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RESEARCH ARTICLE

# Remnant vegetation in farmland - its significance in ethnobotany and local ecosystem

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## Abstract

This paper evaluated the structure of remnant vegetation (RV) in and around the farmlands of the undivided Kancheepuram District, Tamil Nadu of Southern India, to understand its significance in the local ecosystem. Stratified quadrats along nine randomly selected transects were used for sampling vegetation. The study recorded 2495 specimens of 96 plant species under 43 families in 1848 quadrats (88 of 10 m × 10 m, 352 of 5 m × 5 m and 1408 of 1 m × 1 m dimensions) while there was a possibility of recording more species with better sampling efforts. To know the ethnobotanical uses of plants, interviews were conducted with local villagers and people belonging to the Irula tribe, and later the data were collated with published information. Sixty -six plant species were recorded with traditional uses in food, fodder, fuel, condiment and medicine. *Prosopis juliflora*, an alien invasive species, was a serious threat to the native flora since higher *P. juliflora* abundance was associated with declining diversity of other plants. The study found that the absence of monitoring and management protocols leading to uncontrolled propagation of invasive species could cause potential damage to the region's dry evergreen forests, which were often located near the farmlands.

## Keywords

ethnobotany, farmland, remnant vegetation (RV), native biodiversity, invasive species

## Introduction

Currently, farmlands are the predominant landmasses in the world, occupying over 38 % of the total terrestrial areas, and they are most likely to increase in size, especially in tropical countries where they often replace forested ecosystems or are placed within 100 m distance from the forests (1-3). For their vast sprawl and impact on diminishing local biodiversity, farmlands have long been among the significant conservation concerns for ecologists (4-6). Even though, studies on the significance of non-crop biodiversity in farmland habitats, are gaining wide concern, references from the global south are still scanty (7-10). Uncultivated patches with natural or semi-natural remnant vegetation (RV) can be found inside or around farmlands and are globally referred as shelter-belts, hedgerows, vegetative strips or field-margin vegetation (10, 11). Significance of such habitat patches is many-folded including maintenance of β-diversity including useful predator, prey and pollinator species beneficial to farming activities, water and nutrient retention, delineation of farming areas and food security(12, 13).

India's cultivated lands have increased almost fourfold in the past 3 decades (14). At present, they occupy over 60% of the total landmass. Though India has opted for policies like the National Mission for Sustainable Agriculture (NMSA) to combat adversities caused by extreme climates and intensive farming, not much attention is paid towards effective mitigation like heterogenous agrobiodiversity in farmlands by maintaining RV (15). Farmlands in India are often associated with protected areas (PA), thus any change in species composition in the former can significantly influence the native biodiversity, including endemic endangered or vulnerable species (16, 17). It is also a global concern since 70% of forests are found within 1 km of the forest edge (18). Recent studies in India have identified 'invasive species hotspots' located in close association with PAs and farmlands, which endanger health of the native species (19, 20). *P. juliflora* - once introduced for fencing and firewood in arid regions of India, is one of the invasive alien species to get negative feedback from farmers and pastoralists for the unmanageable invasion in functional land areas (21). However, possible impacts of *P. juliflora* on RV in India, has not been documented yet.

RV along farmlands growing annual crops in India often comprises of plant species fundamental to local ecosystems, cultures, traditional practices and economy though very little research has been done on that (11, 22, 23). Such studies are crucial in assessing effective local management practices that address specific problems integral to target areas (24-26). Keeping these points in mind, the current study recorded the structure of RV along paddy fields in the undivided Kancheepuram District in Tamil Nadu of southern India and critically evaluated its importance on local biodiversity and ethnobotany.

## Study area

Fieldwork was conducted over a fortnight in April 2011 at the undivided Kancheepuram District of Tamil Nadu, Southern India (11.00' to 12.00' N and 77.28' to 78.50' E). The district was later divided into Chengalpattu and Kancheepuram in 2019. Study areas were situated on the north-eastern coast of Tamil Nadu, adjacent to the Bay of Bengal. The elevation of the area ranges from 100 m ASL in the west to sea level in the east. The major part of the area is characterized by an undulating topography with innumerable depressions, which are used as irrigation tanks. The coastal plain displays a gently rolling surface and only slightly elevated above the local water surfaces on rivers. There are few sand dunes in the coastal tract. The coastal landforms include estuarine tidal, mud flats or lagoons and salt marsh. Soil in the area are 1) Clayey 2) Red sandy and 3) Alluvial, of which brown clayey soil is the predominant, covering more than 71% of Kancheepuram District. Alluvial soils are found along the banks of rivers. Sandy coastal alluvial soil occurs along the seacoast as a narrow belt. Agricultural land comprises 56.82% of the total area followed by barren land (13.08%) and water bodies (14.77%).

