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A N I N T E R N A T I O N A L J O U R N A L

Phytosociological Studies on Natural Establishment of Vegetation in an Unreclaimed Limestone Mining

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ABSTRACT

Phytosociological structure was studied in limestone mining quarries at Rio Claro, São Paulo, Brazil. Quarries presented a chronosequence, ranging 1 to 40 years old, with focus on vegetation community organization, floristic similarity and plant diversity of three areas in different successive stages, devastated by limestone mining. A total of 1957 individuals distributed in 32 botanical families and 91 species were sampled. Low species diversity was obtained, ranged among quarries ages. In the early-established quarries, Leguminosae, Malvaceae and Sterculiaceae were the families most representative in number of species, while for the age 27, Asteraceae and Poaceae were the most representative. Diversity indices indicated that species diversity changed with the time and was function of environmental conditions.

Key words: Brazil, phytosociology, mining quarry, limestone mine, spoil banks, floristic

INTRODUCTION

After mining exploration, sometimes, a limited number of plant species, which produce a new ecosystem with low diversity appear (McLaughlin and Crowder, 1988). Mine wastes often afford simple ecosystems in which it is possible to study distribution of initial vegetation. Their advantages are: defined boundaries, low density, limited competition and known history (Bradshaw, 1983).

In despite continued attempts at artificial revegetation, little is known about the processes that accompany result natural revegetation of mined sites with pioneer plants, which represent a important knowledge about reclamation of the mining (Roberts et al. 1981; Kimmerer, 1984; Greller et al., 1990; Dias et al. 1994; Gisler, 1995). There are no studies from the phytosociological angle, particularly in tropical region (Simões et al., 1978; Griffith, 1980; Porto, 1989; Motta Netto et al., 1994). A phytosociological study enables one to know about distribution of species as wel as affinities between species or group of species, resulting in a valuable evaluation of the vegetation.

Land degradation during a limestone mining in Brazil is massive, including complete disruption of the soil profile to depths of over 50m (Lima, 1986; Soave, 1996). With the time, the topsoils (spoils) evolved onto the quarries, becomes poor in organic matter, nutrients and large particles, resulting in topsoil without structure (Soave, 1996). Such sites provide an excellent opportunity for testing changes in plant diversity (Reiners et al., 1970; Kimmerer, 1984). Preliminaries studies have shown that vegetation establishment in the limestone wastes at Rio Claro, São Paulo State, have occurred, as soon as, materials were

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abandoned and with a sequence related with spoils banks aging (Lima, 1986; Soave, 1992) and a tendency towards compositional similarity among Brazilian savanna
and semi-deciduous forests (Pagano et al., 1995).
In this work, an attempt was made compare phytosociological data from three spoils of different ages.

MATERIALS AND METHODS

Study Area

The limestone mine at Rio Claro exposes a series of surfaces which may be dated with aerophoto (Fig. 1), and with miners. In chronosequence studies of limited duration it is necessary to assume that a spatial sequence of distinct sites is representative of a temporal sequence at a single site. The study was conducted on a sequence of aged spoil banks from a limestone mining, at Rio Claro, São Paulo State, Brazil, located on the Depressão Periférica (Penteado, 1976). The research area lies in the sedimentar bedrock Fm. Irati, mainly composed of limestone. The coordinates of the site are 22^o 30´40´´ to 22^{o}32´S and 47^{o}35´W.
According to Comissão de Solos (1960), the soils developed in the region were red-yellow podzolic var. Piracicaba and red-dark-orto latosol. The mine area were red-dark podzolic one (Lemos and Santos, 1984). The climate is Awa, according the climatic classification of Köppen (1948), e.g., tropical rainfall with wet season (November to March). Monthly temperature is higher than 18^{o}C and the mean annual temperature is 20,3^{o}C. Precipitation is higher than 1506mm/year. The natural vegetation was probably a semi-deciduous forests (IBGE, 1977).

