher values. Data values comprise the IVI of the ten most dominant species at a site, whether agrestal or ruderal, from four settlements of Manipur (Figures 3 and 4).

IMPHAL		THOUBAL		BISHENPUR		CHURACHANDPUR	
Species	IVI	Species	IVI	Species	IVI	Species	IVI
Ageratum conyzoides	11.11	Alternanthera sessilis	25.5	Alternanthera sessilis	19.49	Amaranthus viridis	12.09
Alternanthera sessilis	12.32	Brachiaria distachya	21.69	Centella asiatica	47.91	Argyreia nervosa	10.01
Cynodon dactylon	20.76	Chrysopogon aciculatus	9.43	Chrysopogon aciculatus	14.55	Bidens pilosa	12.56
Cyperus difformis	20.77	Cynoglossum furcatus	9.4	Colocasia esculenta	16.18	Chenopodium ambrosioides	21.15
Digitaria ciliaris	20.32	Gnaphalium luteoalbum	33.93	Commelina benghalensis	13.6	Dactyloctenium aegypticum	13.38
Emilia sonchifolia	25.16	Gynura crepidioides	12.04	Cynoglossum furcatus	32.04	Rumex crispus	18.31
Leucas ciliata	11.11	Justicia simplex	14.94	Emilia sonchifolia	31.31	Solanum xanthocarpum	17.19
Sorghum halepense	12.72	Portulaca oleracea	29.32	Fimbristylis miliacea	13.41	Stellaria media	15.68
Spilanthes acmela	16.4	Solanum verbascifolium,	11.11	Melinis minutifolia	11.52	Vernonia volkameriafolia	14.79
Vernonia volkameriafolia	25.81	Sorghum halepense	10.78	Polygonum chinensis	39.6	Xanthium strumarium	17.36

Fig. 3 HEATMAP SHOWING ECOLOGICAL DOMINANCE OF TOP TEN SPECIES IN AGRESTAL SITES OF FOUR SETTLEMENTS FROM MANIPUR

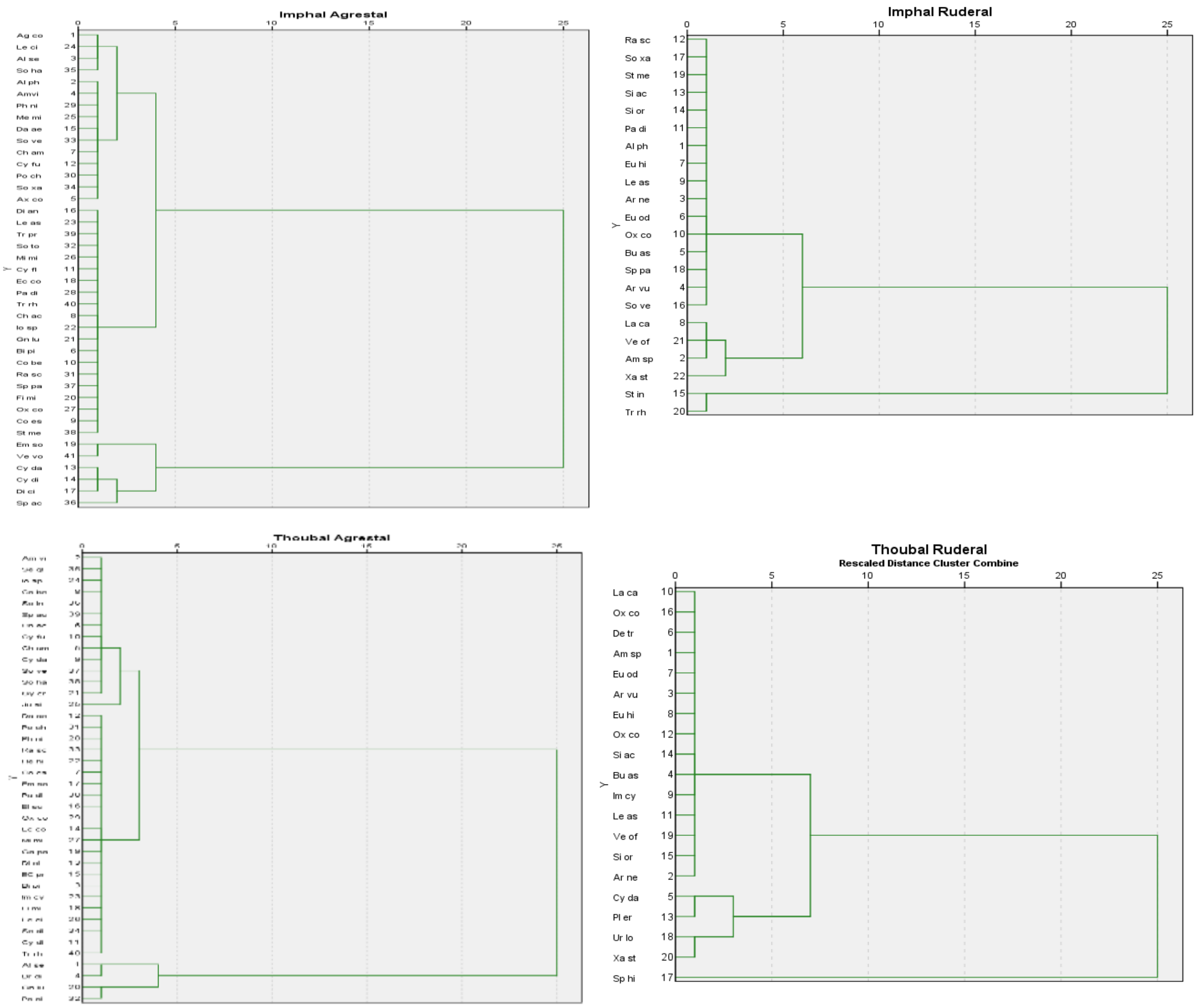
IMPHAL		THOUBAL		BISHENPUR		CHURACHANDPUR	
Species	IVI	Species	IVI	Species	IVI	Species	IVI
Amaranthus spinosus	21.43	Argyreia nervosa	16.29	Amaranthus spinosus	25.52	Ageratum conyzoides	11.09
Artemisia vulgaris	7.8	Cynodon dactylon	20.95	Argyreia nervosa	30.65	Amaranthus spinosus	31.18
Buddleja asiatica	6.69	Leucas aspera	12.74	Axopus compressus	40.03	Cynodon dactylon	17.93
Lantana camara	26.25	Plantago erosa	20.15	Buddleja asiatica	21.39	Cyperus rotundus	28.17
Stachytarpheta indica	58.63	Sida acuta	11.17	Cynodon dactylon	16.63	Eupatorium odoratum	103.42
Solanum verbascifolium	10.43	Siegesbeckia orientalis	14.6	Eupatorium odoratum	35.52	Lantana camara	33.31
Spilanthes paniculata	6.85	Spermococe hispida	45.16	Lantana camara	18.21	Polygonum chinensis	9.14
Triumfetta	57.8	Urena lobata	27.4	Scoparia	45.9	Ranunculus	12.36

