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# Secondary succession in abandoned agricultural lands of Western Odisha, India

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**Key words:** Agricultural land, Plant community, Species sequence curve, Vegetation succession.

**Abstract**

Vegetation succession and quantitative community characteristic were analysed along a chronosequence of abandoned rice fields located in Sambalpur district of Odisha, India. These rice fields were abandoned since 2, 4, 6, 11 and 15 years. The result showed that, total 45 different species belongs to 20 different families were encountered. Family Poaceae was found to be most dominant family among the entire sites. The grass, non-grass and woody vegetation marked increasing trend with increase in the age of the fields. The species richness was found to be 9, 12, 19, 26 and 34 in the 2, 4, 6, 11 and 15 years abandoned fields respectively. The study revealed the change of species sequence curve from geometric to log normal type. Further, increasing trend of species richness, abundance and diversity index with increasing age of fallow period indicates secondary succession in these fields. Evenness index are observed to be highest in 15 year abandoned field indicating the heterogeneity of species with increase in the age of abandonment. Thus the present study indicates that the appearance of secondary succession on the abandoned rice fields retrieve the native vegetation after abandonment of agricultural activity.

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## Introduction

Agriculture is the most dominant form of land use throughout the globe since its origin. In general, most of the tropical country agro-ecosystem is derived from the clearing of natural forest vegetation. Modern agriculture, although successfully increased food production, caused extensive environmental damage. The degradation of soil and water quality due to mechanized tillage and chemical inputs, and declines of non-target species due to inappropriate pesticide application have been reported by McLaughlin and Mineau 1995, Foley *et al.* (2005). This reduced the soil fertility and destabilized the agroecosystem. Very often these lands become abandoned by poor farmer of the tropics. After abandonment, these lands remain fallow and undergo secondary succession. The cessation of land use and the decrease in livestock pressure, favours natural processes of ecological succession in the fallow lands. Usually the abandoned fields are first colonized by pioneer species (ruderal and annual species), which are followed by secondary species (grasses and shrubs) and ultimately by climacic species (trees) (Mouillot *et al.* 2005, 2003; Brown 1991).

Knowledge of secondary succession in abandoned agricultural lands gives insights into conservation and restoration of degraded lands (Jiao *et al.* 2007; Bonet 2004; Lee *et al.* 2002). Secondary succession facilitates natural regeneration in abandoned lands, where the degraded system achieved a new steady state condition (Lamb *et al.* 2005). Natural regeneration has increasingly received attention for its higher natural value and lower cost (Jiao *et al.*, 2007, Prach, 2003, Prach and Pyˇsek 2001). Species diversity, nutrient cycling, equilibrium between community production and respiration and ecosystem stability are attained at the end of natural secondary succession.

India has a total land area of 329 million ha, of which 60.53% is under cropping (according to World Bank report, published in 2010). As per MoEF (2008), during 2003 to 2008 approximately 728 sq km of forest area were cleared for agricultural purpose. Most of these derived agricultural lands in the western part of Odisha become abandoned by the farmers due to unsustainable agricultural production. Immediately after abandonment, these lands usually undergo natural secondary succession and exhibit changes of different vegetation. Prasad (1996) reported that agricultural abandoned land after 10-15 year converted into savana. Scientific study of succession on the abandoned farmland provides an opportunity to gather field observation on natural elements of the local flora reclaiming the sites (Barbazz-Krasny, 2005).

A number of studies have been carried out on the old field succession in many countries. But study of vegetation on the abandoned agricultural land is very scarce in India. However, some pioneer workers like Shrivastava and Singh (1989), Basu and Behera (1993) and Prasad (1996) 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 changes of quantitative analysis of species composition, diversity and dominance resulted due to growth of natural succession in abandoned rice fields.