Soil and phytosociological surveys

As in 1992, the mining area presented vegetation and soil chronosequences on the stripping spoils banks, ranging one to forty years old. The selection of spoil banks to be studied was based on general accessability and freedom from possible human
disturbance. Three mining sites with different ages: 9 (Site 1), 12 (Site 2), 27 years (Site 3) and recently abandoned quarries were studied. These spoils banks were observed from August 1992 until March 1994 for vegetation studies. A morphological study was carried out from spoil banks, considering an area higher than 1000 m^2 with vegetation. Spoil samples were taken in 1992 and in 1994 for determination of organic matter according Walkley-Black method, pH in KCl 1N. Calcium, Magnesium, Potassium and Phosphorus contents were determined by light spectrometer and the results were expressed as meq^{-1}.100g. Total Nitrogen (Nt) and C/N ratio were obtained using equations of Olarte et al. (1979).
A phytosociological survey of the shrub and herbs strata was carried out in permanent plots with 1m^2 (Rice, 1967) during August 1992 to March 1994. The sample sufficiency for the sample areas was deduced through the collector curves. Thus, 20 and 25 plots were established along a transect line equidistant 5m. In each plot, cover percent was estimated to the total height for living plants. All samples were tagged, numbered in order as: a) number of the individual; b) scientific name, if possible; c) total height in centimeters. Collections were carried out insides as well as on the circunferences of the plots.
Each species was processed and identified in Botanic Department of UNESP, Campus of Rio Claro (SP) and deposited at Herbarium Rioclarenses (HRCB) belonging to the same University. The determinations were done with analytical keys and comparisons with materials deposited in the local herbarium. In the absence of these resources, the material was sent to specialists for identification. Phytosociological parameters (density, frequence, dominance and value of importance) were calculated according to Müeller-Dømbois and Ellenberg (1974). Those with were not possible to determined, were determined through percentage cover in the quadrates (Rice, 1967).

Data analysis

To determine the floristic similarity between the observed quarries, Jaccard and Sorensen indices were used (Müeller- Dømbois and Ellenberg, 1974). To estimate species diversity indices at sites 1, 2 and 3, the Shannon index (Zar, 1996) was calculated by using number of species in different lifeforms accompanied by the respective Evenness (E) measure (Müeller-Dømbois and Ellenberg, 1974). Difference in the measure species diversity between quarries was calculated using the Hutcheson test (Zar, 1996).

RESULTS

A complete listing of plant species found at mine area is presented in Table 1. A total of 1957 samples distributed in thirty-two families and ninety-one species at three sites of different ages were collected. The families with the greatest numbers of species available in the quarries flora were generally the families more represented in the quadrats. Amaranthaceae, Leguminosae and Poaceae dominated markedly in sampled species. Amaranthaceae was the first family in number of species (3 species) and represented the herbaceous stratum.

Phytosociological parameters are presented in Table 2 to 4, respectively, for the sites 1, 2 and 3 This revealed the ecological importance relative to each species in the sample and was useful for separating different vegetation types as well as relating them to environmental factors. Approximately 70% of the value of importance indices in Site 1 concentrated on only five species: *Sida rhombifolia*, *Eupatorium maximilliani*, *Parthenium hysterophorus* and *Alternanthera tenella*. Leguminosae and Malvaceae were the families most representative in numbers of species, following by Asteraceae and Poaceae. During 1994, at site 1, *Sida rhombifolia* was the most frequent species, as well as, the most dominant and the highest I.V.I. Asteraceae and Leguminosae were the most important related to the number of the species (3 species each other).

At Site 2, dominant species were *Waltheria indica*, *Tridax procumbens* and *Asclepias curassavica*, however, *Alternanthera tenella* presented the highest I.V.I. (24% of the total). The important families, in number of species were Sterculiaceae and Leguminosae. Most frequent species were *Parthenium hysterophorus* and *Sida rhombifolia*. *Parthenium hysterophorus* was the species that had the highest importance valour index, followed by *Eupatorium maximilliani* (Asteraceae), *Sida rhombifolia* (Malvaceae) and *Sida cordifolia* (Malvaceae).

