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Current and lost diversity of cultivated varieties, especially cassava, under swidden cultivation systems in the Brazilian Atlantic Forest

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Abstract

Tropical agricultural systems characterized by swidden-fallow practices have been studied in many tropical areas of the world. One feature of these systems is the high diversity of cultivated species and varieties. The objective of this paper was to analyze the inter and intraspecific diversity of cultivated crops under swidden cultivation systems adopted by *caiçaras* in the Brazilian Atlantic Forest, and the genetic erosion of this diversity in the last decades. To analyze the inter and intraspecific diversity of cultivated crops under swidden cultivation systems in the Brazilian Atlantic Forest, interviews were performed in 33 swidden agriculturists' households concerning the species and varieties under cultivation and others that have been lost. The plots were visited to check the crops cited in the interviews. The agriculturists cited 261 varieties from 53 crop species, with 30.6% of lost varieties. Each agriculturist cited an average of 25 varieties. The main crop was cassava (*Manihot esculenta* Crantz), followed by yams (*Dioscorea* spp.), sweet potato (*Ipomoea batatas* Poir.), squash (*Cucurbita pepo* L.), sugarcane (*Saccharum officinarum* L.), and beans (*Phaseolus vulgaris* L.). Among the interviewed agriculturists, 87% of them have sons and/or daughters not involved in agricultural activity, reflecting a trend toward the loss of the local agricultural skills. A model was proposed to explain the dynamics of the system focusing on the crop diversity and considering the resource resilience. The exchange of crop varieties among agriculturists builds a network which buffers against the loss of the managed diversity in the regional scale. Features such as the itinerancy cycles of fallow/swidden, and the traditional ecological knowledge contribute to the increasing of the managed diversity. However, the agriculturists also pointed out several factors contributing to the depletion of the managed diversity, related to restrictive environmental laws, rural exodus, increasing tourism, and changing of livelihood activities. The loss of crop diversity indicates the urgency for strategies towards the maintenance of the diversity and knowledge tied to the agricultural systems of *caiçara* communities, calling for specific strategies and policies to avoid the loss of their agricultural legacy.

Keywords: Swidden agriculture; *Caiçaras*; Genetic erosion; Traditional ecological knowledge; Resilience; Atlantic Forest; Brazil

1. Introduction

Shifting cultivation, slash-and-burn agriculture, or the complex approach of swidden-fallow cultivation (Conklin, 1954; Geertz, 1963; Beckerman, 1983; Denevan and Padoch, 1987; Brookfield and Padoch,

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1994; Fox et al., 2000) encompasses a diversity of agricultural practices found throughout tropical humid areas all over the world, including the lowland and mid-elevated forests in tropical America (Kleinman et al., 1995; Piperno and Pearsall, 1998; Coomes et al., 2000). Some of these farming methods mimic natural ecological processes, and their sustainability relates to ecological models they follow (Altieri, 1999).

Agricultural practices are often seen as a primary cause of the disappearance of the remaining forests by well-intentioned conservationists, and are frequently viewed as a "wasteful" and "destructive" technique (Brady, 1996; Tinker et al., 1996; DeJong, 1997; Piperno and Pearsall, 1998). Nevertheless, swidden cultivation is an enormously successful adaptation to the rigors and constraints of the tropical forest. It is associated with a social organization characterized by household autonomy in decision making, relatively small and shifting settlements, often composed of a few related families and low population densities (Kleinman et al., 1995; Piperno and Pearsall, 1998). The management of these systems involves much more than simply slashing, burning, planting, weeding, and fallowing (Alcorn, 1990).

The high inter and intraspecific diversity of cultivated species is one of the features of these agricultural systems, coped with the maintenance of evolutionary processes, including interactions between people and crops, germplasm conservation, and environmental conservation (Oldfield and Alcorn, 1987; Brush, 1995; Salick, 1995; Salick et al., 1997; Peroni, 1998). Traditional varieties are used by agriculturists on swidden cultivation as a key component of their agricultural systems. These varieties are the raw material for the development of virtually all modern varieties (Cleveland et al., 1994; Wood and Lenné, 1997), and are of great strategic importance for all countries in the world (Martins, 1994).