rhomboidea	8		4	dulcis	8	scleratus	
Verbena officinalis	25.82	Verbena officinalis	13.14	Solanum verbascifolium	42.63	Solanum xanthocarpum	17.86
Xanthium strumarium	35.12	Xanthium strumarium	32.74	Tridax procumbens	25.54	Triumfetta rhomboidea	13.89

Fig. 4 HEATMAP SHOWING ECOLOGICAL DOMINANCE OF TOP TEN SPECIES IN RUDERAL SITES OF FOUR SETTLEMENTS FROM MANIPUR.

The communities were recognized on the basis of the maximum dominant Importance Value Index at all the sites. A total of eight communities were identified.

The dendrograms in cluster analysis visually reveal the hierarchy of clusters formed during the analysis, indicating how data points are grouped based on similarity. It separates data into clusters by showing the merging or splitting of groups as the analysis progresses, from individual data points to a single large cluster or vice versa. Similarities are noticed by the distance between clusters on the dendrogram, with shorter distances indicating higher similarity. (Figure 5). As a result of urbanization, the types and frequency of terrestrial communities change within and between landscapes. Fig. 5 depicts the dendrograms of Imphal Agrestal Ruderal; Thoubal Agrestal, Ruderal; Bishenpur Agrestal, Ruderal & Churachandpur Agrestal, Ruderal sites favoring the growth of species with strong adaptability and high tolerance.The agrestal landscape located adjacent to rural areas reveals a very diverse landscape indicating an increase in species richness.