## Materials and methods

*Study Area*

The present study was carried out in five different uncultivated agro-ecosystems abandoned since 2, 4, 6, 11 and 15 year. All the study sites are located on the Sambalpur District of Odisha, India (Fig. 2). Prior to 1950s this area was covered with tropical dry deciduous forest. But after the establishment of Hirakud Dam most of the forest became convert in to agricultural land due to well irrigation facilities. The farmers cultivated different crop like maize, rice, beans, sugarcane etc. by traditional method. Later on these derived agro-ecosystems lost the sustainable production and abandoned by the farmers because of insufficient input of auxiliary energy source. The age of the abandoned land has been ascertained by asking the local farmer and personal interview with the local

people.

*Climate*

The area experienced three distinct seasons i.e. rainy, winter and summer. The rainy season starts normally in the middle of June and continues till the end of September. The cold season starts in the 1st half of November and ends in the middle of February prior to summer. Climatic pattern of the study area during the study period has been represented in (Fig. 1). Relative humidity throughout the year fluctuates from 42.9 percent (during May) to 85.2 percent (during August). Average minimum temperature (coldest) found to be 8.9° C in the month of January whereas, average maximum temperature (hottest) was observed to be 42° C in the month of May during study period of the district. The average annual rainfall that the area received was estimated to be 166.7 cm, of which 75 percent occurs during the rainy season (July to October). Total number of rainy days per year was observed to be averaged around 80 days of which the maximum accounted for 22 days in the month of August.

*Vegetation sampling procedure*

The abandoned agro-ecosystems were randomly sampled for the detail phytosociological study for a period of July 2010 to June 2011. The size of the quadrates for the herb and woody species was 1×1m² and 5×5m² respectively. Tree species was not found because of the human interference. The sampling was done during the month of August (rainy season). Ten quadrates were studied for each observation in each field. After sampling, the plant species that were encountered during the period of sampling were identified in the laboratory with the help of taxonomic manual of Saxena and Brahamam (1996). The data obtained were then, used to quantify the quantitative community characteristics like frequency, density and abundance were determined by the following methods of Mishra (1968).

*Important value Index*

Important value Index (IVI) of each species was calculated by adding relative frequency(RF), Relative density (RD), Relative abundance (RA)of the species (Phillips, 1959).

IVI = RF + RA + RD

Species Diversity (Ĥ)

Species diversity (Ĥ) of the herbaceous species was determined following Shannon and Wiener (1963).

Ĥpeciesni/N) ln ($n_i$/N)

Where $n_i$ =IVI of individual species and

N=Total IVI of individual of all species in the area.

*Dominance Index*

Dominance Iindex ($C_d$) value was estimated by following the methods of Simpson (1949).

$C_d=\sum (n_i/N)^2$

Where ni =IVI of individual species and

N=Total IVI of individual of all species in the area.

Species Evenness Index (E)

Species evenness or equitability index (E) was calculated by following Pielou (1975).

$E=\hat{H}_i / H_{max}$

Where $\hat{H}_i$= Observed diversity (Shannon and Weiner) and

$H_{max}$=Maximum possible diversity and was calculated by log k

Where k= total no of species.

**Results**

The list of species found in different uncultivated abandoned rice fields has been shown in table 1. A total no of 45 different species (31 herbs and 14 woody Sp.) were found in the present study. Among the herbaceous species 9 were grass and 22 were non grass species. These belong to 20 different families: Acanthaceae, Amaranthaceae, Arecaceae, Asteracaea, Ceasalpiniaceae, Commelinaceae, Convolvulaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Lamiaceae, Lythraceae, Malvaceae, Mimosaceae, Oxalidaceae, Poaceae, Rubiaceae, Scrophulariaceae, Tiliaceae and Verbanaceae.

**Table 1.** List of different type of plant vegetation with their Importance value indices (IVI) found in different abandoned rice fields.