Several studies point out the relevance of the traditional ecological knowledge in the understanding, managing, and interacting with the diversity of natural resources (Gliessman, 1992; Plotkin, 1995). In many cases, the biodiversity conservation is considered a cultural imperative (Shiva, 1996). The complexity of these agricultural systems reflects the complexity of the knowledge needed to manage it: besides the great richness of species managed in consortium, the majority of these species have high intraspecific diversity, distinct times for planting, and different uses for each variety (Kerr, 1987; Martins, 1994).

Brazilian Atlantic Forest is an area with a high concentration of endemic species threatened by a severe loss of habitat (Myers et al., 2000). This area, however, is probably been used and managed by indigenous populations since pre-Columbian times (Balée, 1992). Swidden agriculture is one of these management practices, which was also adopted by *caiçaras* (Peroni and Martins, 2000). *Caiçaras* are native inhabitants of Brazilian Atlantic coast, and they descend from native Indians, Portuguese and European colonizers, showing also influences from African culture (Mussolini, 1980; Marcílio, 1986; Hanazaki et al., 1996; Begossi, 1998). The original livelihood of caiçaras was based on swidden agriculture blended with fishing activities (Oliveira et al., 1994; Hanazaki et al., 1996, 2000; Begossi, 1998; Peroni and Martins, 2000).

The objective of this paper was to describe and analyze the inter and intraspecific diversity of cultivated crops under swidden cultivation systems in the Brazilian Atlantic Forest, regarding to: (1) the species and varieties currently cultivated; (2) the species and varieties lost; and (3) the importance of the knowledge associated to the agricultural practices in this region. The genetic erosion of the intraspecific diversity in the last decades was analyzed, recovering the local knowledge on the cultivated varieties.

2. Materials and methods

2.1. Characteristics of swidden systems in the Brazilian Atlantic Forest

According to Kleinman et al. (1995) slash-and-burn agroecosystems are important to rural poor and indigenous peoples in the developing world, and can be ecologically sustainable under some circumstances such as low population density. Schmidt (1958) analyzed the *caiçara* swidden agriculture with slash-and-burn in the first half of 20th century and its historical importance since pre-Columbian times (see also Dean, 1997). Today, in the coastal Atlantic Forest region, swidden agriculture has lost its economic importance, but it is still practiced by persevering agriculturists.

In the studied region, swidden agriculture is practiced with different degrees of itinerancy, ranging

Table 1
Characteristics of the 33 households from 16 *caiçara* settlements from the southern coast of São Paulo State (Brazil) included in this study

Settlement	Local households (estimated)	Agriculturists households	Households included in this study	"Casas de farinha"
Aquários	25	1	1	1
Vila Nova	35	2	2	1
Praia do Leste	15	1	1	0
Icapara	300	18–24	7	13
Sorocabinha	15	3	2	–[a]
Ilha Grande	25	2	2	1
Subaúma	11	3	2	0
Porto Cubatão	100	3	1	3
Itapitangui	200	4	1	–[a]
Prainha	6	2	1	2
São Paulo Bagre	20	3	3	3
Agrossolar	10	1	1	1
Papagaio	1	1	1	1
Juruvaúva	6	2	2	1
Pedrinhas	40	5	5	2
Ubatuba	5	2	1	2
Total	866	53–59	33	31

[a] No data available.

from the slash-and-burn of secondary vegetation ("*capoeiras*" or "*tigueras*"), to the itinerancy within the small holdings, also including almost sedentary agricultural practices, in plots ("*roças*") near the settlement neighborhoods or inside house gardens.

The agriculturists included in this study live in settlements with 1 to about 300 native families (Table 1). Some of these settlements are villages and also include several houses of newcomers and tourists, such as Icapara, Agrossolar, Pedrinhas, Porto Cubatão, Itapitangui, and Subaúma.