The study was confined to agricultural fields, predominantly cultivating paddy and occasionally pulses, groundnuts or vegetables. Post-harvest farmlands, barren lands used for farming in the past were also considered.

The study area generally experiences hot and humid climatic conditions. The average minimum and maximum temperatures are 20 °C and 38 °C respectively. The daytime temperature may reach as high as 43 °C in summer. The mean maximum temperature was 39 °C in May and mean minimum temperature was 21 °C in January during the year when the study was conducted.

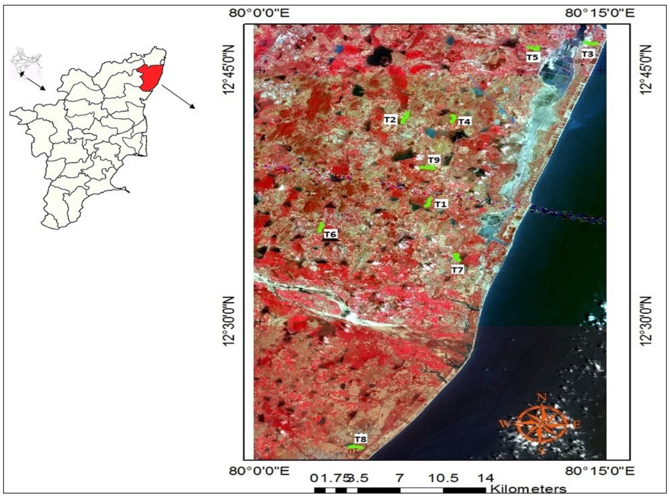


**Fig. 1.** Map showing the study area (IRS Liss III image 2012) in the undivided Kancheepuram district of Tamil Nadu and the nine sites where stratified quadrat samplings were done along fixed transects.

## Data collection

Species composition and diversity of the RV were recorded by stratified quadrat sampling (27) along 9 randomly selected 1 km transects (Fig. 1). Quadrat plots measuring 10 m × 10 m were laid along each transect (Fig. 2). Inside each 10 m × 10 m quadrat, 4 quadrats measuring 5 m × 5 m were set at 4 corners to sample the shrub species. To document the herb species, four 1 m × 1 m quadrats were set inside each 5 m × 5 m quadrat. In total, 1848 quadrats were sampled, covering all 9 transects. Ethnobotanical usage of various plant species was recorded by focus group discussions and semi-structured interviews among 52 respondents including the local villagers and the Irula tribal community (28). Prior Informed Consent (PIC) for sharing tradi-

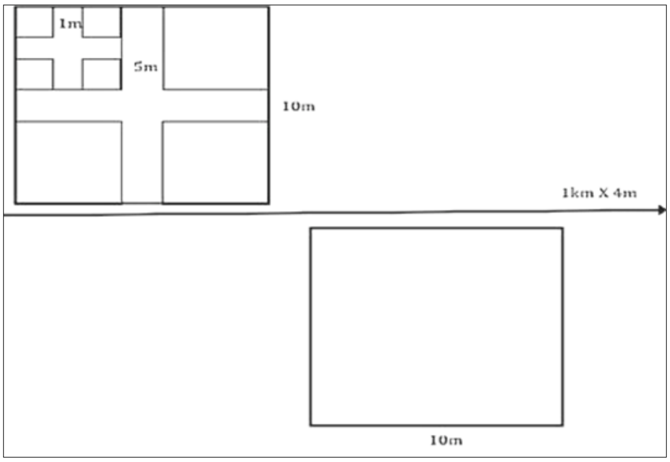


**Fig. 2.** Transact-based quadrats for sampling vegetation.

tional knowledge on biological resources was obtained through the Irula Snake Catcher's Industrial Co-operative Society (ISCICS), Tamil Nadu. The available literature on the uses of plants recorded during the samplings was also referred to.