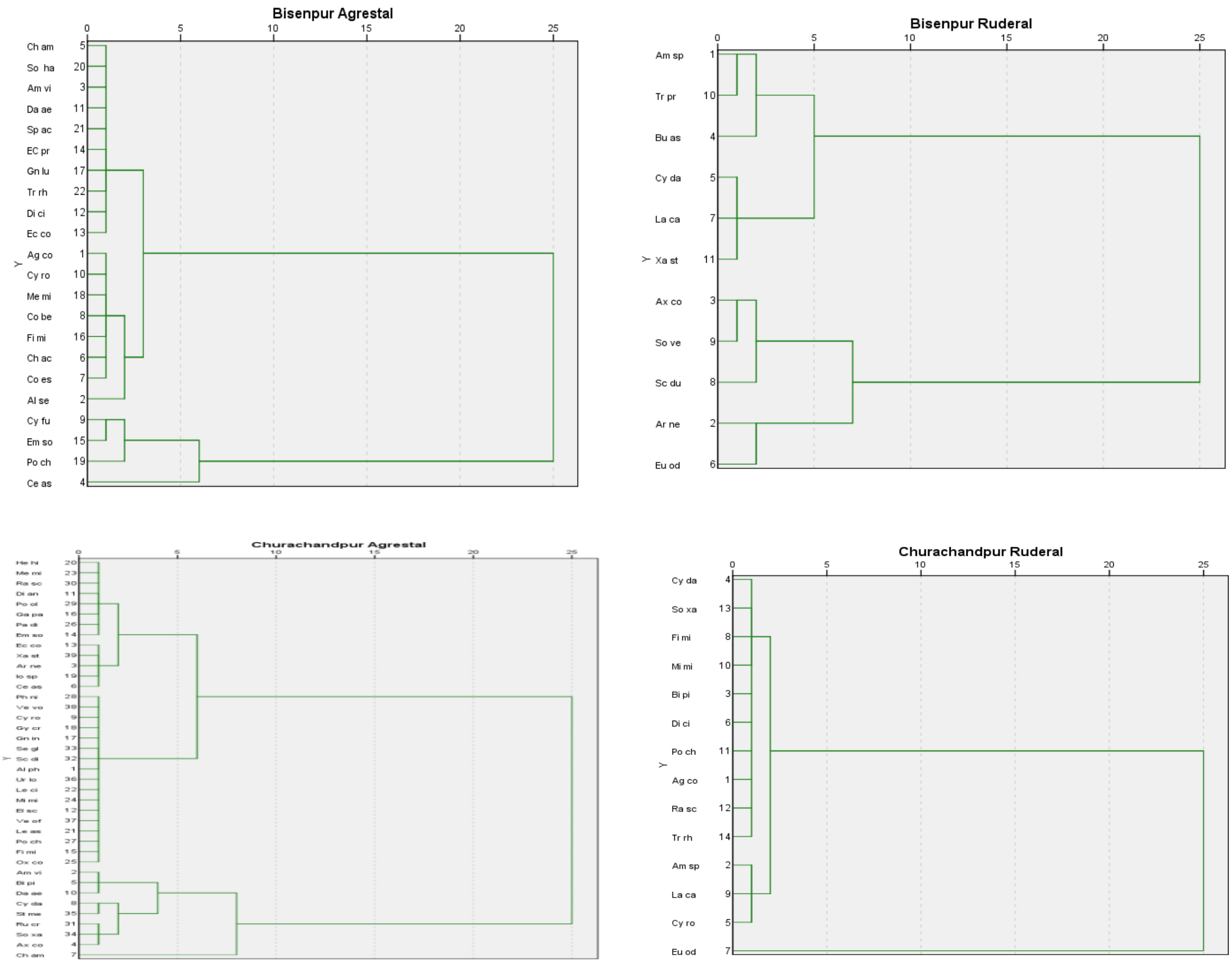


Fig 5 - Hierarchical clustering of herbaceous vegetation along the anthropogenic gradient in Manipur (for eight localities viz. Imphal Agrestal, Imphal Ruderal, Thoubal Agrestal, Thoubal Ruderal, Bishenpur Agrestal, Bishenpur Ruderal, Churachandpur Agrestal, Churachandpur Ruderal).

The statistical summary of edaphic variables for the two groups of herbaceous flora studied is given in Table 1a, providing the main values of edaphic variables along with their variance, standard deviation, and standard error. Table 1b depicts the discriminant analysis results. The discriminant function z was derived as:

Z = -541.74 Nitrogen + 26.10 Phosphorous + 0.33 Potassium - 75.11 pH + 53.80 Moisture

Where the numericals represent the vector of discriminant coefficients.

The Mahalanobis Distance (D^2) was found to be 250.53 between the two groups of vegetation. The centroids of the two groups were 431.70 and 181.17, thus all the sites were plotted along the discriminant function as per their reference scores on the discriminant axis. It was noted that all the localities were located around the group I and II reference scores (Fig. 6).

The relative percentage contribution of soil variables revealed that Phosphorous and soil reaction contributed relatively better in discriminating the two groups of herbaceous vegetation, while Nitrogen had a lower negative contribution in distinguishing them. The contribution of moisture was found to be lower in distinguishing the two groups of vegetation (Table 1c).