| Vegetation | Sl no. | Species name | Family | 2 yr | 4 yr | 6 yr | 11 yr | 15 yr |
|---|---|---|---|---|---|---|---|---|
| Grass | 1 | *Aristida adscensionis* L. | Poaceae | – | – | – | 17.59 | 13.39 |
| | 2 | *Aristida setacea* Retz. | Poaceae | – | – | – | – | 9.41 |
| | 3 | *Chloris barbata* Sw. | Poaceae | – | – | 26.45 | 21.37 | 21.61 |
| | 4 | *Cynodon dactylon* (L.)Pers | Poaceae | 53.58 | 35.7 | 31.59 | 24.08 | 18.32 |
| | 5 | *Digitaria ciliaris* (Retz.) | Poaceae | – | – | – | – | 10.32 |
| | 6 | *Eragrostis ciliaris* (L.) R. Br | Poaceae | 39.82 | 38.5 | 22.62 | – | – |
| | 7 | *Ischaemum indicum* (Houtt.) | Poaceae | 30.56 | 14.3 | 11.1 | 8.62 | – |
| | 8 | *Sorghum halepense* (L.) Pers | Poaceae | – | – | 17.66 | 26.74 | 16.43 |
| | 9 | *Sporobolus diander* (Retz.) | Poaceae | – | – | – | – | 13.63 |
| Non-grass | 10 | *Achyranthes aspera* L. | Amaranthaceae | – | – | – | – | 8.11 |
| | 11 | *Alysicarpus vagenalis* (L.) | Fabaceae | – | – | – | – | 15.26 |
| | 12 | *Cassia tora* L. | Ceasalpinaceae | – | – | – | 17.54 | 11.52 |
| | 13 | *Croton sparciflorus* Morong. | Euphorbiaceae | – | – | – | | 10.72 |
| | 14 | *Cyperus iria* L. | Cyperaceae | – | – | – | 16.15 | 18.01 |
| | 15 | *Cyperus triceps* Rottb | Cyperaceae | – | – | – | – | 6.85 |
| | 16 | *Desmodium dichotomum* (Willd.) | Fabaceae | – | – | 24.5 | 21.37 | 19.37 |
| | 17 | *Euphorbia hirta* L. | Euphorbiaceae | 17.97 | 19.1 | 12.06 | – | – |

**Table-1 Continued**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 18 | *Evolvulus alsinoides* (L.) | Convolvulaceae | 45.93 | 36.3 | 33.22 | 24.74 | 20.51 |
| | 19 | *Hygrophila auriculata* (Schum.) | Acanthaceae | – | 19.1 | 10.75 | 19.94 | 14.48 |
| | 20 | *Lindernia ciliata* (Colsm) | Scrophulariaceae | – | – | – | 19.98 | 16.56 |
| | 21 | *Merremia tridentata* (L.) | Convulvulaceae | – | – | – | – | 5.74 |
| | 22 | *Mimosa pudica* L. | Mimosaceae | – | – | – | 7.26 | 12.3 |
| | 23 | *Murdannia spirata* (L.) | Commelinaceae | 19.22 | 20.7 | – | – | – |
| | 24 | *Ocimum canum* Sims. | Lamiaceae | – | – | 8.12 | 11.29 | 15.79 |
| | 25 | *Oldenlandia corymbosa* (L.)Lam | Rubiaceae | – | 11 | 14.55 | 15.46 | – |
| | 26 | *Oxalis corniculata* L. | Oxalidaceae | 42.76 | 29.7 | 31.27 | | |
| | 27 | *Phyla nodiflora* L. | Verbanaceae | 18.29 | 23.7 | 27.01 | 11.12 | |
| | 28 | *Phyllanthus simplex* Retz. | Euphorbiaceae | – | – | – | 5.87 | 4.01 |
| | 29 | *Rungia parviflora* Nees. | Acanthaceae | 31.82 | 30.1 | – | – | – |
| | 30 | *Scoparia dulsis* L. | Scrophulariaceae | – | 21.3 | 14.4 | 12.58 | |
| Woody | 31 | *Tridex procumbens* L. | Asteraceae | – | – | 14.7 | 18.31 | 17.65 |
| | 32 | *Abutilon indicum* (L.) Sweet | Malvaveae | – | – | – | – | 21.90 |
| | 33 | *Adhatoda vasica* Nees | Acanthaceae | – | – | – | 24.01 | – |
| | 34 | *Butea monosperma* (Lam.) | Fabaceae | – | – | 96.75 | 60.46 | 38.57 |
| | 35 | *Cassia fistula* L. | Fabaceae | – | – | – | – | 14.03 |
| | 36 | *Eugenia jambolina* Skeels. | Myrtaceae | – | – | – | – | 18.58 |
| | 37 | *Indigofera pulchella* L | Fabaceae | – | – | – | – | 24.07 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 38 | *Ipomoea digitata* auct. non L. | Convolvulaceae | – | – | – | 27.19 | 20.43 |
| 39 | *Justicia adhatoda* L. | Acanthaceae | – | – | 80.78 | 37.78 | 21.9 |
| 40 | *Phoenix acqualis* Buch. | Arecaceae | – | – | – | 43.18 | 28.21 |
| 41 | *Tephrosia purpurea* (L.) | Fabaceae | – | – | 76.95 | 45.31 | 42.98 |
| 42 | *Triumfetta pilosa* Roth. | Tiliaceae | – | – | – | – | 23.34 |
| 43 | *Urena lobata* L. | Malvaceae | – | – | – | 26.69 | – |
| 44 | *Vitex negundo* L. | Verbenaceae | – | – | – | – | 19.78 |

