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Vegetational dynamics in some tropical abandoned rice fields in the western part of Orissa, India

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In many areas of tropics, agroecosystems are developed by clearing the natural forests. Conversion of natural forests to agricultural systems leads to loss of several soil ecological attributes responsible to maintain the soil fertility. Therefore in such converted agroecosystems the soil fertility often declines. In order to meet the deficiency of soil fertility, the farmers adopt the practice of nutrient input to such agricultural systems. However, poor farmers of tropics being unable to adopt such soil management strategy abandon the agricultural systems because of decline in production and leave the fields to remain fallow. The present study examined the vegetational succession and quantitative community characteristics in some abandoned agricultural ecosystems of western part of Orissa, India. The phytosociological attributes in different abandoned rice fields were studied by taking quadrates of suitable sizes (1 × 1, 5 × 5 and 10 × 10 m^2 for herbaceous grass and nongrass, shrubs and tree species respectively). Quantitative community characteristics like frequency, abundance, density of different plant species, diversity and dominance index were examined. Importance Value Index (IVI) was calculated to understand the importance of individual species in a community. The distribution patterns of different species were analyzed by species sequence curve method. Our finding showed that there is decrease in the number of grass stands and increase in the nongrass stands with the increase in the year of fallow periods. The study also indicated an increasing trend of species richness, abundance and diversity with increasing year of abandonment indicating the growth of secondary succession in this region.

Key words: Vegetational succession, quantitative community characteristics, importance value index, species sequence curve.

INTRODUCTION

Change in species composition as vegetation develops from an open field towards a closed canopy forest is a basic concept in forest ecology (Little and Escheman, 1976). Merz and Plass (1952) estimated that at least 404,700 hectare (1 million acres) land in unglaciated portion of Ohio and 22,000 hectare land of the Athens of the Wayme natural forest were old fields (abandoned rice fields). The concept of secondary succession as a process of system repair is central to ecological theory (Bazzaz, 1975). Bazzaz opined that through the secondary succession, attributes of mature ecosystems are restored. These attributes include high species diversity, structural complexity, closed mineral cycling, the balance between community production and respiretion and system stability (Margalef, 1963; Odum, 1969).

A great number of abandoned rice fields are seen abundantly in various landscapes throughout the world. In past few decades, vast forest area that had been converted to agricultural fields has been abandoned because of economic interest, industrialization and urbanization process (Thomilson et al., 1996).

The potential for natural succession after abandoned wetland agriculture is less certain, and available literature is scarce. In a few phytosociological studies, change in species composition in abandoned flooded agricultural fields has been inferred (Shimada and Suzuki, 1981; Shimada, 1996; Kim and Nam, 1998). The colonization

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and the sequence of changes in plant community on abandoned agricultural lands form large body of ecological research (Rejmanek, 1990; Glenn-Lewin and van der Maarel, 1992) and studies of old fields continue to yield new findings of interest to community ecology (example, Inoue and Tilman, 1988; Schmidt, 1988; Osbornova et al., 1990; Holt et al., 1995).

Models and observations of secondary succession can be highly pertinent to vegetation management in restoration ecology (van der Maarel, 1988), especially those programs that seek to promote successional processes for land reclamation and habitat restoration (example, Bradshaw, 1992; Robinson and Handel, 2000). Several studies in the eastern and mid eastern United States have dealt with plant species diversity during the first 7 years of succession in Piedmont, South Carolina and showed that the number of dominant species increased with time. Janzen (2002) reported that tropical forests are one of the most degraded and threatened forest ecosystems in Central America. Martein et al. (2009) studied the species composition, diversity and population structure of woody species recovered from agricultural fields in Nicaragua.

Evidences indicate that after abandonment the abandoned rice fields are rapidly colonized by vegetation through natural succession depending on the severity of land use intensity prior to abandonment (Guariguata and Ostertag, 2001). The study of colonization and vegetation dynamics of the abandoned agricultural systems plays an important role in our understanding of secondary succession and enables us to design successful restoration strategies for tropical forests (Aide et al., 2000).