At Site 3, *Pterocaulon lanatum*, *Baccharis dracunculifolia* and *Eupatorium maximiliani* were the dominant species while *Alternanthera tenella*, *Eupatorium maximiliani* and *Crotalaria mucronata* concentrated about 47% of the value of importace. In number of species, the ranking families were Malvaceae (4 species) followed by Asteraceae and Leguminosae (3 species). This last family was presented in both strata: trees (personal observation) and herbs. The most frequent species during March 1994 were *P. hysterophorus* and *Cyperus flavus*, but *Parthenium hysterophorus* was the dominant species, followed by *Crotalaria mucronata* and *Sida spinosa*, while the most important families were Malvaceae, Asteraceae and Leguminosae.

Cover importance indices (I.V.C.) values of the vegetative growth species are presented in Table 5. Cover indices were higher for *Aeschynomene* sp and *Paspalum notatum* in 1992 and decrease significatively at 1994. Vegetative growth was more at 1992 and after two years began to cease for all species. With relatively short span of about two years of competition from herbaceous and shrub strata, at 1994, initiated a progressive decline of these plants started.

Indices of Jaccard in August 1992 between Sites 1 and 2 was 31,57% and 57,89% in March 1994; for the Sites 1 and 3 the indices were 26,08% and 37,50%, respectively for 1992 and 1994. Considering composition species, the index was higher for the Sites 1 and 2, probably due the difference in age. Sörensen indices presented the following results: sites 1 and 2 the values were 48 and 70.96%, respectively to 1992 and 1994; and among Sites 1 and 3, Sörensen index values were 41.37% and 52.94%, respectively 1992 and 1994. Although the number of individuals of some species (mainly Poaceae), that had a hard growth, probably prevented the recover of others plant species and interfered in the structure of community. Jaccard and Sörensen indices indicated there was a succession process, occurring a replacing of annual and biannual for perennial species, mainly for Site 3.

Table 6 presents the Shannon (H´) and Evenness (E) indices during 1992 and 1994. In 1992, H' indices showed that species diversity presented a tendency to decrease with the time. The lowest value was obtained for the oldest site and it indicated a low diversity. Statistical analysis indicated that, although, were not significant ($0.05<P<0.10$ for $t = 0.05$ degrees of freedom). Similar results were obtained during 1994.

Some chemical properties (pH, % organic matter, total nitrogen, P, K, Ca, Mg and C/N ratio) of Ap horizons from spoils are presented at Table 7. The spoils profile was developed from relatively unweathered limestone wastes, and for this reason, the pH values were slightly alkaline. In addition, nitrogen contents and C/N ratio values were similar for the three ages.

DISCUSSION

Floristical analyses showed that species that belonged to Leguminosae family was predominant and had ranked first in many other tropical forests sites sampled (Gentry, 1982; Gentry and Emmons, 1987). Poaceae was the third ranking family in number of species and was represented in the herbaceous stratum. Grasses dominated the sparse herbaceous community. *Paspalum notatum*, a shade tolerant species contributed with more than 70% of the plots. Other principal species were *Aeschynomene* sp in permanent plots. The family more important was Asteraceae.

The nutrient concentrations as total nitrogen contents were considered sufficient for plant growth (Mello et al., 1983). C/N ratio values indicated relatively high contents of cellulose, probably derivated from roots, specialy from grasses. Organic matter was accumulating during soil and vegetation development what collaborates to better conditions of the soil. For example, Roberts et al. (1981) found significant relationships between organic matter and other nutrient contents of the ecosystem and age of the waste material. Similar results were found by other authors (Andrew and Rhoades, 1947; Richardson and Evans, 1987; Dias et al., 1994; Bell, 2001).

When comparing phytosociological parameters during 1992 and 1994, relative importance of herbaceous and shrub species indicated a progressive shift from this period. At site 3, stages of conversion from annual to biannual and perennial cycles of life were evolved. Some species were persistents even with the age appeared like *Sida rhombifolia*, *Eupatorium maximilliani* and *Parthenimu hysterophorus* and almost always were presented with high I.V.I.

The overall pattern of forest recovery in abandoned limestone mining quarries showed a medium relationship with age since abandonment. At sites ≤ 40 years old, there was a positive relationship between vegetation characteristics (plant density, $p = 0.62$ and species diversity $p = 0.45$) and age. Plant density increased from recently abandoned quarries (9 – 12years old) to abandoned quarries approximately 27 to 37 years old. The age of the site was the only significant variable for species number and diversity species.