Table 1: A Simple Discriminant Analysis (SDA) Between Soil Variables from Two Groups from Sites along Anthropogenic Gradients in Manipur

(Group I - Agrestal Group II - Ruderal)

(A) BASIC STATISTICS FOR ENVIRONMENTAL VARIABLES WITHIN GROUPS

Group	Environmental Variables	Mean	Variance	SD	SE
I	Nitrogen	0.14	0.01	0.12	0.06
	Phosphorous	1.57	3.46	0.59	0.30
	Av. Potassium	7.11	88.13	9.38	4.69
	pH	5.90	6.82	2.61	1.31
	Moisture	6.75	27.77	5.27	2.64
II.	Nitrogen	0.10	0.00	0.008	0.004
	Phosphorous	1.04	1.57	0.39	0.19
	Av. Potassium	3.85	73.42	2.71	1.35
	pH	5.24	0.12	0.35	0.17
	Moisture	6.43	2.44	1.57	0.78

(B) RESULT OF DISCRIMINANT ANALYSIS

Discriminant Coefficients C_1 = -541.74; C_2 = 26.10; C_3 = 0.33;
C_4 = -75.11; C_5 = 53.80.
Mahalanobis distance D^2 = 250.53
Group Centroids on the discriminant axis:
Z_I = 431.70
Z_{II} = 181.17

(C) RELATIVE PERCENTAGE CONTRIBUTION BY SOIL VARIABLE.

Environmental Variable	Contribution
Nitrogen	7.6%
Av. Phosphorous	56.2%
Av. Potassium	4.3%
pH	40.1%
Moisture	7.0%

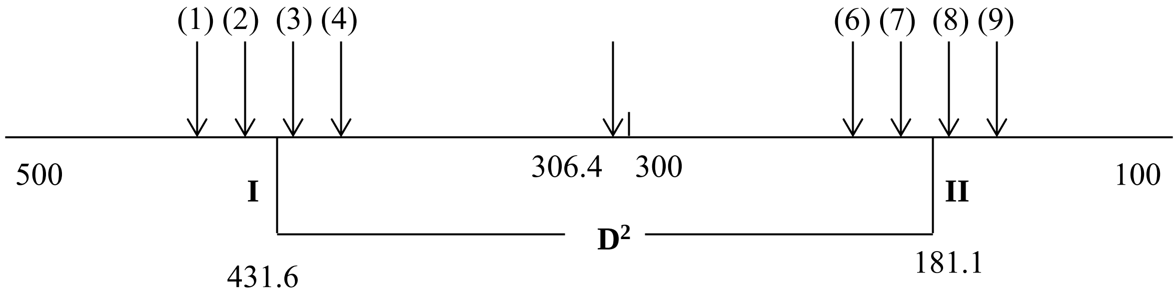


Fig. 6: The discriminant axis between group I and II showing reference score of 8 localities along the discriminant function. The Mahalanobis D^2 is also shown.

4 Discussion

Urban landscapes challenge species through human-driven processes [22] Species responses are expressed in traits that impact growth, reproduction and survival indirectly (functional traits) or directly as performance traits [23]. Understanding the dynamics of communities is crucial for predicting invasive species abundances and assessing invasion issues, including potential spread, to effectively manage bioresources [24]. We assess the vegetation composition, species' presence, diversity, richness and evenness along rural-urban gradients.

4.1 Species richness, community structure, and composition

Many species enjoy environment disturbed in various ways by human activities and well represented in both agrestal and ruderal sites like Ageratum conyzoides, Alternanthera philoxeroides, Bidens pilosa, Leucas aspera, Leucas ciliata, Mikania micrantha, Oxalis corniculata, Polygonum species, Potentilla species, Ranunculus scleratus, Solanum torvum, Solanum xanthocarpum, Spilanthes paniculata, Tridax procumbens and Vernonia volkameriafolia among dicots and Axonopus compressus, Commelina bengalensis, Cymbopogon flexuosus, Cynodon dactylon, Cyperus difformis, Cyperus rotundus, Dactylocetenium aegypticum, Dichanthium annulatum, Digitaria ciliaris, Paspalum distichum among the monocots.

Thus,the species present in both the agrestal and ruderal sites are subjected to the significant environmental stress that favors the growth of species with strong adaptability and high tolerance.

The component of the agrestal localities typical to agrestal habitats were Alternanthera sessilis, Amaranthus viridis, Chenopodium ambrosiodes, Colocasia esculenta, Cynoglossum furcatus, Dicrocephala latifolia, Eclipta prostrata, Emilia sonchifolia, Gnaphalium luteoalbum, Ionidium species, Phyllanthus niruri, Solanum verbascifolium, Spilanthes acmela, Stellaria media and Triumfetta rhomboidea among the dicots and Chrysopogon aciculatus , Echinocloa colonum, Fimbristylis miliacea, Melinis minutifolia and Sorghum halepense among the monocots . Guptaand Haobijam's study[25] on weed communities in Imphal East,NE India revealed that plants best adapted for unfavorable periods, such as those with underground carbohydrate reserves stored in the perennating parts, such as stolons, bulbs, tubers,and rhizomes, have a competitive advantage over associated species.