The vegetation data were separated into two major groups - tree and non-tree. Woody plants with Girth at Breast Height (GBH) more or equal to 10 cm at 1.3 m height from the ground were classified as trees, and lianas had ≥ 1cm diameter at 1.3 m from the stem base (29). Different life forms of plants, including climber, twiner, shrub, undershrub and herb were documented considering growth forms relevant for the study area, and species-level identifications were primarily made based on Mathew (30, 31). Taxonomic identification of plants done in the field was reconfirmed using photographs. Variables recorded for all plants were species name, family name, the total number and local usage.

### *Data analyses*

Richness, evenness and relative abundance of the flora were estimated to understand the ecological diversity of the sampled vegetation (32). The software SPADE (33), PAST (34) and Microsoft Excel (version v12) were used to compute the following diversity estimators -

1) Richness estimator:

Chao1-bc or the bias-corrected estimator for

Chao-1: $$\hat{S} = D + f1(f1 - 1)/[2(f2 + 1)]$$

was used because the sampling involved abundance-based data. It was assumed that there were probabilities for more species in the study area despite the best sampling efforts.

2) Rarefaction curve was the statistical expectation of the number of species as a function of the accumulated number of individuals found through several sampling efforts (35). The curve helped understand if more sampling efforts would increase the number of species.

3) Diversity index was the estimator combining species richness and evenness. Shannon diversity (36) was calculated with the Chao1-bc richness estimator considering equal detection probability for all species. Diversity indices for all nine sites were later compared with the total number of *P. juliflora* to find if the latter had an impact on species diversities.

Shannon's index $$(\hat{H}) = -\sum_{k=1}^{n} f_k \frac{k(1-\frac{f_1}{n})/n)\log[k(1-\frac{f_1}{n})/n]}{1-\left[1-\frac{k\left(1-\frac{f_1}{n}\right)}{n}\right]^{n}}$$

4) Morisita index was used as a similarity measure and was expressed as C_qN Where N communities were compared based on species information shared by at most q communities (37). Here, the index was used to compare similarities in species diversity between the sites.

S=total number of species; $x_i$=the number of individuals (frequency) when the ith species was observed in the given sample; n=sample size; $f_j$= the number of species present j times in the sample; D= the number of distinct species; both the rare and abundant groups were covered in the total sample and in the number of distinct species; k=the cut-off point of 10 separating the 'abundant' and 'rare' group of species; $Q_k$=the number of species seen in k samples based on 'presence absence' data.

## Results and Discussion

Agricultural fields under the survey had certain human-made features for facilitating cultivation (high and low bunds, well-tailing mounds) which later supported thick vegetation including big trees such as *Azadiracta indica*. A good mosaic of RV were observed in all these structures and around the farmland borders. A total of 2495 specimens of 96 plant species under 43 families were identified from all the quadrat plots (Supplementary Table 1). Among these predominant were undershrub and shrub species (n=38) followed by trees (n=30), climbers and twiners (n=24) and herb species (n=4). A high Chao1-bc richness estimate of 110.4 (± 8.7 SE) and different life forms found during the limited span of the study indicated a heterogenous plant diversity in the area (Supplementary Table 1 & Table 1). Among the 43 families, Malvaceae was the most species-heavy (n=11) with maximum numbers of medicinal plants. Malvacecae is considered to be one among the most over-utilized plant family in the world and its pharmacological significances are also known for many years (38-40). Apocynaceae and Fabaceae were the 2 other families rich with 10 species each, representing various life forms including undershrub, twiner, climber- many of which had medicinal properties. Moraceae, Mimocaceae and Areceae were the three primary families with trees and were often planted or protected by the farmers for socio-cultural-economic significances. A total of 66 plant species were recorded with various ethnobotanical usage.

