

Species-area Curves of Native Species in Sal Forest of Chota Nagpur Plateau, India

Chandravir Narayan*, Anshumali and Bijendra Kumar

Laboratory of Biogeochemistry, Department of Environmental Science and Engineering, Indian Institute of Technology (Indian School of Mines), Dhanbad–826 004, Jharkhand, India; chandravirnarayan@gmail.com, malijnu@gmail.com, bijendra2k8@gmail.com

Abstract

Objectives: To evaluate species-area relationship of the sal (*Shorea robusta*) dominated tropical dry deciduous forest of Chota Nagpur plateau, India. **Methods/Statistical analysis:** One hectare (ha) plot was selected in which quadrats of 10 m x 10 m size were equally disturbed. In each specific quadrant, the number of species and density of adult trees was determined. Species-area relationship was analyzed by plotting an increasing number of species as a purpose of plot size. The Species-Area Relationships (SAR) were compared by using the Power curve, the Exponential curve, and the Logistic curve. **Findings:** The major finding in terms of density comprises of 436 adult stems having a diameter greater than and equal to 9.6 cm, 874 saplings having a diameter greater than and equal to 3.2 cm but less than 9.6 cm, and 6147 seedlings having a diameter less than 3.2 cm in one ha. The observed species-area curves were firstly steep, followed by continuing species accumulation. Where curves were best fitted by the power model because of low P value (possibility underneath the null hypothesis), high F ratio (regression mean square more the error mean square) and high Ra^2 (adjusted coefficient of determination) representing one ha study area. Moreover, the high P value, low F ratio, and low Ra^2 of exponential and logistical models showed an extreme deviation from the observed fashions of species-area for the plant species. In this study, the Z-value decreased with increase in C-value, indicating both were directly fitted constant and autonomous of biotic and a biotic features of the study area. **Application/Improvements:** The species-area relationships expressed distinct habitat heterogeneity and dispersal constraint of plant species in the *Sal* forest.

Keywords: Exponential Curve, Logistic Curve, Power Curve, Sal Forests, Species-area Relationships

1. Introduction

Globally, the tropical forest area was 52% of the total forests, and about 42% of this forest were categorised as dry forest¹. The dry forests have had a long history of human use² and consequently, are more threatened and less protected than moist and wet forests³. Species diversity was an important index in community ecology⁴. Recognition was made by essential observations of the specimen and examination of relevant literature⁵. It is now

globally well-know that forests would be managed in an ecologically sustainable environment^{6,7}. For conservation management practise, deciphering the information about floristic composition were an added advantage for any ecological and phyto-geographical studies^{8,9}. The species composition and diversity can be used as indicators of past management preparation in forest areas^{10,11}. Degraded plant communities were frequently somewhat difficult or occasionally unfeasible to bring back¹²; Similarly, due to the constant disturbances, there

*Author for correspondence

was a reduction in the number of species and their composition¹³. The formal primary trend in which the total number of species rises with a rise in the assessed area. Interpreting previous works^{14,15} and enacted accordingly as the species-area curve¹⁶⁻¹⁹. This increase of species number with the area would be found in few laws of ecology²⁰ and making these curves would be the first extent of ecological forms. The rise in a number of species arises almost for two main reasons; firstly, as more individuals was sampled, the chance of meeting more species increases, especially if species were not arbitrarily distributed, and secondly, a large area is anticipated to be more environmentally-mixed, therefore, comprising extra species that differ in their niches. The SAR is one of the most renowned and ancient forms in ecological modelling²¹⁻²³, and also has some useful applications for handling natural communities. For example, SARs can be used for forecasting the degree of extinction of a species from habitat loss^{24,25}, for prophesying the species richness of assured taxa based on richness of other species²⁶, for calculating human influences on biodiversity²⁷, for identifying hotspots and geographical regions of high species richness²⁸, for designing optimal reserve sizes²⁹, and for assessing the species richness of enormous areas³⁰. Species-area curve would be used to investigate the assumption regarding processes which are accountable for patterns of diversity by assisting comparisons assessed at different spatial scales³¹. Example³² in a study of Iberian plant diversity, used species-area curves to calculate roughly species richness at two scales: 100-m² of total sites. They also found that species richness at the confined scale were negatively correlated with precipitation in different seasons, but not at the landscape scale, and that limitation vanishes the adaptation to harsh environments possible had a higher effect at smaller spatial scales. The primary feature of SAR modelling is to species richness increases with the sampling areas. Identifying the most biologically appropriate mathematical SAR model to characterize these behaviours has been one of the utmost substantial and tarnished concerns in biodiversity. Two of the most primitive and most frequently applied mathematical models for the SAR, i.e., the power and logarithmic