I.V.I. values of species during 1994 indicated that the species changed with the time and was function with environmental conditions, as nutrient availability in the mine spoils, organic matter content, structure and texture besides interespecific competition (Soave, 1996).

Natural establishment of vegetation in limestone mining was observed in recently accumulated was (approximately one year of storage) and the species commonly found were *Mellinis minutiflora, Phaseolus lathyroides* and *Rhynchelitrum roseum* (Lima, 1986; Soave, 1992; 1996). After the time, it was observed that the pioneer community didn't persist for a long time. Developed community was composed with a little species (Humphries 1980; Lima 1986; Roberts et al., 1981; Aide et al., 1996). Sites 1 and 2 could be considered at the initial stages of development, because plant species that occurred there, were considered pioneers (Lorenzi, 2000), with exception for the site 3 where three strata: the herbaceous, shrubs and trees were observed (Soave, 1992). Besides, the number of species at the Site 3 was higher than other sites, probably due to the best soil profile development which favored the evolution of the plants. The initial rate of recovery of vegetation in abandoned quarries was slow when compared with recovery in many other types of human and natural disturbance (Uhl, 1987; Lugo, 1992; Parrota, 1992). Aide et al. (1996) obtained the 10-15 years old, abandoned pastures, that in the dominant vegetation was composed by herbaceous species, but once shrubs and small tree established, herbaceous cover was reduced and other woody species colonized the site.

Environmental conditions of the mining supported the establishment of plant community the higher number of weeds (Lorenzi, 2000), because the agricultural activity around the mine, especially with sugar cane plantations.

In 1992, H' indices showed that species diversity presented a tendency to decrease with the age, i.e. the lowest value was obtained for the oldest site and they indicated a low diversity. In 1994 the index of species diversity increased with aging. Gisler (1995) compared Shannon indices obtained at Poços de Caldas (MG), in a bauxite mining with other forests and were also very low. Evenness varied between only 1.02 to 1.73 between Sites 1 and 3 so that it too did not contributed to notable change. Although, it is true that species number did increase with time, the rate of increase was low Changes in relative importance of dominant species responded to logging add a subsequent and progressive increase in competition. Declining dominance may be attributed to intolerance and/or growth or roots into the herbaceous and shrubs species, and latter, the appearance of tree stratum. Also, when soil conditions changed, plant diversity changed, appearing tall shrubby and tree species.

CONCLUSION

The major objective of this work was to determine changes in plant community diversity with successional development. Rather rapid increase in diversity in early succession was expected, these data seem to indicate that in spite of gross changes in species and physiognomy, species diversity of vegetation in the limestone mining chronosequence varies little between one to forty years of age. Replication and data on sites of intermediate between those sampled must be required to make such a generalization conclusive.