The studied settlements are in areas of "*restinga*" which are coastal vegetation formations in sandy areas (Monteiro and Cesar, 1995) and secondary forest under sand to clay dominated soils. Some agriculturists plant their crops over remains of shells mounds named "*casqueiras*" or "*sambaquis*" (Gaspar, 1998). These environments allow the use of the same plot by longer periods, due to its soil rich in nutrients such as phosphorus, potassium, calcium, and magnesium.

The plots are planted between August and October, and used during 2 years in average. The plots are kept in fallow for 1–20 years, and cultivated again. However, there is a trend toward the dissociation of swidden and fallow cycles. The agriculturists revealed that the time span of the fallows is reducing and the plots are being cultivated during longer periods, to fit the Brazilian legislation about secondary vegetation use.

The use of areas in early stages of succession (1–4 years) are being preferred due to the facility of cleaning and the labor shortage, but also leading to the re-utilization of areas with reduced fertility. Communitary labor systems ("*mutirões*"), in which relatives and neighbors cooperated in plot openings, were common in the past but now are rare or inexistent. Plot openings are now in charge of family members only.

Agriculture is not the major economic activity in the region, as suggested by the number of agriculturist's households in each settlement (Table 1). Since the 1950s, this original *caiçara*'s livelihood activity has been replaced by fishing, and more recently by tourist related jobs (Hanazaki et al., 1996).

Cassava (*Manihot esculenta* Crantz) is the main crop in this system, also representing a key crop for the understanding of the particularities of the shifting cultivation. This species was domesticated in Neotropical lowlands (Allem, 1994; Piperno and Pearsall, 1998), and was historically important to the subsistence of Amerindian and native people. It has high intraspecific diversity, it is propagated vegetatively, and it can be useful as a model to explain tropical patterns of agriculture and domestication.

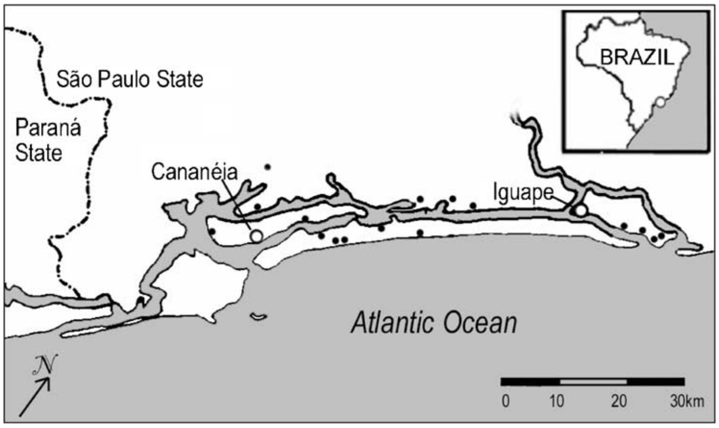

Fig. 1. Study site: southern coast of São Paulo State, Brazil. Black dots indicate the settlements included in this study.

"*Casas de farinha*" or "*tráficos*" are the places where the cassava flour is processed (Schmidt, 1958). They are small houses with a grater, a press, and an oven. Their presence in each settlement (Table 1) points out the importance of agricultural activity, especially concerning the bitter cassava, which must be processed into flour prior to consumption. Bitter cassava are those varieties with high content of cyanidric acid (HCN), while sweet varieties are those with lower HCN contents. Among *caiçaras*, sweet cassava can be consumed boiled, fried, as flour, or even raw, while bitter cassava needs to be processed as flour before consumption.

Agricultural products are mainly directed to household's direct subsistence. Cassava flour is the main agricultural product marketed, sold few and far in the neighborhoods. Rarely, some yams (*Dioscorea* spp.) are also sold. Although the high intraspecific diversity of cassava, the preference for processing flour involves a few varieties only, such as "*cascuda*" (and its sub-varieties "*cascuda grande*" and "*cascudinha*"), "*mandipóia*", "*imperial*" and "*jurema*". All these varieties are bitter.