Family poaceae was found to be represented by 11 species. Family fabaceae was noticed to have 6 species. Family Acanthaceae, Convolvulaceae, Euphorbiaceae ware showed trispecific. Bispecific plants were shown by families like Cyperaceae, Scrophulariaceae, Verbanaceae and Malvaceae and rest of the families (Arecaceae, Asteracaea, Ceasalpiniaceae, Commelinaceae, Lamiaceae, Lythraceae, Mimosaceae, Oxalidaceae, Rubiaceae and Tiliaceae) were monospecific in nature. Among these family, Poaceae, Convolvulaceae and Verbenaceae were present in all sites irrespective of abandonment.

Further, analysis of floristic composition on the abandoned fields indicated that the number of families and species increased with increasing age of abandonment. A total of 7 (9 species), 9 (12 species), 12 (19 species), 16 (26 species) and 17 (34 species) families were registered in 2, 4, 6, 11 and 15 years old abandoned fields respectively. The total number of families in 11 and 15 yr old fields was more than double compared to that of the 2 YrF lands. In addition to this the total number of grass, non-grass and woody species were found to be increased with the age of abandoned rice field.

**Table 2.** Species richness, diversity ($\hat{H}$), dominance ($C_d$) and Evenness (E) indices of the vegetation in the abandoned rice fields.

| Parameters | | 2 yr | 4 yr | 6 yr | 11 yr | 15 yr |
|---|---|---|---|---|---|---|
| Species richness | Herb | 9 | 12 | 15 | 18 | 22 |
| | Woody sp | - | - | 4 | 8 | 13 |
| Diversity index ($\hat{H}$) | Herb | 2.126 | 2.424 | 2.621 | 2.821 | 3.024 |
| | Woody sp | - | - | 1.353 | 2.037 | 2.521 |
| Concentration of dominance (Cd) | Herb | 0.126 | 0.093 | 0.077 | 0.062 | 0.051 |
| | Woody sp | - | - | 0.265 | 0.136 | 0.084 |
| Evenness index (E) | Herb | 0.967 | 0.975 | 0.945 | 0.976 | 0.978 |
| | Woody sp | - | - | 0.976 | 0.979 | 0.983 |

The analysis of IVI value (Table 1) indicated that *Cynodan dactylon* was dominant species showing IVI value of 53.58 and the least dominant species was *Euphorebia hirta* (17.89) in 2 year abandoned rice field. *Eragrostis ciliaris* was the dominant species in 4 year showing IVI value of 38.50. *Evolvulus alsinoides* was found to be dominant in 6 year field with IVI value of 33.22. In the 11 YrF and 15 YrF, *Sorghum halepense* (26.74) and *Chloris barbata* (21.6) were the dominant species. The least dominant species were *Euphorebia hirta* (17.89), *Oldenlandia corymbosa* (11.06), *Ocimum canum* (8.11) *Phylanthus simplex* (4), *Mimosa pudica* (5.8) in 2, 4, 6, 11 and 15 year abandoned rice fields respectively. The shrub analysis was absent in early fields i.e. 2 and 4 year. The number of woody species gradually increased and maximum 12 in 15 year old abandoned uncultivated rice field. In the 6 and 11 year old fields *Butea monosperma* was dominant species on the basis of IVI. In the 15 Year land species *Tephrosia purpurea* exhibited dominant showing IVI value of 42.97.