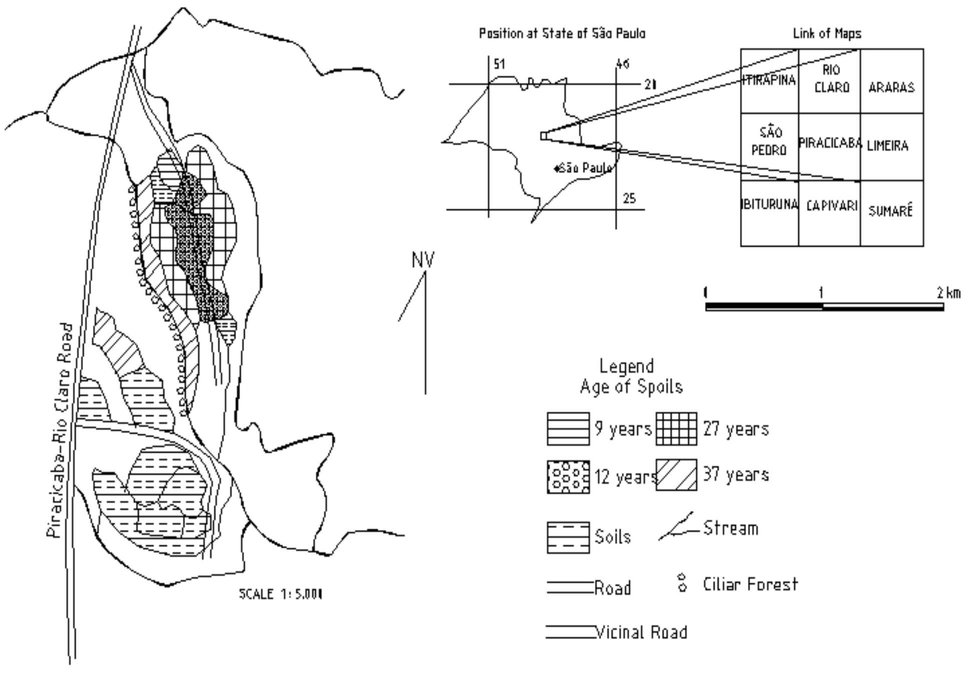

Figure 1 - Map of the study area.

Table 1 - Plant species of different strata found in limestone mine area located at Rio Claro - SP, Brazil.

Family	Species	Voucher number
Acanthaceae	*Thumbergia alata* Bojer	26.298
Amaranthaceae	*Alternathera tenella* Moq.	12.630
	Gomphrena celosioides Mart.	27.607
	Amaranthus sp1	1.884
Asclepiadaceae	*Asclepias curassavica* Linn.	29.717
Asteraceae	*Ageratum conyzoides* Linn.	6.586
	Baccharis dracunculifolia DC.	4.016
	Bidens pilosa Linn.	942
	Chaptalia integerrima (Vell.) Burkart	7.186
	Eupatorium laevigatum Lam.	6.345
	Eupatorium maximiliani Schrad. Ex DC.	32.490
	Emilia sonchifolia DC.	1.863
	Gochnatia pulchra Cabrera	8.937
	Merostachys sp	001
	Mikania cordifolia Willd.	4.259
	Parthenium hysterophorus Linn.	1.849
	Porophyllum ruderale Cass.	30.665
	Pterocaulon lanatum Kuntze	5.882
	Siegesbeckia orientales Willd.	904
Asteraceae	*Tagetes minuta* Linn.	5.883
	Tridax procumbens Linn.	5.884
	Vernonia polyanthes Less.	1.867
Bignoniaceae	*Stenolobium stans* Seem.	6.423
	sp1	003
Borraginaceae	*Cordia sellowiana* Cham.	11.280
Convolvulaceae	*Ipomoea cairica* Sweet.	3.601
Cucurbitaceae	*Cicyos poliacanthus* Cogn.	3.468
	Momordica charantia Linn.	799
Cyperaceae	*Cyperus brevifolius* (Rottb.) Hasskn	27.291
	Cyperus flavus J. and C. Presl.	25.834
Dennstaetiaceae	*Pteridium aquilinum* (L.) Kuhn.	
Dilleniaceae	*Curatella americana* Linn.	4.692
Euphorbiaceae	*Euphorbia heterophylla* Linn.	1.899
	Euphorbia hirta Linn.	985
	Euphorbia hyssopifolia Linn.	988
	Ricinus communis Linn.	30.798
Flacourtiaceae	*Casearia sylvestris* Linn.	10.564
Lamiaceae	*Hyptis lophanta* Linn.	5.130
Lauraceae	*Nectandra megapotamica* Mez	14.287
Lecytidaceae	sp1	002
Leguminosae	*Acacia plumosa* Lowe	7.185
	Aeschynomene sp	7.188
	Bauhinia foficata Link	5.695
	Cassia hirsuta Linn.	30.586
	Crotalaria incana Linn.	30.578
	Crotalaria lanceolata E.Mey.	30.577
	Crotalaria mucronata Desv.	30.567
	Desmodium canum Schins and Thellung	32.334
	Desmodium purpureum Fawcet and Rendle	32.454
	Indigofera truxillensis H.B. and K.	33.444
	Lonchocarpus sp	15.799
	Phaseolus lathyroides Linn.	4.233
	Stylosanthes viscosa Sw.	4.244

(Cont.)