functions, were proposed by^{33,34}. Consequently, several researchers investigated how well these simple mathematical models fit the field data set obtained from different taxa³⁵⁻³⁸. To interpret the SAR coefficients is likely to adopt the simple power function as the evasion function without considering their meaning concerning other functions such as exponential and logistic. In³⁹⁻⁴² this study, the objective was to identify the species-area relationships and to decipher the best-fit curve in the lack of asymptotic species richness.

2. Materials and Methods

2.1 Study Area

The study area was selected as the tropical deciduous forest in the province of Chota Nagpur Plateau, India (23° 35' 87" N to 23° 37' 03" N lat, 85° 48' 30" E to 85° 50' 42" E long, elevation 200 to 350 m asl). The yearly average precipitation of the Study area is 1363.57 mm. The area is deliberated as hot and dry summer from March to June and cold winter from November to February⁴³. The gradient of the study area is headed for east and precise the position of the streams of Damodar River. *Sal* (*Shorea robusta* Gaertn.) was the most abundant tree species in the study area. The soil in the study area was commonly clustered into the different formations like granite or granite gneiss of Archean age, sandstone, and shales of Gondwana development and alluvial plains as shown in Figure 1.

2.2 Field Survey

The study was carried out by selecting one-hectare (ha) plot at Chiruvabera in the tropical deciduous forest around Chota Nagpur Plateau on December 2012. The In selected sites, 1-ha plot (100 m x 100 m) was delineated by nylon string, and every one plot was detached into 100 quadrats of 10 m x 10 m in dimension each. In individual quadrat, the diameter at breast height (dbh) of the adult trees (≥ 9.6 cm) and saplings (≥ 3.2 to < 9.6 cm) were assessed respectively. The portfolio of recognised seedlings was conceded out at diameter < 3.2