The most prominent ruderal species recorded were Alternanthera philoxeroides, Centella asiatica, Gynura crepidioides,, Hydrocotyle asiatica,Lantana camara, Leucas aspera, L .ciliata., Mentha piperata, Mikania micrantha, Polygonum hydropiper, Potentilla sp; Solanum toruum, Solanum xanthocarpum, Stachytarpheta indica,Xanthium strumarium which may be regarded as k strategists. among dicots and Axonopus compressus, Carex manipurensis, Commelina sp., Cymbopogon flexuosus and Dactyloctenium aegypticum among monocots. The communities recorded from ruderal sites include Stachytarpheta-Triumfetta, Spermacoce-Xanthium, Scoparia-Solanum, Eupatorium-Lantana from ruderal localities.

The growth forms existing in ruderal vegetation included erect branched prostrate giant tussock form, tussock form, prostrate tussock foliose rosette form and climbing form. The erect form comprised of Ageratum conyzoides, Artemisia vulgaris, Bidens pilosa and Eupatorium odoratum; the branched form comprised of Drymaria cordata, Stellaria media, the branched prostrate form included Borreria hispida, Oxalis corniculata, the giant tussock form comprised of Arundinella benghalensis, Imperata cylindrica, Saccharum spontaneum, the prostrate tussock form included Cynodon dactylon, Digitaria adscendens, Digitaria sanguinalis, Oplismenus compositus, Panicum repens, Paspalum conjugatum, Paspalum dilatatum, Paspalum distichum, the prostrate form was represented by Centella asiatica, rosette form by Oxalis corymbosa and climbing form as Milkania micrantha. The species tend to emerge in large number at the beginning of the rainy season.

Our findings reveal the predominance of equilibrium species or k strategist in ruderal urban system which with their adaptation allow persistence in the harsh marginal habitat with provision for vegetative multiplication and allocation to rhizomes, branches etc. Gupta and Haobijam's study [24] on weed communities in Imphal East,NE India revealed that plants best adapted for unfavorable periods, such as those with underground carbohydrate reserves stored in the perennating parts, such as stolons, bulbs, tubers,and rhizomes, have a competitive advantage over associated species.Understanding the dynamics of communities is crucial for predicting invasive species abundances and assessing invasion issues, including potential spread, to effectively manage bioresources [25] . The dispersal of some species between urban sites may be limited which contributes to a degree of isolation like those of ephemeral and aliens, as has been reported in isolated woodlands by Dzwonko and Lobster [26] . Küzmicˇ and Šilc[27] compared numbers of ruderal communities reported from various regions of Europe and found the correlation on the border of significance between the number of communities and size of the investigated area. The propagules of neophytes and exotics in urban environment might be supplied through transport and trade activities like packing material but the pool of species in urban habitat is limited with a number of ephemerals and hardy woody species predominating. It appears that in ruderal habitat, the species show a continuum of possible strategies between opportunists and equilibrium extremists.

Many species in ruderal group enjoy environment disturbed in various ways by human activities. Yet difference between rural and urban sites exist due to a variety of reasons. The heterogeneity of rural community may be due to the fact that with several stages of succession the vegetation changed with time on a given site. The seral changes noticed in the rural habitat over the gradient of time include from annual pioneer species to biennials and even to herbaceous perennials. The species composition includes the specialist species of surrounding ecosystem and the characteristic species of the ruderal habit. The species are r-strategist with provision of rapid multiplication and dispersal and which can make best use of available resources.

Our analysis revealed how urban landscape influences floristic similarity along the ruderal sites. Urban-rural gradient appears to be the most important environmental variable in our analysis, highlighting the effects of urban environment on habitat.

Accordingly, a large variety of specialized pl ant species, including invasive alien weeds a nd ruderal plants [also known as "urban speci alists"; [28], are found in urban environments . Urbanization also benefits several invasive species [29] , which due to the high propagule pressure, reduce the diversity of native species .

The Central European ruderal vegetation has shown a tendency of declining species variety and richness [30]. Furthermore, neophytes, or alien species introduced after 1500 AD, have become more abundant on average over time, according to several research [31]. In addition to the appearance of new communities with foreign species, Rendeková [32] claims that many once-widespread plant communities are now rare or have even vanished, reflecting shifts in the spectrum of ruderal communities. A higher percentage of alien species is known to be present in disturbed habitats, such as ruderal areas, than in other habitats [33]. However, the percentage of alien species varies in various ruderal habitats based on the degree of disturbance [34].

To evaluate the long-term consequences of urbanization on local biodiversity and ecosystem functioning, as well as to advise management, information is required on how the mechanisms determining species' responses (plasticity, adaptation, or extinction) operate along the different environmental gradients. Plasticity and adaptation are likely instrumental in ensuring the persistence of these urban-performant species.