India has a total land area of 329 million ha, of which 43% is under cropping and 23% under forest. (Ministry of Environment and Forestry Government of India, New Delhi, 1999). As per MoEF (2008) during 2003 to 2008 approximately 728 sq km of forest area were cleared for agricultural purpose. Very few literatures are available regarding the occurrence of secondary succession on the abandoned crop fields in India. Some pioneer workers in this field like Shrivastava and Singh (1989), Basu and Behera (1993) and Prasad (1997) reported that establishment of herbaceous vegetation after the abandonment of cropping, check the soil erosion and loss of soil nutrients. The present study describes the species composition, structure and diversity resulted due to growth of natural succession in abandoned rice fields located in the western part of Orissa, India.

MATERIALS AND METHODS

Study sites

The present study was confined to the revenue district Sambalpur, located in the western part of Orissa in India. The natural vegetation in the area is classified as tropical dry deciduous forest. Prior to 1950s the study sites were dense forest forming a part of Barapahar forest range. After the establishment of multipurpose hydroelectric Hirakud dam project and subsequent industrialization, urbanization and increase in population pressure, the district forest coverage had been reduced to 30% (Joshi, 1990). The climate is tropical monsoonal with three distinct seasons: Summer (March to June), rainy (July to October) and winter (November to February). The annual average rain fall is 1667 mm, out of which 70 to 80% falls during the rainy season. The mean air temperature varies from 8.9°C (during December) to 47°C (during May). Red and yellow lateritic soils are present in the area (Mohanty, 1971). Some of the soil physico-chemical properties of Western Orissa were studied by Prasad (1997) (Table 1). She reported a change in soil texture in the in the study sites with increase in percentage of clay and decline in the percentage of sand. Water holding capacity, organic carbon, total nitrogen and total phosphorus of soil showed increasing trend with increasing year of abandonment in the study area.

In the 1950s, most forest lands were cleared and used for production of agricultural crops (rice, maize, beans, and sugarcane). Subsequently these agricultural lands were abandoned due to poor production because of insufficient nutrient input and remained fallow. In the present study three abandoned rice fields, that is., abandoned since 3 year, 5 year and 10 year, were selected for the community analysis. The age of the abandoned rice fields were ascertained by asking the local farmers.

Methodology

Phytosociological analysis of the abandoned rice fields were studied during October to November 2008 (post monsoon period). The size of the quadrates for herbs, shrubs and woody species were 1 × 1 m^2, 5 × 5 m^2 and 10 × 10 m^2, respectively. Ten randomly placed quadrates were used for the analysis of herbaceous vegetation, shrubs as well as for woody vegetation. The plant species encountered during sampling were identified following the taxonomic manual of Saxena and Brahamam (1996). Nomenclature was based on Ciocarlan (2000). The vegetational data collected were then used to calculate following indices for each site. The importance value index (IVI) was calculated by adding relative frequency (RF), relative density (RD) and relative abundance (RA) of the species (Philips, 1959).

$$IVI = RF + RD + RA$$

where, RF = (Frequency of a species / sum frequencies of all species) × 100, RD = (Number of individuals of a species / total number of individuals) × 100. RA = (Abundance of a species / sum abundances of all species) × 100

Frequency of a species was calculated as per Rauinkiaer (1934), density and abundance were calculated following Mishra (1964).

The species diversity index was calculated following Shannon and Wiener (1963) using the equation

$$\hat{H} = -\Sigma (n_i / N) \times \ln (n_i / N)$$

where $\hat{H}$ is the Shannon's index, n_i is the IVI of individual species and N is the total IVI value of species in the area (that is, 300)

The concentration dominance index (Cd) was calculated following Simpson (1949), as

$$Cd = \Sigma (n_i / N)^2$$

Correlation coefficient was calculated to find out the relationship between species richness and diversity with the year of

Table 1. Soil physico-chemical properties of the region (Prasad, 1997).

Soil parameters	Plots with different fallow period			
	2 year	5 year	10 year	15 year
Soil texture (%)				
Sand	75 ± 5	73 ± 6	70 ± 5	68 ± 5
Silt	19 ± 2	20 ± 2	21 ± 2	20 ± 2
clay	6 ± 1	7 ± 1	9 ± 1	12 ± 1
Water holding capacity (%)	36.2 ± 2	38 ± 3	41 ± 2	43 ± 2
Organic carbon (mg / g soil)	10.58 ± 0.05	11.58 ±0.075	13.06 ± 0.12	15.65 ± 0.48
Total nitrogen (mg / g soil)	1.15 ± 0.03	1.26 ± 0.03	1.306 ± 0.03	1.38 ± 0.04
Total phosphorus (mg / g soil)	0.21 ± 0.03	0.21 ± 0.016	0.208 ± 0.02	0.25 ± 0.02

abandonment and between diversity and dominance.