2.2. Interviews

This study was carried out during 1998–1999 in the southern coast of São Paulo State, Brazil, in chosen settlements where swidden practices and fishing activities are still found. Thirty-three households from 16 *caiçara* settlements were included in this study (Fig. 1).

A sample of the agriculturists, both men and women, was interviewed in these *caiçara* settlements. The choice to include or not an agriculturist's household was based on the following: (a) the family practiced swidden cultivation in the last 5 years or still practices it; (b) the agriculturists are *caiçaras*; and (c) the family agreed to participate in this study. The semi-structural interviews were based on questionnaires about the swidden cultivation, crop species and varieties cultivated in the present and in the past 30 years, and management practices. The period of 30 years was defined as the approximate age when the agriculturists would have begun their agricultural activities as an independent family. The species and varieties quoted in the interviews were checked through visits to past and current cultivated plots (*roças*), and to the yards near the houses.

2.3. Data analysis

Data on diversity were analyzed through methods used by quantitative ethnobotany (Begossi, 1996; Hanazaki et al., 2000), such as diversity indices. The Brillouin index (Magurran, 1988; Zar, 1996) was used, considering that the recording of all varieties cultivated by each agriculturist is a collection and not a sample. The index is used to compare the managed varieties per species by each agriculturist, and not the abundance of varieties or species cultivated in each plot. The Brillouin index (HB) is given by the following equation:

$$\mathrm{HB} = \log_2 N! - \frac{\sum \log_2 n_i!}{N} \quad (1)$$

where N is the total number of varieties cultivated by the agriculturist and n_i the number of varieties per each species.

The number of varieties cited as lost divided by the total of citations for each variety gives the index of loss (IL), which ranges from 1 (totally lost) to 0 (still cultivated by some agriculturist). It expresses the risk of a variety being lost in the whole assemblage of agriculturists included in this study.

3. Results and discussion

3.1. Diversity of crops

Although the percentage of agriculturists was low (10%) among the total population (Table 1), the number of cultivated varieties was high (Table 2). The agriculturists cited 263 varieties from 43 crops currently cultivated and seven crops that were cultivated in the last 30 years but are currently lost.

Each agriculturist cited an average of 25 varieties (standard deviation (S.D.) = 14 varieties) from 10 species (S.D. = 4 species). The average number of the current varieties per agriculturist was 14 (S.D. = 12 varieties) from six species (S.D. = 5 species). The average number of lost varieties was 11 varieties per

Table 2
Main crops cultivated in plots by the *caiçaras* in the southern coast of São Paulo State (Brazil), cited by at least 10% of the agriculturists

Crop	Species	Family	NV[a]	NL[b]
Mandioca	*Manihot esculenta* Crantz	Euphorbiaceae	62	11
Cará	*Dioscorea* spp.	Dioscoreaceae	29	8
Batata doce	*Ipomoea batatas* Poir.	Convolvulaceae	29	8
Arroz	*Oryza sativa* L.	Poaceae	26	23
Banana	*Musa paradisiaca* L.	Musaceae	24	4
Cana	*Saccharum officinarum* L.	Poaceae	22	4
Feijão	*Phaseolus vulgaris* L.	Fabaceae	16	11
Abóbora	*Cucurbita pepo* L.	Cucurbitaceae	5	3
Taiá	*Xanthosoma sagittifolium* Schott	Araceae	3	0
Milho	*Zea mays* L.	Poaceae	2	0
Mangarito	*Xanthosoma* sp. 1	Araceae	1	0
Inhame	*Xanthosoma* sp. 2	Araceae	1	1
Pepino	*Cucumis sativus* L.	Cucurbitaceae	1	0
Tomate	*Lycopersicon esculentum* Mill.	Solanaceae	1	0
Abacaxi	*Ananas comosus* Merr.	Bromeliaceae	1	0
Melancia	*Citrullus lanatus* (Thunb.) Matsum. And Nakai	Cucurbitaceae	1	0
Araruta	*Maranta arundinacea* L.	Marantaceae	1	0
Other[c]			36	7
Total			261	80
Percentage of loss			30.6	