Species predominant in ruderal sites were Amaranthus spinosus, Argyreia nervosa, Artemisia vulgaris, Buddleja asiatica, Eupatorium odoratum, Euphorbia hirta, Lantana camara, Solanum verbascifolium, Sida acuta, Siegesbeckia orientalis, Solanum xanthocarpum, Verbena officinalis, and Xanthium strumarium, which may be regarded as K strategists. Land transformation by humans inflicts multiple impacts on biodiversity [35]. Urbanization can result in the creation of unnatural and impermeable surfaces [36], leading to the establishment of unique plant biotic assemblages. In terms of plant diversity in urban areas, anthropogenic activities are responsible for the disturbance of natural vegetation and plant richness in urban settings.

High levels of anthropogenic disturbance, such as soil compaction [37], temperature and insolation [38], and drought [39], are experienced by urban ecosystems. Such pressures function as environmental filters, altering the species composition of plant communities [40] by promoting species with life strategies adapted to disturbances caused by urbanization. Community patterns are influenced by physiological tolerances and competition outcomes [41]. This suggests that deterministic assembly processes, like environmental filtering, may play a larger role in these communities' assembly than stochastic processes, like colonization [42].

The relation between the number of plant species and the type of settlement is obvious. In agrestal localities, an increase in the number of species was reflected. Whereas in ruderal areas, the homogeneous habitat offered by trade and anthropogenic activities and limited safe microsites resulted in fewer species. The dispersal of species between ruderal areas is limited, which may contribute to a degree of isolation. This is the case with rarely occurring ephemerals and aliens not capable of successful naturalization outside the city boundaries. The species in agrestal habitats, which represent plants within the agricultural landscape, is a function not only of area but also of the agrestal species diversity and degree of isolation, as has been reported in isolated woodlands by *Dzwonko and Lobster* [26].

The cropping effect opens almost unlimited possibilities for diversity, as random environmental hostility serves to reduce populations and gives comparable opportunities for other plants to invade. A few species are in very high population density. Our findings differ from those of Sukopp et al. [43], Sukopp and Werner [44], Pysvek [45], and Kowarik [15], who obtained urban sites as species-rich and heterogeneous. Our findings revealed an increase in the number of communities in ruderal habitat with a decrease in the value of H (Diversity Index). Though the occurrence of a species may be either an accidental or ephemeral event, still only those species for which environmental factors of the place favor are able to establish.

Increase in the number of species in agrestal sites as compared to the ruderal sites appears due to the presence of r strategists capable of rapid multiplication and dispersal, which can make the best use of available resources. Küzmicˇ and Šilc [27] compared the numbers of ruderal communities; they reported the correlation on the border of significance between the number of communities and the size of the investigated area. According to Rendeková and Micˇieta [32], changes in the spectrum of ruderal communities are reflected not only in the emergence of new communities with alien species but also in many once widespread plant communities that are now rare or have even disappeared. The propagules of neophytes and exotics in the ruderal environment might be supplied through transport and trade activities like packing material, but the pool of species in ruderal habitat is limited, with a number of ephemerals and hardy woody species predominating.

The pattern of increase in richness was found to be of the same type in different agrestal settlements. It appears that the increase in the number of species is reflected in a greater number of safe microsites and availability of propagules. The tussock grasses and species with strong rhizomatous systems resisting grazing and trampling pressure are predominant in rural systems. As the propagules are always resupplied from surrounding habitats like agro-ecosystems, the principles of island biogeography work to set a high species equilibrium. However, in ruderal habitat, the species show a continuum of possible strategies between opportunists and equilibrium extremists.

The functioning of agroecosystems depends on the flora that is specific to arable lands. Aggressive species provide food sources and habitat architecture for insect species that serve as pollinators or natural enemies of pest species [46,47]. Furthermore, a diverse flora may promote the cycling of nutrients, regulate the microclimate, or aid in the breakdown of toxic substances [48,49]. Compared to conventional fields, organic fields have a higher species richness of plants [50]. When there is less management intensity and more propagule pressure towards the edge of fields, plant variety is typically higher near field margins than at field centers, regardless of the kind of management [50].

However, in ruderal habitat, the species show a continuum of possible strategies between opportunists and equilibrium extremists. According to Chiuffo et al. [51], species origin interacts with disturbance type to determine dominance in communities with coexisting native and non-native ruderals.

Thus, structural heterogeneity may be an important factor for maintaining biodiversity.

Strategies for biodiversity inclusion in rural urban planning need to consider both local and neighborhood conditions.