Many native plant species among these were used by the local Irula tribal community for treating various ailments, including critical health emergencies like snake-bite. The Irulas directly consumed different parts of a few plant species for their medicinal properties and also used them in cooking. Some plant species were integral to the Irulas and local villagers since they served as food, fodder and fuel; many were worshipped as sacred and widely planted to serve as shade trees (Supplementary Table 1). Compared to the local villagers, Irulas consumed fruits of many native plant species like *Carissa spinarium*, *Phoenix spp.*, *Opuntia dillenii*, *Guazuma ulmifolia, Pandanus odorifer, Streblus asper, Ziziphus oenoplia* and *Glycosmis pentaphylla*. Besides this, wide usage of plants like *Cocos nucifera, Borassus flabellifer, Moringa oleifera, Pithecellobium dulce* were common for all the local inhabitants of the area alike (Fig. 3). Despite the diverse usage of *M. oleifera* in local cuisine and medicine, the number of trees in the study area was considerably low, making it a suitable species for future plantation initiatives. *Cissus quadrangularis* had specific ethnographic usage in some caste rituals, although Irulas used this plant and leaves of *Carmona retusa* in their culinary preparations mostly because of their medicinal attributes. Another locally available climber, *Mukia*

**Table 1.** Richness, diversity and similarity of plant species found in nine sampling sites. Pairwise comparison between Morisita similarity indices of two combination sites revealed that species diversity indices were most similar between sites 1 and 7(0.76±0.05).

| Cumulative sp. richness | Richness Estimator (mean) | Estimate for sp. Richness (± SE) | Number of shared sp. in two sites | Diversity Estimator C29 (pair wise comparison) | Estimate / Est_Standard Error | |
|---|---|---|---|---|---|---|
| 95 | Chao1-bc | 110.4 ± 8.7 | D12=14 | C22(1.2) | 0.51 | 0.06 |
| | | | D13=14 | C22(1.3) | 0.1 | 0.02 |
| | | | D14=11 | C22(1.4) | 0.21 | 0.04 |
| | | | D15=15 | C22(1.5) | 0.35 | 0.06 |
| | | | **D16=17** | C22(1.6) | 0.68 | 0.06 |
| | | | D17=16 | **C22(1.7)** | **0.76** | **0.05** |
| | | | D18=13 | C22(1.8) | 0.35 | 0.05 |
| | | | D19=6 | C22(1.9) | 0.1 | 0.02 |
| | | | D23=9 | C22(2.3) | 0.03 | 0.01 |
| | | | D24=12 | C22(2.4) | 0.43 | 0.05 |
| | | | D25=12 | C22(2.5) | 0.44 | 0.06 |
| | | | D26=12 | C22(2.6) | 0.35 | 0.05 |
| | | | D27=13 | C22(2.7) | 0.47 | 0.05 |
| | | | D28=12 | C22(2.8) | 0.45. | 0.05 |
| | | | D29=7 | C22(2.9) | 0.21 | 0.04 |
| | | | D34=6 | C22(3.4) | 0.03 | 0.01 |
| | | | D35=11 | C22(3.5) | 0.35 | 0.07 |
| | | | D36=12 | C22(3.6) | 0.1 | 0.01 |
| | | | D37=11 | C22(3.7) | 0.06. | 0.01 |
| | | | D38=11 | C22(3.8) | 0.04. | 0.01 |
| | | | D39=6 | C22(3.9) | 0.04 | 0.01 |
| | | | D45=12 | C22(4.5) | 0.64. | 0.06 |
| | | | D46=9 | C22(4.6) | 0.45 | 0.05 |
| | | | D47=10 | C22(4.7) | 0.34 | 0.05 |
| | | | D48=8 | C22(4.8) | 0.66 | 0.05 |
| | | | D49=6 | C22(4.9) | 0.57 | 0.05 |
| | | | D56=11 | C22(5.6) | 0.54 | 0.06 |
| | | | D57=14 | C22(5.7) | 0.51 | 0.06 |
| | | | D58=11 | C22(5.8) | 0.7 | 0.06 |
| | | | D59=7 | C22(5.9) | 0.55 | 0.06 |
| | | | D67=16 | C22(6.7) | 0.74 | 0.04 |
| | | | D68=11 | C22(6.8) | 0.45 | 0.05 |
| | | | D69=10 | C22(6.9) | 0.37 | 0.05 |
| | | | D78=13 | C22(7.8) | 0.35 | 0.05 |
| | | | D79=6 | C22(7.9) | 0.26 | 0.04 |
| | | | D89=5 | C22(8.9) | 0.57 | 0.05 |