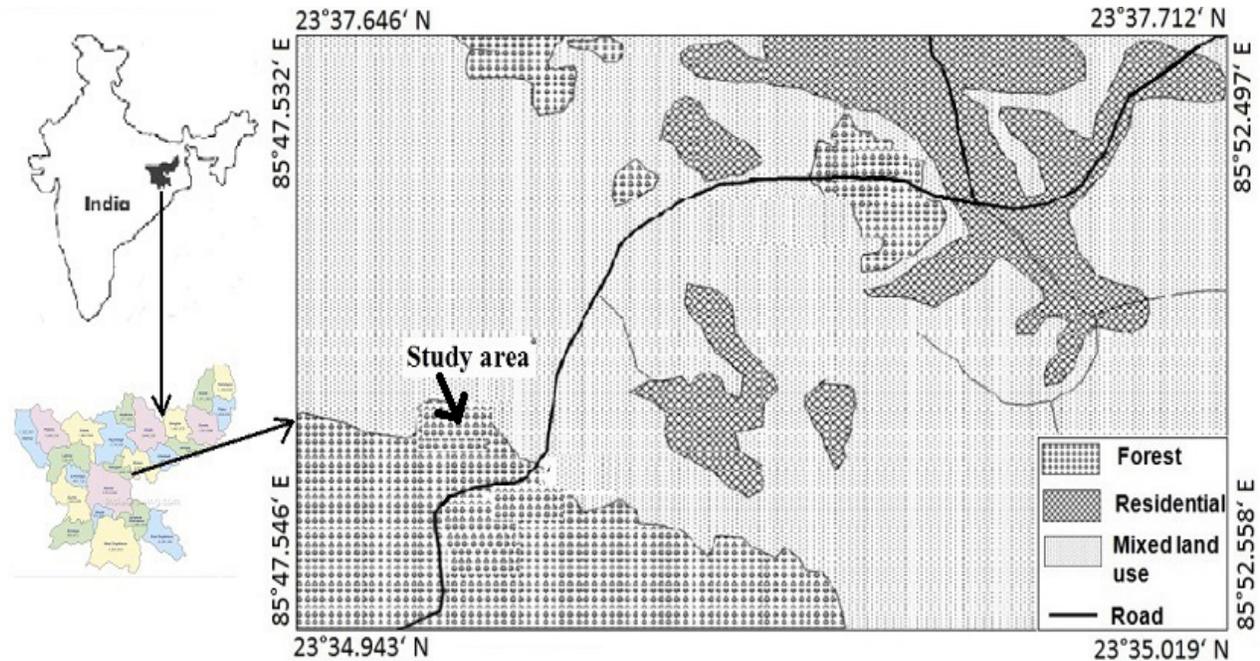


Figure 1. Map of the *Sal* forest of Chota Nagpur Plateau, India.

cm at ≥ 30 cm height^{44,45}. The circumference of adults and sapling species were dignified at 1.37 m from the ground surface and for seedlings at 10 cm above the ground. For an individual, 10 m x 10 m quadrat, stem density and a total number of species were noted⁴⁶. Nowadays, for identifying plant species these tools were widely used by the ecologist, scientist and researcher throughout the world⁴³.

2.3 Ecological and Statistical Analysis

Species-area relationship was analyzed by plotting an increasing number of species as a purpose of plot size. Considerate the spatial distribution of these plant species, the species-area relationships (SAR) were compared by using the Power curve, i.e., $S = cA^z$ ⁴³, the Exponential curve, i.e., $S = Z \ln(A) + C$ ¹⁷ and the Logistic curve, i.e., $B/C + A^z$ whereas⁴⁷, c and z expressed regression-derived coefficients, area (A) and the number of species (S). While the best-fitting criterion was selected by F ratio (regression mean square over the error mean square), P value (probability under the null hypothesis),

root mean-square deviation (Δ) and accustomed coefficient of determination (Ra^2). The Ra^2 was calculated as:

$$Ra^2 = 1 - [(n-1) \text{RSS} / (n-k) \text{TSS}]^{48}$$

where, RSS is the residual sum of squares, TSS is the total sum of squares, k is the number of parameters, and n is the number of samples in this model. The “root mean-square deviation (Δ)” is the square root of the RSS divided by the number of samples⁴⁹. The statistical analysis was carried out using the SPSS package (SPSS 16.0).

3. Results and Discussion

A total of 21 number of tree species associated with 20 genera and 13 families were noted in the study sites, while two species stayed unidentified (Table 1). Combretaceae and Fabaceae with three species each ruled the forest canopy, followed by Anacardiaceae and Lythraceae (two species each). Density-wise, Dipterocarpaceae (240 trees), Lythraceae and Fabaceae (38 trees) ruled the forest cover. Genera with a vast number of plant species

Table 1. List of plant species with a seedling, sapling, and adult in Sal forest of Chota Nagpur Plateau, India