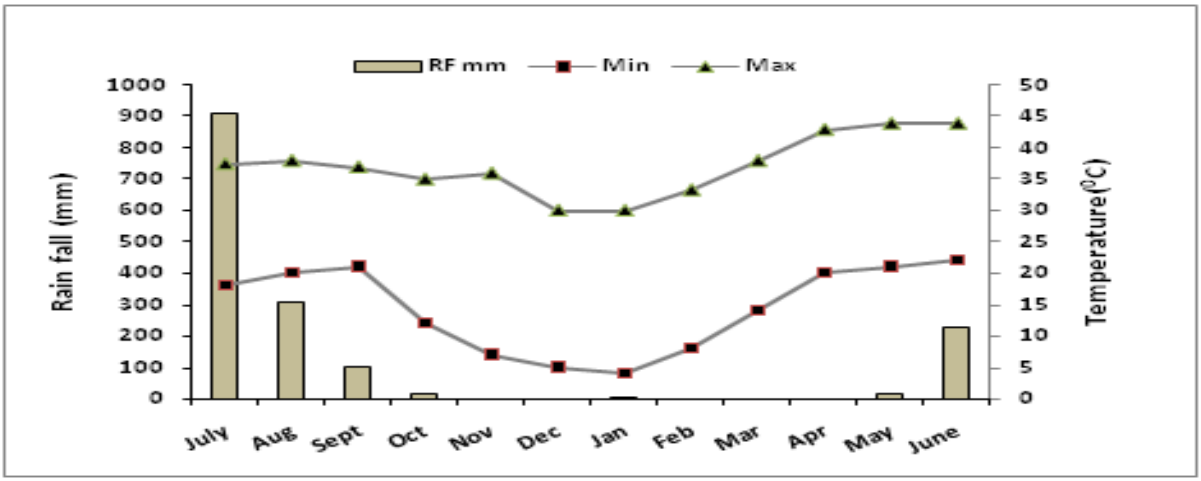


**Fig. 1.** The maximum and minimum temperature and rain fall of study sites from July 2010 to June 2011.

Species sequence curve of herbaceous vegetation on five different sites have been depicted in (Fig.3). These species sequence curve was plotted by taking species sequence in X-axis and IVI of different species in Y-axis. The analog of species sequence curve in these old fields indicated a broken stick model with clubbing of different species in the early stage of abandoned fields (2, 4 and 6 YrF), whereas perfect log normal curve distribution was observed towards later stage of land abandonment (11 & 15 YrF). Same trend like herbaceous vegetation the species sequence curve (Fig. 4) in case of woody vegetation was observed along the abandoned rice fields (Geometric curve in 6 YrF land and log normal curve in 15 YrF land).


**Fig. 2.** Study sites (Abandoned rice fields since 2, 4, 6, 11, and 15 years.

Species richness, diversity index (Ĥ), concentration of dominance ($C_d$) and evenness index (E) of vegetation in the abandoned rice fields have been depicted in table 2. The species richness and diversity index showed increasing trend with increased in the age of land abandonment. The species richness, diversity indices was found to be highest in 15 year fallow land and lowest in 2 YrF land. But the concentration of dominance declined with respect to increasing age of land. The dominance indices showed reverse to the diversity indices. The evenness indices found to be highest in 15 YrF field.

**Discussion**

Different abandoned agricultural fields were floristically different. Floristic exploration of abandoned uncultivated rice fields indicated the recovery of floristic composition with progressive year of abandonment. In the recent abandoned fields (2 YrF), six families accounted for 66.6 percent of total vegetation. With the progress of abandonment, the total no of families and species increased. Eight families in 4 year represented 66.6 percent of the total vegetation, 11 families covered 57.89 percent of the total vegetation in 11 year and 16 families represented 45 percent of the total vegetation in 15 year fallow land.