RESULTS

The analysis of vegetation along with their family attributes and their IVI value in different abandoned rice fields during post monsoon period is represented in Table 2. We registered a total no of 35 different species (herb, shrub and trees) belonging to 14 different families in the rice fields abandoned for 3, 5 and 10 years. The total number of species and families found in 10 year abandoned field was almost double as compared to that of 3 year abandoned field. A total number of 6, 8, 13 families were registered in 3 year, 5 year and 10 year abandoned fields, respectively. Number of shrub and tree species were absent in 3 year abandoned field. However, 2 shrub species, 1 pioneer tree species were encountered in 5 year and 3 shrub species, 4 tree species were encountered in 10 year abandoned fields. On the basis of IVI value the dominance of the vegetation was found to be changed with increasing year of abandonment (Tables 2 and 3). *Sporobolus indicus* belonging to family Poaceae was dominant species (IVI = 63.64) in 3 year abandoned field, whereas species *Thysanolena maxima* belonging to family Poaceae was dominant in the 5 year abandoned field (IVI = 45) and *Sida acuta* belonging to family Malvaceae was dominant in the 10 years abandoned field (IVI = 41.08) . Further analysis of floristic composition during the developmental stages indicated that the number of families and species increased with increasing age of abandonment (Table 2). The result also indicates that the diversity of the vegetation increased and the dominance of the vegetation decreased with the increase in fallow period. The species richness and diversity indices were found to be positively correlated with the fallow period (r = 0.97 for species richness and r = 0.88 for diversity (Figures 1a and 1b). There is strong negative correlation (r = - 0.98) between diversity and dominance in (Figure 1c).

The species sequence curves for abandoned rice fields show a log normal pattern of distribution for 3 year abandoned fields abandoned rice fields (Figure 2a) and broken stick type pattern for both 5 year and 10 year abandoned fields (Figures 2 b and 2c, respectively).

DISCUSSION

The general trends of plants species diversity in the present study showed an increase in diversity with succession which is in agreement with Bazzaz's finding (1975) who observed a sharp rise in diversity in the initial phase of regeneration after abandonment. The results from present study indicate that the floristic composition changes with the age of abandonment. At the early stage of succession (3 year), 4 families covered 81% of the total individuals. Six families represented 84% of the total vegetation in the 5 year abandoned rice fields and 13 families covered 76% of total vegetation in 10 year abandoned rice field. Further it was observed that with the advancement of succession, the number of families and species increased. The families like Poaceae Cyperaceae and Asteraceae were present in all sites. Helm (1995) Skeel and Gibson (1996), on the basis of their study opined that family Poaceae and Cyperacae have the maximum seed dispersal mechanism and the grass species (Poaceae) have the capacity to tolerate drought, low soil nutrient and climatic stress, which facilitate their colonization on early abandoned rice fields. In the present study the moisture content of soil and climatic conditions were not stressful to the appearance of species belonging to family Poaceae, but the nutrient content of soil appears to be very low at the early stage of abandonment due to intensive cropping prior to the abandonment of these rice fields (Martin et al., 1991). The present study revealed a shift in dominant species along the chronosequence of abandoned fields (*Sporobolus indicus* in three year, *Thysanolena maxima* in 5 year old field and *Sida acuta* in the 10 year field) which indicates that species achieved their highest dominance at different times during the successional period. This is a general pattern of floristic and structural recovery following abandonment (Guariguata and Ostertag, 2001).

Secondary succession leading to forest can be divided

Table 2. Phytosociological analysis of vegetational community of three different abandoned crop fields.