*maderaspatana,* named after the capital city of Tamil Nadu (Madras), had specific culinary usage among the locals who were aware of its healing properties against the common cold. Villagers were aware of the medicinal properties

A B

C

D

E

F

**Fig. 3**. A farmland in the study area showing (**A**) RV bordering the rice paddy cultivation, with diverse native flora providing ecosystem services like (**B**) *Anisomeles malabarica*; (**C**) *Cayratia trifolia*; (**D**) *Solanaum trilobatum*; (**E**) *Calotropis gigantea* with usage in traditional medicine and (**F**) *Borassus flabellifer* (leaf) serving as platter to an indigenous Irula family to enjoy cooked food in field.

of locally available trees, shrubs and herbs like *Azadirachta indica, Vitex negundo, Corymbia citridora, Achyranthes aspera*, *Cardiospermum halicacabum, Solanum trilobatum*. *A. indica* was considered sacred for the majority of Hindu communities and it had an important place among the Irulas as 'Kanniamman' or the 'snake goddess' whom they ardently worshipped. Extensive samplings conducted over different seasons, would probably reveal additional information on the local plant species like *Rauvolfia tetraphylla* or *Andrographis paniculata* which have important ethnomedicinal usages (41-44).

Local usage also varied for the distribution of plant species in the area which changed according to the soil salinity and land use. Morisita similarity index for species diversity was found to be high between sites- 1, 2, 4, 6 and 7 rather than sites- 3, 5, 8 and 9 (Supplementary Table 1). The proximity to the sea and inadequate rainwater harvesting systems made sites like 3, 5 and 8 less species diverse compared to those with ample water resources. Site 9, although placed away from the shoreline, was found to be the least species-rich. Considering the asymptote in the rarefaction curve, it was assumed that plant species richness would not increase there even with greater sampling efforts (Fig. 4). This could be due to local practices of eradicating native vegetation at the cost of alien invasive species like *P. juliflora* which served as fuelwood or fodder and restricted the propagation of native species for the strong allelopathic and allelochemical properties (45). Since plant species richness is directly proportional to species abundance and diversity, the sites with single-species domi-

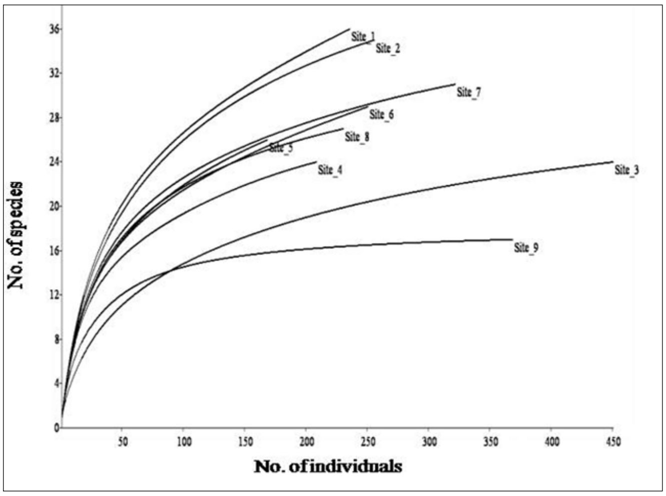


**Fig. 4.** Individual-based rarefaction curve showing species accumulation pattern (cumulative) for plants recorded in nine sites. Sites 1, 2, 4-8 had the potential for higher species richness with bigger sample sizes or more sampling efforts.

nance showed lower species diversity. A similar situation was also observed at site 4. The main reason contributing to low species diversity at both the sites were due to local practices of managing RV and frequent clearing and burning of 'apparently unwanted wild plants' which added to the amount of harmful greenhouse gases. Mainstreaming large scale biodiversity conservation requires active involvement of local stakeholders, aware of the ecological services or disservices associated with the landscapes they manage. The above findings strongly suggest that farmland associated RV can be managed by frequent monitoring and preservation through a more participatory approach from the landowners and policy makers alike (46).