It is remarkable that Manipur flora represented many elements of the world that have now become established. Thus, the ruderal flora showed the presence of elements from Europe (Chenopodium album, Polygonum persicaria, Senecio vulgaris, Solanum nigrum, Sonchus oleraceus, Spergulla arvensis, Stellaria media); from South America (Oxalis corymbosa, Paspalum dilatatum, Paspalum notatum, Scoparia dulcis); from the entire American continent (Acanthospermum hispidum, Ageratum conyzoides, Bidens pilosa, Tridax procumbens, Gallinsoga parviflora among Asteraceae, and Amaranthus spinosus, Euphorbia hirta, Oxalis corymbosa, Sida acuta among other dicots. Cyperus eragrostis, Cyperus haspan, Echinocloa crassipes among monocots), from Africa (Achyranthus aspera, Kyllinga species), cosmopolitan or pantropical species like Gnaphalium luteoalbum, Boerhavia diffusa, Datura stramonium, Heliotropium indicum, Oxalis corniculata, Portulaca oleracea, Sida cordifolia, Sida rhombifolia, Tribulus terrestris, Trichodesma zeylanicum, and Triumfetta sp., besides its endemic flora and Chinese, Burmese elements.

4.2 Diversity Measures

According to Münkemüller et al. [52], indicators that assess three distinct aspects of community diversity—richness, evenness, and beta-diversity, or variation in composition—can identify distinct patterns within a community and, as a result, may offer more insight into the possible mechanisms underlying resource supply and disturbance responses.

Species distribution is controlled by a combination of environmental and anthropogenic influences [6]. Changes in mean temperature along the agrestal-ruderal sites can also be an important factor, leading to changes in species diversity and the establishment of communities.

The Shannon-Weiner function is popular for measuring species diversity. The agrestal sites exhibited a Shannon–Wiener diversity index of vegetation with higher values, which may be due to the rich diversity of terrain and substrates, forming a rich variety of micro-habitat types that better support the diversity of plant communities compared to the conditions displayed by other habitat types. The agrestal patches can provide more significant edge effects, with more opportunities for introduction and dissemination, and suitable habitats for resource utilization.

The value of l (index of Co-dominance) increases in urban sites. Similarly, the value of evenness shows the same trend of increase in urban sites, except for Churachandpur, which reveals a higher value in the agrestal site. The increase of evenness in the Churachandpur agrestal site seems to be related to the co-dominance of the species out of the total species studied and their very similar nature of individuals compared to the remaining species. The number of native species was higher in agrestal localities, while exotics were more prevalent in the ruderal areas, indicating the influence of the type of settlement on the number and growth forms of the species.

Especially in light of the ongoing biodiversity crisis and global climatic change, it is crucial to understand how the alteration of ruderal regions due to increased urbanization affects occurrence and species composition, richness, and plant diversity that are associated with moisture, and how rural regions can uphold biodiverse landscapes and safeguard regional diversity to ensure vital ecosystem services along the anthropogenic gradient.

Community diversity may be impacted by the interaction between disturbance and resource availability; for example, higher disturbance frequency may only increase diversity when resource availability is high, and vice versa [53,54]. Variation in plant communities and species diversity is linked to environmental gradients, with community types varying in size. Vegetation patterns are influenced by factors like the physical environment, land use history, disturbance, and initial composition. The identified patterns reflect a shift in environmental variables, indicating how urbanization filters species displaying different traits [55].

Predicting when disturbance will decrease or increase biodiversity, especially as a restoration strategy, can be aided by investigating the interplay between disturbance and resource supply on plant community diversity. According to MacArthur and Wilson [56], the ability of these habitat specialists to colonize source populations in the surrounding landscape may be necessary for their survival in urban environments, thus enhancing the functional diversity of plant species in this type of ecosystem.

4.3 Community Classification, Cluster Analysis

Heatmaps aid in rapid data analysis, identifying patterns and trends, detecting anomalies, and enabling informed decision-making in various fields through their visual summary. The IVI of the generic names of the two most dominant species at a site is used as a community; thus, we identified eight distinct communities. The changing colors across the two axes reveal patterns in the IVI, and the variation in values of IVIs for the ten most dominant species in a column is due to the total number of species occurring at a site.

The communities recognized on the basis of the Importance Value Index were Vernonia-Emilia, Gnaphalium-Portulaca, Centella-Polygonum, and Chenopodium-Rumex from four agrestal localities, whereas Stachytarpheta-Triumfetta, Spermacoce-Xanthium, Scoparia-Solanum, and Eupatorium-Lantana were from four ruderal localities of settlements, namely Imphal, Thoubal, Bishenpur, and Churachandpur. Richness in agrestal sites is notable.