Vegetation type	Plots with different years of abandonment								
	3 year			5 year			10 year		
	Family	Species name	IVI	Family	Species name	IVI	Family	Species name	IVI
Grass	Poaceae	*Sporobolus Indicus*	63.64	Poaceae	*Sporobolus. indicus*	13.77	Poaceae	*Sporobulus indicus*	17.5
		Cynodon dactylon	7.8		-	-	-	-	-
		-	-		*Sporobolus ruspolianus*	6.67	-	-	-
		-	-		*Thysanolena maxima*	45.31	-	-	-
		-	-		*Sopubia halepense*	42.09	-	-	-
	Cyperaceae	*Cyperus tricep*	30.66	Cyperaceae	*Cyperus tricep*	24.35	Cyperaceae	*Cyperus tricep*	21
		Cyperus rotundus	25.57		-	-	-	-	-
		Cyperus iria	40.08		-	-	-	-	-
		Cyperus pangorei	9.29		-	-	-	-	-
								-	-
	Asteraceae	*Ipomea potentilloides*	51.8	Asteraceae	*Ischaemum indicum*	5.18	Asteraceae	*Tridex Procumbence*	5.46
					Chrysanthemum pyrethroides	4.43	-	-	-
							-	-	-
							-	-	-
	Commelinaceae	*Cyanotis speciosa*	8.79	Commelinaceae	*Cyanotis alans*	27.17	-	-	-
Non grass		*Cyanotis lapidosa*	13.97		*Aneilema hockii*	8.91	-		
		-	-				-		
		-	-				-		
		-	-	Schrophulariaceae	*Sopubia delphiniphola*	7.41	Schrophulariaceae	*Sopubia delphiniphola*	7.8
		-	-	Tiliaceae	*Corchorus olitorius*	29.89	Tiliaceae	*Corchorus eastuan*	18.37
		-	-		-	-	Convulvulaceae	*Ipomoea hederaceae*	5.12
		-	-		-	-	Oxalidaceae	*Oxalis corniculata*	4.43
		-	-		-	-	Amaranthaceae	*Achyranthus aspera*	32
		-	-		-	-	Lamiaceae	*Perilla ocymoides*	36.24
	Acanthaceae	*Hygrophila spinosa*	27	-	-	-	Acanthaceae	*Justecea orchioides*	7.88
	Verbenaceae	*Lippia nudiflora*	21.4	-	-	-	-	-	-
					-				
								Sida acuta	41.08
Shrub	-	-	-	Malvaceae	*Sida acuta*	14.23	Malvaceae	*Urena lobata*	35.3
					Urena lobata	39.51		*Sida cordifolia*	38.6

Table 2. Continued

Tree	-	-	-	-	-	-	Fabaceae	*Butea monosperma*	3.39
		-	-	-	-	-		*Desmodium levigatum*	6.15
		-	-	-	-	-		*Crotolaria albida*	4.77
	-	-	-	Ceasalpinaceaer	*Cassia tora*	31.12	Ceaselpinaceae	*Cassia tora*	14.91

Table 3. Species richness, diversity and Dominant indices of different vegetation on different abandoned rice field.

Status of studied plots with respect to abandonment		Species richness	Species diversity Ĥ	Dominance (Cd)
3 year	Grass	2	0.423	0.045
	Non grass	9	1.770	0.082
	Shrub	Absent	Absent	Absent
	Tree	Absent	Absent	Absent
5 year	Grass	6	0.780	0.045
	Non grass	5	0.979	0.026
	Shrub	2	0.411	0.019
	Tree	1	0.235	0.010
10 year	Grass	1	0.165	0.003
	Non grass	9	1.246	0.036
	Shrub	3	0.787	0.049
	Tree	4	0.345	0.003

in to four phases (Finegan, 1996; Whitmore, 1998). The first phase is a dense growth of herbs, shrubs and climbers that rapidly colonize the site and disappear under shade of the emerging small pioneer tree species, which takes place in a short time (1 to 3 year).

The second phase is dominated by small pioneer tree species, which emerge and form a continuous woody canopy which takes 10 to 30 years.

The third phase is dominated by big light demanding tree species that takes a long time 75 to 150 years. The fourth is stable climax community. In the present study, the 3 year abandoned field was dominated by herbaceous grass species, but in five year old field shrub species and pioneer tree species appeared and the shrubs dominated the community. This is in agreement with the idea of Finegan (1996) and Whitmore (1998).