The two most abundant plant species found in all the sites were *P. juliflora* (n = 284) and *P. odorifer* (n = 282), closely followed by *A. indica* (n = 176), *Morinda pubescens* (n = 141) and *B. flabellifer* (n = 137). Other plants found in significant numbers were undershrubs and shrubs like, *V. negundo* (n = 120), *Ipomoea carnea* (n = 109), *Lantana camara* (n = 104), *C. retusa* (n = 75) and *Hygrophila auriculata* (n = 64). *P. odorifer* was found to form natural clumps in fields, most of which were not cultivated for a while. *P. odorifer* showed almost equal distribution in all the ten quadrats laid at two sites closely placed to the seashore and often in close proximity with saltpans. The sandy brown soil with higher salinity, supported specialist species like *P. odorifer*. Such plant species are often found in high density along with water bodies in coastal areas and the complex structure of their aerial roots like that in *Pandanus* are advantageous in preventing land erosion against natural calamities like tsunamis (47, 48).

Most sites with a high diversity of native plants as RV, also had farming activities round the year as per observations and information collected from the local farmers. However, the data was not quantified scientifically. This observation indicated that RV did not impose any negative impact on the overall functionality of farmlands and the average yield (Fig. 3), as was also observed by Rey Benayas and Bullock in a European context (49). Maintaining native plants along field margins is beneficial for local biodiversity, pest control, crop pollination, better water retention and soil quality, food/nutrition security and additional ecosystem services (50-53). Few particular tree species like *A. indica*, *Ficus benghalensis*, *Ficus religiosa*, *Pongamia pinnata* received local attention due to their religious affiliations and importance to serve as effective shade trees for the farmers, agriculture laborers or pastoralists. Locally abundant tree species like *B. flabellifer* were preserved for their integral connection with local socio-cultural and economic environment. Almost all parts of *B. flabellifer* including tender root, tender and ripened fruit, stem, bark, leaf and inflorescence were used as food, condiment, beverage, medicine, fuel, building/thatching material and craft (Fig. 3). But other than a few eminent species like these, local farmers of the present days, were unaware of the diverse prospects of farmland associated RV including their potential in aiding to annual crop yield and livelihood options (54, 55). The study area did not have any major crop-raiding species which would use farmland associated vegetation for shelter and thus add to ecological disservice. Instead beneficial species crucial in maintaining ecosystem balance including snakes, amphibians, insectivore birds, Indian grey mongoose, golden jackal etc were found in such habitat patches. The importance of preserving RV along farmlands has been emphasized since a long time (56) though, such resolutions are not reflected in the agriculture policies of India. This coupled with declining resilience towards wildlife and less dependence on native plants for food or nutritional supplement, often lead to the complete removal of RV in and around farmlands. India currently has an estimated 110 million Ha of agricultural area with RV which, if properly managed, can support considerable biodiversity in agroecosystems despite the alarming habitat loss threatening the country's natural heritage, help to achieve India's 'Conference Of the Parties -21' and Sustainable Development Goals by increased carbon sink and sustainable agriculture, enhance food security and secure traditional knowledge which otherwise may be lost over time(15, 57).

Higher abundance of farmland associated *P. juliflora*- an alien invasive species to India was identified as a threat to the local ecosystem. The species was favoured by the local people mostly because of services provided as firewood or fodder When the number of all other species and *P. juliflora* were computed, it was evident that sites with higher *P. juliflora* abundance, supported less number of all other plant species (Fig. 5). This also affected the overall plant species diversities in the concerned areas. Site six (Shannon index 2.75) and Site two (Shannon index 2.97) showed almost similar compositions of plants as Site seven (Shannon index 2.83) and Site one (Shannon index 3.03). All these sites were species diverse and had more native plants than *P. juliflora* (Fig. 5).