(Cont. Table 1)

	Teramnus sp	005
	Vigna sp	32.230
Malvaceae	*Sida carpinifolia* Linn. f.	31.948
	Sida cordifolia Linn.	30.699
	Sida hyssopifolia Linn.	30.228
	Sida rhombifolia Linn.	798
	Sida spinosa Linn.	4.162
	Sida viarum A . St. Hil.	12.425
	Sida viscosa Linn.	4.164
	Sida urens Linn.	27.412
Meliaceae	*Cedrela fissilis* L.	20.163
	Melia azedarach Linn.	30.783
	Trichilia elegans A . Juss.	2.739
Myrtaceae	*Eucalyptus citriodora* Hook.	1.417
	Eucalyptus saligna Sm.	1.406
	Psidium guajava Linn.	13.457
Piperaceae	*Piper* sp1	30.563
	Piper sp2	25.593
Poaceae	*Digitaria insularis* (L.) Mea ex Ekman	977
	Eragrostis ciliaris (L.) R.Br.	25.858
Poaceae	*Hyparhenia rufa* (Ness) Stapf	25.857
	Mellinis minutiflora Beauv.	30.772
	Paspalum notatum Fluegge	998
	Rhynchelitrum roseum Stapf and Hubbart.	12.778
	Setaria geniculata (Lam.) Beauv.	19.294
	Sporobolus indicus (L.) R. Br.	4.882
Polypodiaceae	*Polypodium* sp	006
Rhaminaceae	*Rhaminidium* sp	33.545
Sapindaceae	*Cardiosperma halicacabum* Linn.	18.797
	Guazuma ulmifolia Linn.	34.390
Solanaceae	*Solanum aculeatissimum* Jacq.	29.718
	Solanum lycocarpum A . St. Hil.	5.653
Sterculiaceae	*Melochia pyramidata* Linn.	22.374
	Waltheria indica Linn.	4.727
Tiliaceae	*Luehea divaricata* Mart.	18.256
	Triumfetta bartramia Linn.	32.099
Ulmaceae	*Celtis iguanae* Linn.	33.933
Urticaceae	*Morus alba* Linn.	26.360
Verbenaceae	*Lantana camara* Linn.	31.918
	Lantana lilacina Desf.	29.724

Table 2 - Phytosociological parameters of species for Site 1. IVI values in descending order for 1994. Ni = individual numbers; DeR = relative density; FeR = relative frequence; DoR = relative dominance; IVI = importance value index.

Species	Ni		DeR (%)		FeR (%)		DoR (%)		IVI	
	1992	1994	1992	1994	1992	1994	1992	1994	1992	1994
Sida. rhombifolia	24	74	11,11	35,92	17,24	20,51	9,15	26,31	37,50	82,74
Eupatorium maximilliani	0	74	0	22,33	0	10,26	0	0	0	54,97
Parthenium hysterophorus	04	24	1,85	11,65	3,44	17,95	13,19	16,93	18,48	46,53
Alternanthera tenella	20	20	9,26	9,71	6,89	7,69	7,32	10,15	23,47	27,55
Solanum sp	12	12	5.55	5,82	3,44	10,26	8,05	7,00	17,04	23,68
Crotalaria incana	0	11	0	5,34	0	7,69	0	0	0	20,63

(Cont.)

(Cont. Table 2)

Pterocaulon lanatum	0	5	0	2,43	0	5,13	0	0	0	11,41
Gomphrena celosioides	0	5	0	2,43	0	5,13	0	1.39	0	8,95
Cyperus flavus	0	4	0	1,94	0	5,13	0	0.91	0	7,98
Stylosanthes viscosa	0	3	0	1,46	0	5,13	0	1.10	0	7,79
Melochia pyramidata	0	1	0	0,48	0	2,56	0	0.86	0	3,90
Asclepias curassavica	0	1	0	0,48	0	2,56	0	0.82	0	3,86
Desmodium purpureum	36	0	16,66	0	20,69	0	6,96	0	44,31	0
Walteria indica	36	0	16,66	0	10,34	0	8,80	0	35,80	0
Sporobolus indicus	40	0	18,52	0	6,89	0	7,70	0	33,11	0
Sida viscosa	24	0	11,11	0	13,80	0	6,22	0	31,13	0
Indigofera truxillensis	4	0	1,85	0	3,44	0	10,98	0	16,27	0
Thumbergia alata	4	0	1,85	0	3,44	0	10,98	0	16,27	0
Euphorbia hyssopifolia	8	0	28,57	0	6,89	0	4,39	0	14,98	0
Sida carpinifolia	4	0	1,85	0	3,44	0	6,22	0	11,51	0

Table 3 - Phytosociological parameters of species for Site 2. IVI values in descending order for 1994. Ni = individual numbers; DeR = relative density; FeR = relative frequency; DoR = relative dominance; IVI = value of importance.