The dynamics and structure of the vegetation arising through secondary succession depend on the availability of various potential sources for colonization and on environmental constraints as reported by Noble and Slatyer (1980). Post agricultural succession is also strongly modified by site history that is, by the type, frequency and intensity of stress or disturbance imposed by people both during the agricultural phase and during the period following abandonment of the field. Very often the abandoned agroecosystems under natural secondary succession are converted to fallow lands. As per Woomer et al. (1994), in vegetated fallow, there is usual tendency for increase in soil organic matter level due to higher herbaceous root production and litter input to the soil. As a result, fallowing promotes the restoration of carbon content after a decline resulting from intensive cropping (Martin et al., 1991). This might have facilitated the appearance of new species in the present study with the increasing year of abandonment.

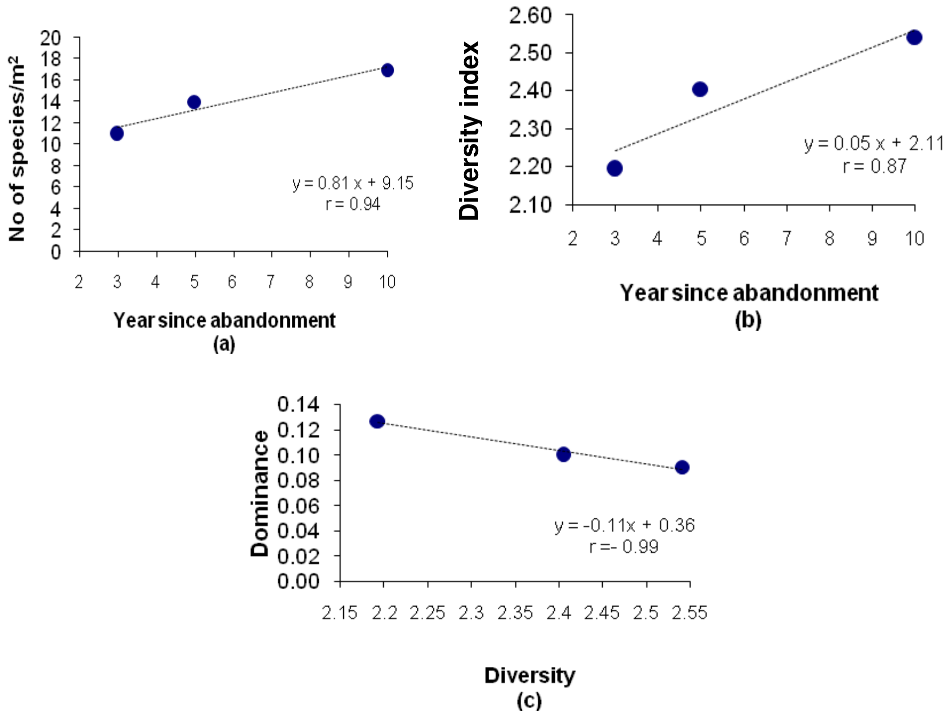

Figure 1. Correlation between year since abandonment with species richness (a) with diversity index, (b) correlation between diversity index and (c) dominance index.

The species sequence curve during early abandoned rice fields in the present study showed log normal distribution confirming the finding of Whittaker (1970) who observed that during early parts of old field succession the relative importance value shows log normal type of species sequence curve. Our findings showed that, towards later stage of abandonment the vegetation showed broken stick model. Usually the community during stress is expected to show the broken stick model with clubbing of different species which might be due to grazing pressure and anthropogenic disturbance in the later part of secondary succession. Yossi and Dembele (1993) and Mitja and Puri (1993) noted that, when clearing is undertaken with heavy equipment and deep ploughing, all woody stumps are removed for which the return of woody species is much slower. Our study conforms to this penomenon by the appearance of pioneer tree species in 5 and 10 year abandoned field.

Present study shows a strong correlation between the species richness as well as diversity with the year of abandonment (r= 0.97 for species richness and r = 0.88 for diversity) (Figures1a and b). Odum (1969) and Whittaker (1970) observed a general increase in plant species diversity with the succession at least during seral stages of succession. They also observed a negative correlation between diversity and dominance as observed in the present study (r = - 0.98) (Figure1 c). This indicates that the secondary succession in the present study is in the seral stage and suggests that important changes of vegetation have taken place following the abandonment of agricultural fields.

Conclusion

The development of species richness following abandonment in fields which were previously under agriculture is due to gradual improvement of soil fertility with the passage of time. The decadal scale secondary succession development in these fields remains in seral stage. Therefore, the species diversity in the abandoned field can be an effective indicator to assess the regeneration stages in such fields. The chronosequence method provides a general view of main trends in the regeneration of abandoned fields on a regional scale and explains most important successional changes that occur over short period of time. This can be successfully used to develop restoration strategies for tropical forests on local and regional scales.