Human practices are known to exert direct and long -term effects on local plant diversities which often have global consequences (58). As an example, *P. juliflora* -once introduced in India for specific ecological services, is currently detrimental to native flora and fauna (59). *P juliflora* is adept to propagate in a variety of habitats including

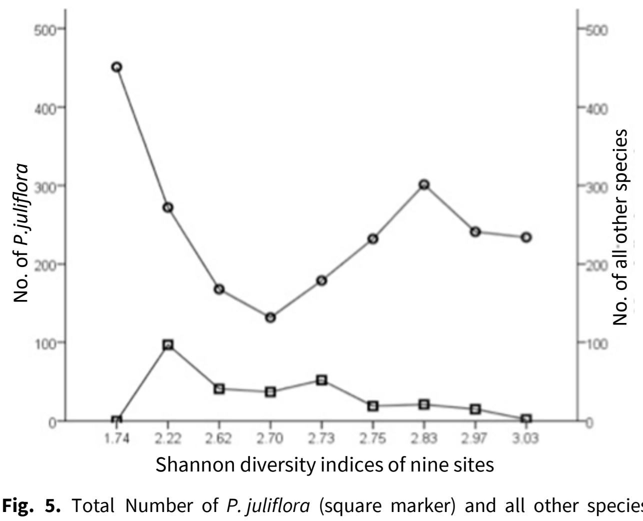


**Fig. 5.** Total Number of *P. juliflora* (square marker) and all other species (round marker) plotted against the consecutive Shannon (MLE) diversity indices of nine sites. Most cases, higher Shannon index were related to lower abundance in *P. juliflora* and higher abundance of other plant species.

farmland associated RV patches and shows high dispersal through local inhabitants and livestock (60). A recent study in the Pudukkotai district of Tamil Nadu found *P. juliflora* to occupy 94% of the total geographic area (61). It also found that *P. juliflora* invaded more in the agricultural fallow lands along the water bodies, and thus had the capacity to quickly propagate into the neighbouring districts. Since the current study area was adjacent to the dry evergreen forests in the undivided Kancheepuram district, there were chances of *P. juliflora* invasion inside the PAs if not monitored regularly (62). There is an urgent need to create awareness among various stakeholders since *P. juliflora* is not only harmful to the native biodiversity but also to livestock grazing, crop production, groundwater level, economy and human health (63, 64). Without region-specific studies on *P. juliflora* and management practices to arrest further spread of the species, there is ample scope for irreversible damage to the local ecosystem since future climatic conditions in India, are predicted to favour fast proliferation of this species throughout the country (65). Further detailed studies to determine the regeneration rate of *P. juliflora* in the study area, future probabilities of invasion and its impact on ecological health, remain essential.

## Conclusion

Falling broadly under the same physiographic zone, nine sites selected to study the RV along farmlands in undivided Kancheepuram District in Tamil Nadu, showed differences in plant species richness and diversity based on various factors including proximity to sea or extent of salinity in the soil, agriculture practices and localised management. The species composition of the RV represented plants under diverse life forms and families which provided important ecological services to the area. A total of 66 among 96 recorded plant species in the RV were integral to the local villagers and the Irula tribal community as food, fodder, fuel, therapeutic resource, religious symbols and other socio-cultural or economic provisions. Hence, proper management of the RV had significant potential to maintain a heterogenous and sustainable agroecosystem in the area while securing biodiversity and related traditional knowledge. Certain localized practices like burning and clearing of useful RV and preference for alien invasive weeds like *P juliflora* were found to be detrimental not only to the native plant diversity but also to the local ecosystem including the nearby tropical dry evergreen forests. The study indicated 1) the urgency of more participatory research involving the local stakeholders into understanding attributes of the RV along farmlands and 2) the need to apply suitable policy decisions in small scale agriculture practices.

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## Authors contributions

DGD carried out the project work by identifying the study area and human resources, finalized methodology, collected and analysed data and drafted the manuscript. SB helped in collection, organization of data and taxonomic identifications of the plant species. PC identified suitable methodology to sample vegetation, helped in data curation and identification of plant species and prepared the detailed map of the study area. CV provided necessary resources, conceived of the study and participated in its design and coordination. PPNR conceived of the study, helped in drafting the manuscript. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest**: Authors do not have any conflict of interests to declare.

**Ethical issues**: PIC for sharing traditional knowledge, was obtained from the Irula members of the ISCICS. In case of any commercial usage of data provided here, the State Biodiversity Board of Tamil Nadu must be informed as per the Biological Diversity Act (2002). Irula members associated with ISCICS retain the right to any commercial profit which may derive from the information provided in this article.

## Supplementary data

Supplementary Table 1: Total number of plant species recorded in all quadrats. Family, life form and ethnobotanical/local usage of each species is mentioned. Literatures are referred for the data collected on 'local usage'(35, 36)

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