Communities are classified based on the dendrogram by cutting it at a certain level to separate the clusters and assign data points within those clusters to their respective communities. The agrestal sites show the dominance of agrestal species together with those occurring commonly at both agrestal and ruderal sites. Similarly, the ruderal sites indicate the predominance of ruderal species along with species common to both ruderal and agrestal sites. The cluster analysis is applied for the identification, classification, and analysis of communities along the rural-urban gradient at the eight sites. The proposed methodology allowed the modeling and classification of communities on the rural-urban gradient and the recognition of the key species sequences in the sites.

Thus, cluster analysis reveals that plant diversity is adversely affected by anthropogenic activities disturbing plant richness in urban areas, which may be due to a fragmented urban landscape. As a result of urbanization, the types and frequency of terrestrial communities change within and between landscapes. Anthropogenic activities are the cause of the disruption of natural vegetation and plant richness in urban settings, which negatively impacts plant diversity. Terrestrial ecosystem frequencies and types have been shown to vary both within and between landscapes. Anthropogenic disturbances cast significant influence on the diversity of herbaceous plants in urban sites. The community types in the rural-urban gradient reflect the variation in plant linkage due to their variation in richness, diversity, and abundances of adjoining species, resulting in unique plant assemblages. As species types and frequencies differ within and between sites, the units vary. The goal of cluster analysis is to gather unrelated individuals in various clusters. The agglomerative hierarchical cluster analysis is the technique utilized in this study to cluster (group) the data and to unite the units in a comparable state while taking into account their similarities.

Rapid urbanization may result in artificial and impermeable surfaces, which may contribute to the creation of unique land cover types and plant biotic assemblages affecting the movement of nutrients, water, energy, and organisms [34]. According to Williams et al. [57], understanding how the environment responds to urbanization is crucial for ensuring the long-term survival of nature. While evaluating the performance of an invasive species' environment, Czortek et al. [58] reported that the main factor influencing the performance of the invasive plant Solidago canadensis was habitat filtering, and to preserve nature and landscape values, greenery should be conducive to the development of ecosystem services. Bouchair [59] also mentions significant landscape fragmentation as a result of the substantial increase in human disturbance in the recent decade, causing consequently dwindling native plant variety [60].

4.4 Discriminant Analysis

The discriminant analysis has revealed that habitat heterogeneity is an important differentiating factor in discriminating the herbaceous vegetation along anthropogenic gradients. The species richness and diversity indices of the ruderal habitat group are relatively low, which may be mainly related to the limitations of urban soil characteristics or other environmental pressures. From the perspective of geographical composition, the ruderal vegetation is mainly characterized by tropical geographical components. This may be due to global warming and the urban heat island effect, which have led to an increase in local air temperature in cities, allowing vegetation with tropical components to colonize and further affect the distribution of ruderal diversity to varying degrees in different sites. Results show that agrestal sites provide more resources, allowing for more opportunities for colonization and dispersal. Thus, it can be concluded that there has been tremendous pressure on the herbaceous flora, particularly from anthropogenic influence in the ruderal habitat.

The discriminant analysis indicated significant differences between environmental variables in different habitat types within two groups, indicating that targeted protection and optimization measures are a necessity in urban habitats for biodiversity planning.

For the preservation of plant diversity in urban landscapes, this study recommends the development of green areas. The study suggests how edaphic factors vary in rural-urban settings, paving the way for further detailed research to understand the mechanisms underlying urbanization and plant diversity.

5 Conclusion

The study found that urbanization significantly affects the richness, diversity, dominance, and evenness of herbaceous plant species. The agricultural landscape is richer in species richness, diversity, and dominance than the urban landscape. The physicochemical characteristics of soil, fragmentation, and limited availability of pervious spaces—all typical of the urban landscape—are the causes of a decline in plant diversity in urban locations. According to the study's findings, anthropogenic stresses and disturbances have a stronger effect on the diversity of herbaceous plants in urban areas. As a result, improved urban landscape planning can aid in the conservation and maintenance of plant diversity. By maintaining biodiverse landscapes and regional diversity, rural-agrestal areas can ensure essential ecosystem services along the anthropogenic gradient.

Various anthropogenic pressures may alter the composition and species diversity. It is anticipated that this fact will be used in the planning and policy-making process for the sustainability of green zones along the anthropogenic gradient in the rural-urban sites so that the ecosystem services provided by these unique sites may be preserved for posterity.

Urban areas are more likely to have exotic species, be more disturbed, be under more development pressure, and have soils with lower levels of moisture and nutrients. More long-term research may provide solid insights into how change drivers, such as disturbance and biotic interactions, interact to shape community types and composition.

Acknowledgement:
The author wholeheartedly thanks the three anonymous reviewers whose criticisms and constructive suggestions helped to a great extent in the improvement of the present paper. The author also acknowledges the Head of the Centre of Advanced Study, Department of Life Sciences, Manipur University, for the facilities.

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