Botanical name	Family	Adult (No.)	Sapling (No.)	Seedling (No.)
<i>Acacia catechu</i>	Fabaceae	8	3	52
<i>Anogeissus latifolia</i>	Combretaceae	4	14	34
<i>Bombax ceiba</i>	Bombacaceae	0	0	1
<i>Boswellia serrata</i>	Burseraceae	7	13	28
<i>Buchnanan lanzan</i>	Anacardiaceae	18	14	194
<i>Butea monosperma</i>	Fabaceae	27	116	241
<i>Cassia fistula</i>	Fabaceae	3	18	4
<i>Diospyros melanoxylon</i>	Ebenaceae	12	229	1183
<i>Lagerstroemia parviflora</i>	Lythraceae	38	2	412
<i>Manilkara hexandra</i>	Sapotaceae	5	25	228
<i>Moringa oleifera</i>	Moringaceae	13	19	10
<i>Phoenix dactylifera</i>	Arecaceae	5	15	146
<i>Semecarpus anacardium</i>	Anacardiaceae	6	12	12
<i>Shorea robusta</i>	Dipterocarpaceae	240	305	3430
<i>Soymida febrifuga</i>	Meliaceae	17	30	10
<i>Syzygium cuminii</i>	Myrtaceae	3	12	25
<i>Terminalia arjuna</i>	Combretaceae	21	35	120
<i>Terminalia tomentosa</i>	Combretaceae	5	0	12
<i>Woodfordia fruticosa</i>	Lythraceae	0	9	3
A*	-	4	1	1
B*	-	0	2	1
	Total	436	874	6147

Note: *unidentified flora

include *Terminalia* (two species). The study area covers were moderately dense with total 436 adult stems (> 9.6 cm), 874 saplings and 6147 seedlings in one-hectare plot. *Shorea robusta* was common tree species at the sampling location. Further, ally, *Bombax ceiba*, *Diospyros melanoxylon*, and *Phoenix dactylifera* were also frequent.

The experimental species-area curves were initially steep, followed by gradual species accumulation, but not any of the curves reach an asymptote (Figure 2). The modest increase in the species accumulation indicates the occurrence of favourable microsites at intervals. As a result, species-area curves labelled off rapidly. Consequently,

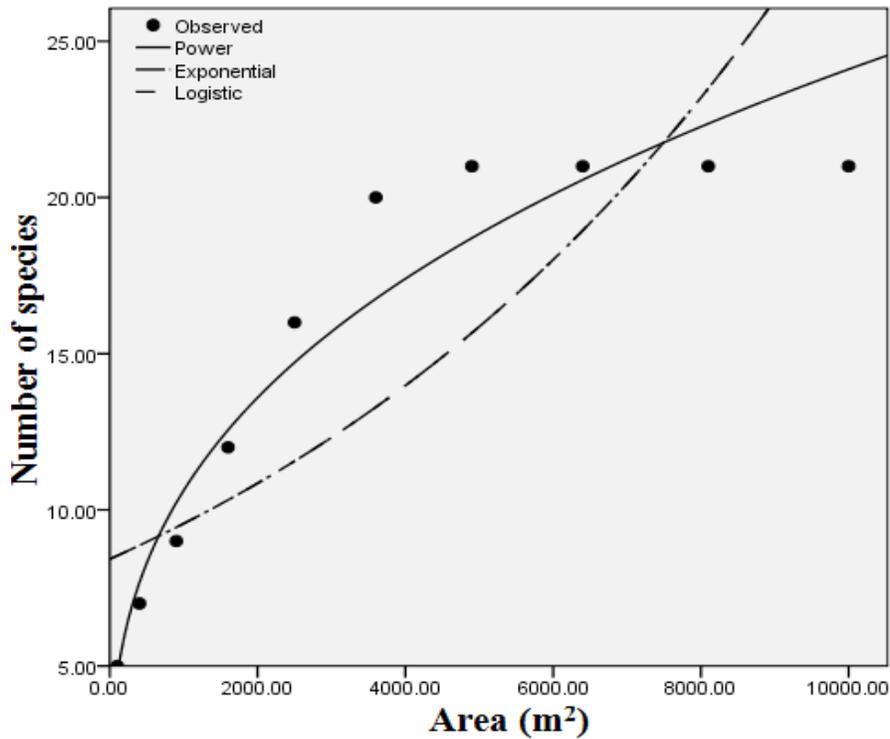


Figure 2. Species-area curves for all the species in *Sal* forest of Chota Nagpur Plateau, India.

many subplots of 10 m x 10 m were identical in species composition. This hypothesis is known as a disreect-community concept and reveals that each community has

distinct boundaries within which its species composition is more or less homogenous, and the transition between the communities is relatively quick⁵⁰.