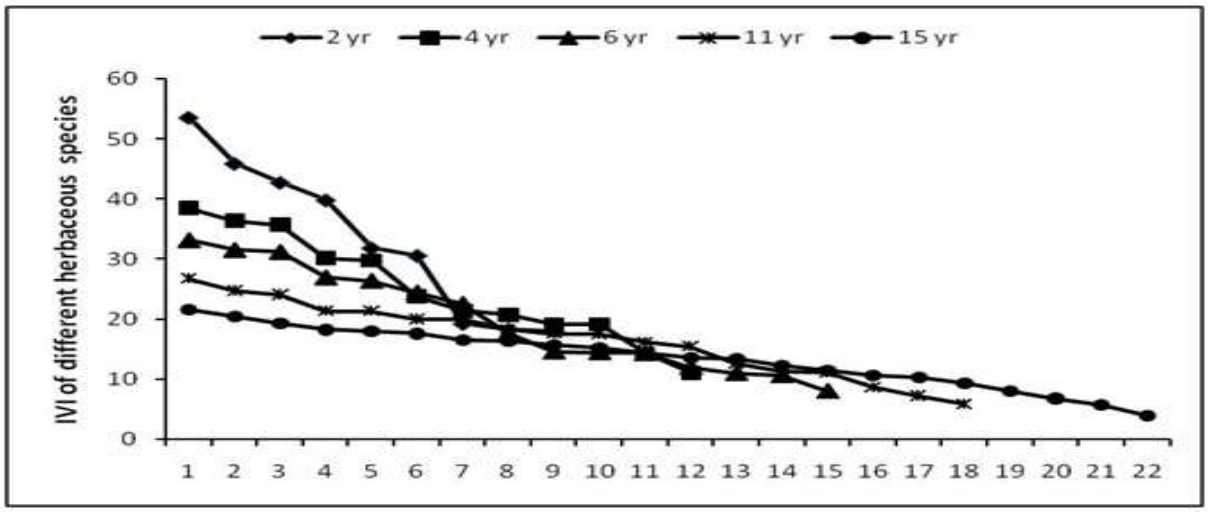


**Fig. 3.** Species sequence curve of herbaceous vegetation in the different abandoned rice fields.

The family Poaceae was dominant all over the site. Helm (1995), Skeel and Gibson (1996) reported in their study that the family Poaceae 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 soil moisture content of soil and climatic condition were not stressful to the appearance of species belongs 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 abandonment of these rice fields. These results were accordance with the study of Martin *et al.* (1991).