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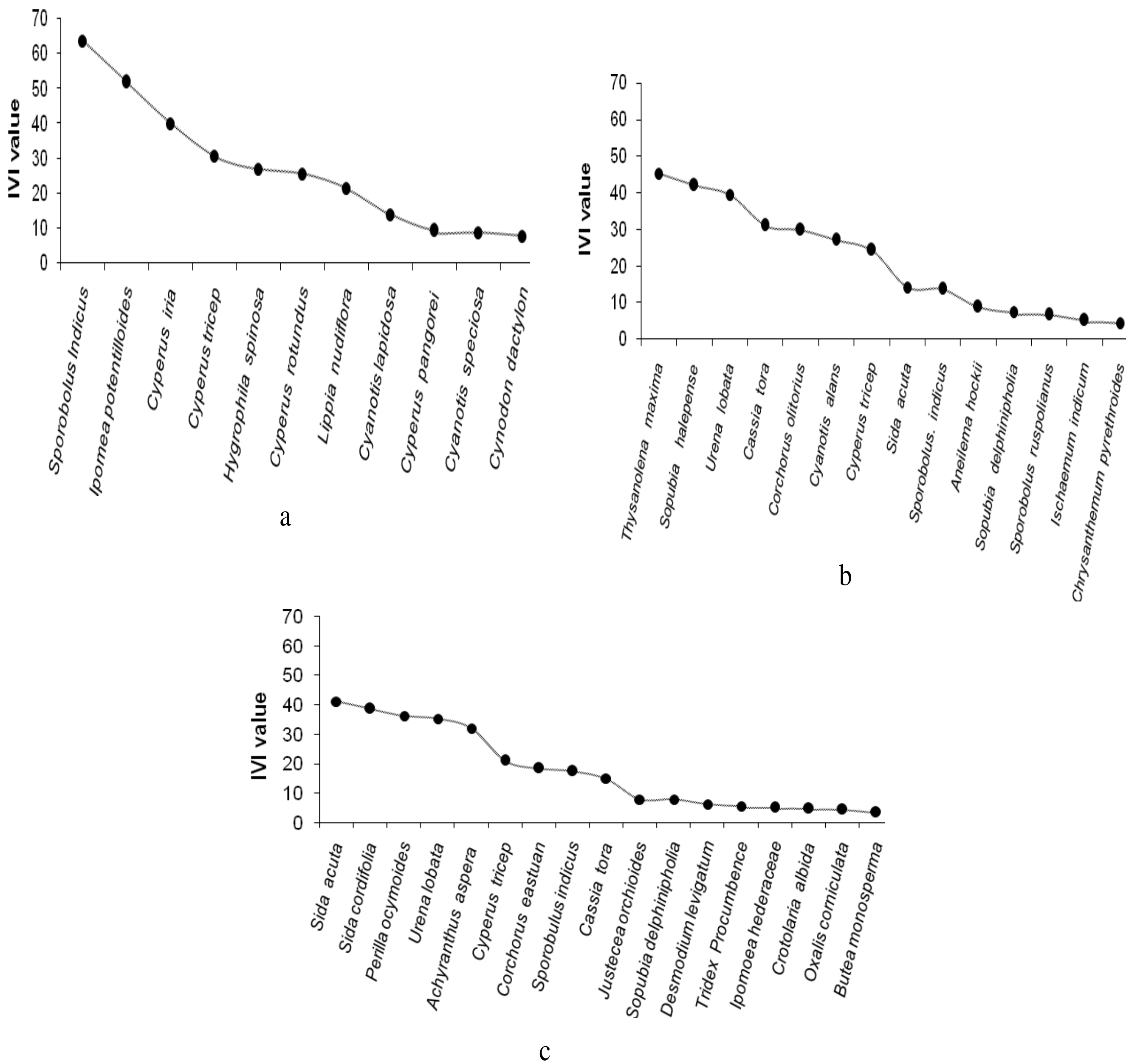

Figure 2. Species sequence curve of abandoned rice field (a- 3 year, b- 5 year, c- 10 year).

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