Species	Ni		DeR (%)		FeR (%)		DoR (%)		IVI (%)	
	1992	1994	1992	1994	1992	1994	1992	1994	1992	1994
Parthenium hysterphorus	0	24	0	17,39	0	19,51	0	21,58	0	58,48
Eupatorium maximilliani	0	29	0	21,11	0	9,76	0	25,64	0	56,51
Sida rhombifolia	16	25	10,26	18,11	9,52	19,51	11,32	10,55	31,10	48,17
Sida cordifolia	0	8	0	5,80	0	9,76	0	12,27	0	27,83
Crotalaria mucronata	4	12	2,56	8,69	4,76	4,87	12,83	8,76	20,15	22,32
Stylosanthes viscosa	0	13	0	9,42	0	7,31	0	5,46	0	22,19
Asclepias curassavica	4	6	2,56	4,35	40,76	4,87	15,09	7,82	22,41	17,04
Alternanthera tenella	60	8	38,48	5,80	28,57	7,32	5,66	2,97	72,71	16,09
Melochia pyramidata	4	5	2,56	3,62	4,76	4,87	5,28	1,72	12,60	10,21
Gomphrena celosioides	0	4	0	2,90	0	4,87	0	1,72	0	9,49
Amaranthus sp	0	3	0	2,17	0	4,87	0	1,10	0	8,14
Euphorbia hirta	0	1	0	0,72	0	2,44	0	0,39	0	3,55
Waltheria indica	28	0	17,94	0	28,57	0	19,62	0	66,13	0
Tridax procumbens	32	0	20,51	0	9,52	0	15,85	0	45,88	0
Euphorbia hyssopifolia	8	0	5,13	0	9,52	0	14,34	0	28,99	0

Table 4 - Phytosociological parameters of species for Site 3. I.V.I. values in descending order for 1994. Ni = individual numbers; DA = absolute density; DR = relative density; FA= absolute frequence; FR = relative frequence; DoA = absolute dominance; DoR = relative dominance; I.V.I. = value of importance.

Species	Ni		DeR (%)		FeR (%)		DoR (%)		IVI (%)	
	1992	1994	1992	1994	1992	1994	1992	1994	1992	1994
Parthenium hysterophorus	0	17	0	13,70	0	18,52	0	20,33	0	52,55
Sida spinosa	0	40	0	32,36	0	3,70	0	14,77	0	50,73
Crotalaria mucronata	20	9	10,00	7,25	9,85	7,40	9,85	17,33	32,89	31,98
Sida viarum	0	11		8,86	0	7,40	0	9,55	0	25,81
Cyperus flavus	0	10	0	8,05	0	11,11	0	5,22	0	24,38
Alternathera tenella	72	11	36,00	8,86	4,18	7,40	4,18	4,55	61,92	20,81
Asclepias curassavica	0	6	0	4,84	0	3,70		10,00	0	18,54
Euphorbia hyssopifolia	0	4	0	3,22	0	7,40	0	1,77	0	12,39
Sida rhombifolia	8	3	4,00	2,42	6,40	7,40	6,40	1,77	14,74	11,59

(Cont.)