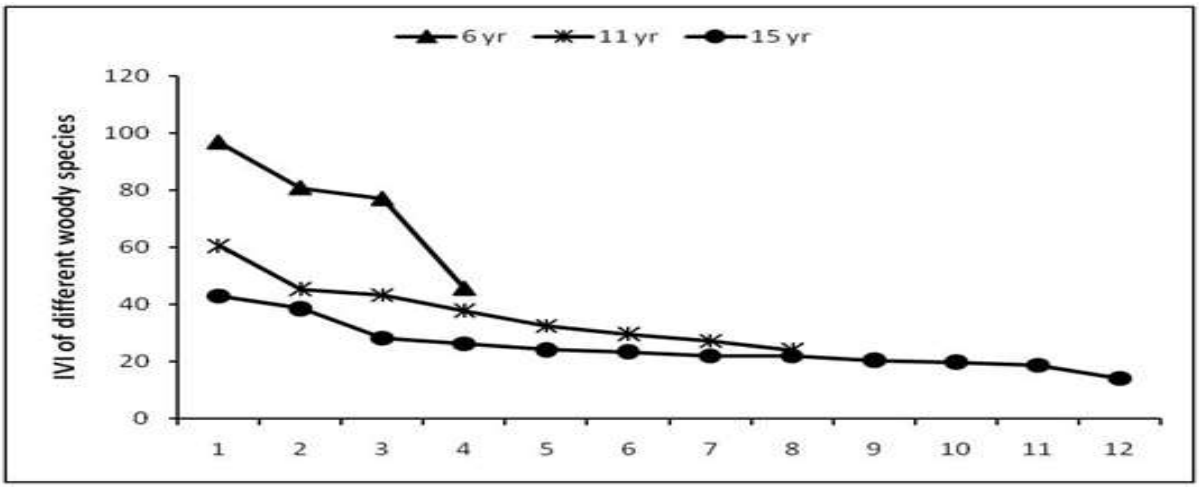


**Fig. 4.** Species sequence curve of woody vegetation in the different abandoned rice fields.

Comparative phytosociological analysis of vegetation along the chronosequence abandoned rice fields were observed to be differ from site to site. The shrub vegetation was absent in the early stage of abandoned fields (2 and 4 year) but the shrub species were found in the later stage of succession. A gradual change in IVI of different herb and woody vegetation within and between the abandoned fields was also marked. This difference is thought to be due to variation in sites, adaphic characteristic of soil, microclimate, and biotic influence. Besides that the variation in species composition is due to change in environmental conditions and life history characteristic. Shifting of dominant species was marked along the different stage of chronosequence. In the recent abandoned fields (2 YrF) *Cynodon dactylon* as dominant plant emerge in the bare soil. This plant was replaced by another competitive species *Eragrostis ciliaris* as succession progressed (4 YrF). Another species Evolvulus *alsinoides* became dominant in the 6 year fallow land. *Sorghum halepense* was dominant in the 11 year fallow land and finally in the 15 year fallow lands the *Chloris barbata* was the dominant species. The dominance pattern of shrub species in the study sites (6, 11 and 15 year) were *Butea monosperma* - *Butea monosperma* -*Tephrosia purpurea* respectively. This indicates that species achieved their highest dominance at different times during successional period. This is a general pattern of floristic and structural recovery following abandonment as reported by Guariguta and Ostertag (2001).

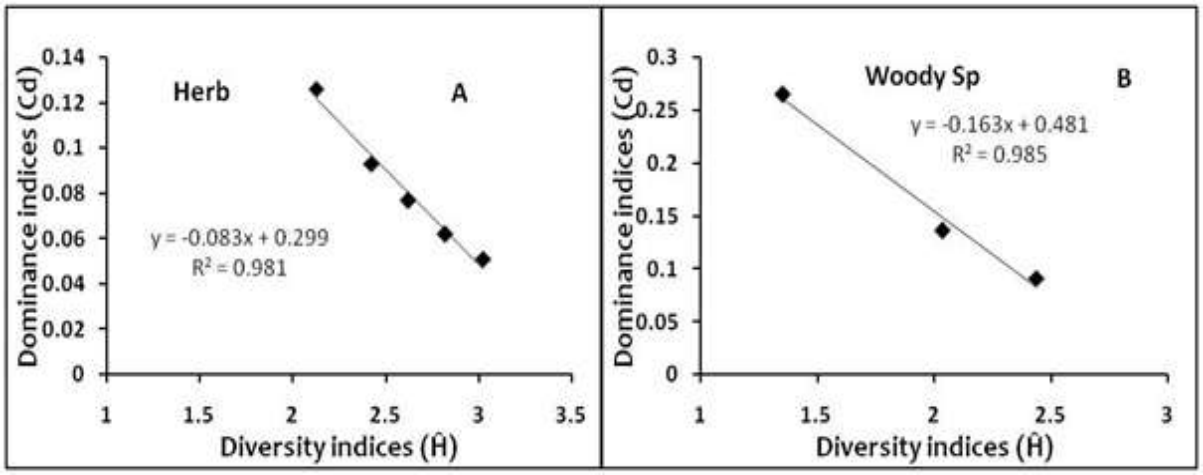


**Fig. 5.** Correlation of diversity-dominance indices of herbaceous (A) and woody vegetation (B) vegetation in different abandoned uncultivated rice fields.