Table 2. Comparison of the Power, Exponential and Logistic models for all species in *Sal* forest of Chota Nagpur Plateau, India

Statistical parameter	Power	Exponential	Logistic
RSS	0.106	1.685	1.685
F ratio	184.592	15.454	15.454
Df	1, 8	1, 8	1, 8
Probability	0.001	0.004	0.004
Ra ²	0.9534	0.259	0.259
C	0.908	8.422	0.119
Z	0.356	0.0001	1.0
Δ	0.102	0.410	0.410

On the contrary, the species-area curve support self-similarity concept, i.e., the communities are not discrete⁵¹ and the same pattern of heterogeneity was seen at all three sites. The species showing similar trends indicate an increasing number of species with an increase in area favour concept of self-similarity. Variations in the species-area relationships may be considered as a mechanism to avoid competition for microhabitats and resources in the *Sal* forests around Chota Nagpur Plateau. Among three models, the power function model observed as a best fitting one (Figure 2) due to low P value, high F ratio and high Ra^2 (Table 2). The lesser value of Z indicated scale dependent nature without any specific biological meanings⁵². However³³ predicted that species-rich community should have low Z values.

Similarly, the C values are entirely different, i.e., not related with the species-richness; it is fitted merely constant devoid of specific biological meanings. The root mean-square deviations ($\Delta_{(P)}$ and $\Delta_{(E)}$) showed significant variations. Based on one ha sampling plots, many researchers could not observe an asymptote inside the species area curve⁵³⁻⁵⁵. Species-area relationship indicates that the discreet-community concept and the concept of self-similarity were intrinsic belongings of plant species or community, which cannot be changed by anthropogenic turbulence. Distribution of the species in Chiruvabera reflects polarity in the habitat conditions, i.e., *in-situ* seed germination, and seedling establishment of plant species may not be successful at those sites where plant species prefer to grow or vice-versa. This may be attributed to the habitat heterogeneity in the tropical deciduous forests.

In⁵⁶ reported that the Z varied systematically with spatial scale, and from habitat to habitat at the same spatial scale. On the other hand⁵⁷ suggested that the Z was independent of scale. In⁴⁴ showed that Z is site-as well as scale-dependent, and, therefore, the location of the sample (i.e., site), as well as the scale used, need be considered in the extrapolation of species diversity from species-area curve parameters. In⁵⁸ showed that the Z-values are suggestive of the processes establishing species richness and composition patterns, while C-values are suggestive of the realized carrying capacity of the arrangement per

unit area. Notable general trends are that C-values vary with system type and dominant taxon and that Z-values increase as one switch from considering systems with high species overlap to systems with low species overlap. In⁵⁹ this study, the exponential and logistic models were outliers that might be due to the lack of exponential enhance in the number of species and intermediate size of the sampling area (one ha), respectively. Moreover, the high P value, low F ratio and low Ra^2 of exponential and logistical models showed an extreme deviation from the observed trends of the species-area relationship intended for the plant species. Several studies recorded that samples from small areas [less than 1 ha] have species-area relations in the form of the exponential model, while the power model was more appropriate for intermediate sampling areas [1-10 ha], and the logistic model is best for data from larger sampling areas, higher than 50 ha⁵². Additional by⁵² found at a local scale, if the addition of new species is relatively slow within an area, the species-area relations are well-described by the exponential model, probably because of a substantial similarity (autocorrelation) of environmental conditions and species composition among adjacent sites. In this study, the plant species were different in terms of species composition while the substantial similarity of environmental conditions found in the *Sal* forest. The poor richness at Chiruvabera showed the impact of dispersal limitation on species diversity and SARs⁶⁰.

4 Conclusion

Species-area curves for one-hectare plot can be considered as an intermediate in size and also sufficient to make known the observed species-area relationship found to be satisfactorily fitted by the power model. The species tendency is signifying an increasing number of species with an increase in area favour concept of self-similarity. Dispersal limitation and habitat heterogeneity may be accountable for the variations in the species-area relationships and considered as a mechanism to avoid competition for microhabitats and resources in the *Sal* forests around Chota Nagpur Plateau.

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