(Cont. Table 4)

Lantana lilacina	0	3	0	2,42	0	3,70	0	4,44	0	10,56
Stylosanthes viscosa	0	3	0	2,42	0	3,70	0	2,77	0	8,89
Chaptalia integerrima	8	3	4,00	2,42	7,88	3,70	7,88	1,66	16,22	7,78
Pterocaulon lanatum	08	01	4,00	0,80	19,70	3,70	19,70	2,22	28,04	6,72
Waltheria indica	08	01	4,00	0,80	3,20	3,70	3,20	1,77	15,90	6,27
Euphorbia hirta	0	01	0	0,80	0	3,70	0	1,11	0	5,61
Sida urens	0	01	0	0,80	0	3,70	0	0,66	0	5,16
Eupatorium maximiliani	36	0	18,00	0	12,81	0	12,81	0	48,21	0
Baccharis sp	08	0	4,00	0	14,77	0	14,77	0	27,47	0
Vernonia sp	04	0	2,00	0	8,86	0	8,86	0	19,56	0
Hyptis lophanta	12	0	6,00	0	7,39	0	7,39	0	17,73	0
Desmodium canum	16	0	8,00	0	4,92	0	4,92	0	17,26	0

Table 5 - Cover importance index (I.V.C.) of plant species with vegetative growth, at 1992 and 1994.

Espécie	**Site 1**		**Site 2**		**Site 3**	
	1992	**1994**	**1992**	**1994**	**1992**	**1994**
Aeschynomene sp	70,70	7,74	153,60	1,35	71,73	1,63
Paspalum notatum Fluegge	54,18	5,18	240,00	3,16	98,88	0,09
R.hybcheliturm roseum Stapf and Hubbart	15,80	1,72	?	0,08	67,22	0,07
Eragrostis ciliaris (L.) R.B.	–	–	–	0,43	–	0,72

Table 6 - Shannon's index (H') and Evenness index (E) of species for sites 1,2 and 3 in 1992 and 1994.

	Shannon Index (H')		**Evenness Index (E)**	
	1992	**1994**	**1992**	**1994**
Site 1	0,87	0,80	1,28	1,02
Site 2	0,87	0,69	1,04	1,72
Site 3	0,83	0,76	1,08	1,73

Table 7 - Soil properties of the Ap horizons of limestone mining quarries of the areas on Sites 1, 2 and 3.

Year	**Nutrient concentrations (meq.100g-^{1})**						
	% Organic Matter	**pH**	**P mg.100g^{-1}**	**K**	**Mg**	**Ca**	**C/N**
1992							
Site 1	2,49	8,47	0,46	21,40	23,20	41,20	12,01
Site 2	4,79	7,95	< 0,10	30,85	43,50	36,40	11,63
Site 3	5,57	7,87	< 0,10	47,11	36,22	29,74	11,62
1994							
Site 1	10,11	8,18	6,94	20,50	7,44	35,20	11,71
Site 2	7,41	8,22	6,94	8,70	25,30	35,70	11,62
Site 3	10,51	6,75	0,25	5,30	23,05	28,23	11,51

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RESUMO

O presente estudo apresenta os dados sobre a estrurtura fitossociológica de uma comunidade desenvolvida em rejeitos de mineração de calcário em Rio Claro, SP, Brasil. Na área, foi encontrada uma cronoseqüência de rejeitos variando entre um a quarenta anos de abandono. Este tipo de comunidade, constituída principalmente por espécies ruderais colonizadoras, tem sido pouco estudada, principalmente em ambientes tropicais. O presente estudo enfoca a organização da comunidade vegetal, a similaridade florística e a diversidade de três áreas com materiais de rejeitos de diferentes idades, degradados pela mineração. As idades dos rejeitos localizadas na área da mineração foram 9, 12 e 27 anos, identificados como Áreas 1, 2 e 3, respectivamente. Para o estudo fitossociológico, em cada idade, foram estabelecidos 20 plotes permanentes de $1m^2$ onde todos os indivíduos pertencentes aos estratos herbáceo e arbustivo foram amostrados. No levantamento florístico foram encontrados 1957 indivíduos distribuídos em 32 famílias e 91 espécies. Para cada idade, foram calculados parâmetros fitossociológicos, os índices de diversidade de Shannon-Wiener, de Sörensen e de Jaccard. Nos rejeitos recém acumulados (Áreas 1 e 2), Leguminosae, Malvaceae e Sterculiaceae foram as famílias mais representativas em número de espécies, enquanto que na Área 3, Asteraceae e Poaceae foram as mais representativas. Os índices de Shannon e de similaridade (E) indicaram que a diversidade de espécies mudou com o tempo provavelmente em função de fatores abióticos e bióticos.

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