The species sequence curve along the abandoned uncultivated rice fields revealed the niche pre-emption hypothesis (Motomura, 1932, Whittaker, 1975). Initially the abandoned uncultivated rice field showed geometric curve but towards later stage of abandonment it turned to be lognormal distribution where the species diversity high and community resource are shared by many species. Several literatures indicated that community during stress expected to show the broken stick model with clubbing of different species. The younger abandoned uncultivated fields (2, 4 and 6 tear fallow) the dominant was confined to a single species with strong dominant community. But with increasing age of fields large number of species accumulated where niche specialization becomes overlapped.

Structural feature of vegetation survey indicated an increasing trend in species richness, species diversity and decreasing dominance index with increasing year of fallow period during secondary succession indicating the succession to be in seral stage (Odum, 1969). Annuals are dominated in the above five sites in early abandoned fields, but appearance of woody shrub vegetation in the later part of the fallow period due to establishment of seedling of wood land

vegetation in the abandoned fields. Mitja and Puig (1993), noted that clearing with heavy equipment and deep ploughing are removed all the woody stumps results slower the return of the woody species. The appearance of pioneer woody shrub species in 6, 11 and 15 year abandoned uncultivated rice fields was in accordance with the study of Mitja and Puig (1993). The high species richness is due to coexistence of different life form at later stages of succession. The species richness and composition during secondary succession were influenced by several factors like intensity of land use history, available of propagule donors, post-dispersal of seed and abiotic factors like light, soil physicochemical properties.

As per Woomer *et al.* (1994), during vegetation succession on fallow land increase soil organic matter level through litter input and root production. As a result soil carbon content increase after seize cropping (Martin *et al.* 1991) thus promote the appearance of new species with the increasing year of abandonment. Some species like *Alysicarpus vaginalis, Atylosia scarabaeoides*, *Butea monosperma*, *Cassia fistula*, *Desmodium dichotomum*, *Tephrosia purpurea* belongs to family Fabaceae appeared towards later stage of land abandonment, which poses the capacity for nitrogen fixation. This showed a positive symptom for soil fertility recovery point of view during secondary succession.

The Shannon-Wiener diversity indices (Ĥ) of different sites ranged from 2.12 to 3.02 for herbaceous vegetation and from 1.35 to 2.52 for woody shrub vegetation. The result displayed that the diversity index was highest in 15 year old abandoned uncultivated field both in herb and woody vegetation. This may be due to the advancement of natural secondary succession that caused the recovery of nutrient in soil and make the soil fertile, which facilitate the appearance of new species in the abandon fields. Several studies have shown that species diversity index increases with age of succession (Marin *et al.,* 2009; Haripal and Sahoo, 2011) confirming our observation.

Simpson indices ($C_d$) of different sites ranged from 0.12 to 0.05 for the herbaceous vegetation 0.20 to 0.08 for woody vegetation along the abandoned rice fields. The results revealed that the concentration of dominance (Simpson's index) showed decreasing tendency with increasing age and minimum value were observed in the 15 year field in the present study. The high range of evenness value of different fields indicated homogenous distribution of different species in the above communities.

The dominance-diversity curve for herb and woody vegetation in old fields were depicted in the (Fig. 5 A & B). This figures showed a negative correlation between diversity and dominance. A square value of R=0.98 and linear equation (Y=-0.083x+0.299) for herbaceous species and square value of R=0.97 and linear equation (Y=-0.157x+0.471) for woody vegetation was noticed in the present study. Mc Naughtons work (1967) on some grass land of California indicated that dominance is inversely related to diversity. The present study confirms the finding of Mc Naughton's work (1967).

The chronosequence method provide a general view of main trend in the regeneration of abandoned fields on a regional scale and explains most important successional changes that occurs over a short period of time (Ruprecht, 2005). As per Prach and Hobbs (2008), spontaneous succession may be useful, low cost restoration in many situations. From the above study it is evident that, the agricultural land that are once derived from natural tropical forest when subjected to abandonment (i.e. fallow) exhibit improvement in terms of increased species diversity, species. Thus the present study justified the importance of fallow period for effective management of fertility status of tropical agro-ecosystem.

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