[a] Number of varieties cited.
[b] Number of varieties cited as lost.
[c] Other species with two varieties: almeirão (*Cichorium endivia* L.) and cajú (*Anacardium occidentale* L.); with one variety: abacate (*Persea americana* Mill.), acelga (*Beta vulgaris* L. var. *cicla* L.), alface (*Lectuca sativa* L.), alho (*Allium sativum* L.), amendoim (*Arachis hypogaea* L.), ata (*Annona squamosa* L.), bucha (*Luffa* spp.), cabaça (*Lagenaria vulgaris* Ser.), café (*Coffea arabica* L.), cebola (*Allium cepa* L.), couve (*Brassica oleraceae* L. var. *acephala* DC.), graviola (*Annona muricata* L.), jaca (*Artocarpus integrifolia* L.), jiló (*Solanum gilo* Raddi), laranja (*Citrus sinensis* L. Osbeck), limão (*Citrus aurantifolia* Swingle), mamão (*Carica papaya* L.), manga (*Mangifera indica* L.), maracujá (*Passiflora edulis* Sims), palmito (*Euterpe edulis* Mart.), pimentão (*Capsicum annuum* L.), pitanga (*Eugenia uniflora* L.), salsinha (*Petroselinum sativum* L.), and uva (*Vitis vinifera* L.); with one variety cited as lost: abacaxi do mato (*Ananas* sp.), açafrão or safroa (non-identified), cenoura (*Daucus carota* L.), couve flor (*Brassica oleracea* L.), pepinel (maxixe) (*Cucumis anguria* L.), quiabo (*Hibiscus esculentus* L.), and vagem (Leguminosae, non-identified).

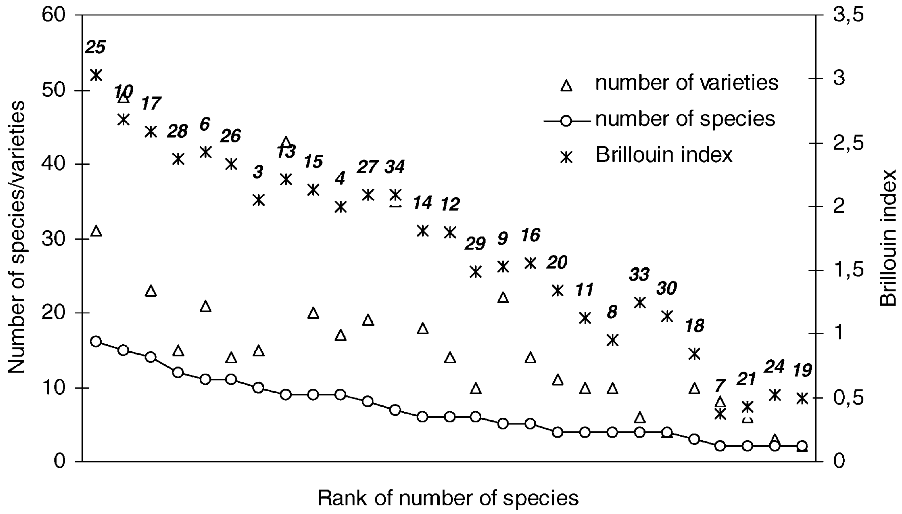

Fig. 2. Rank-frequency distribution following the number of species per agriculturist (richness) from the highest to the lowest, number of varieties cultivated per agriculturist, and diversity of current cultivated varieties per agriculturist (Brillouin index). The numbers in italics indicate the agriculturists interviewed in the southern coast of São Paulo State, Brazil.

agriculturist (S.D. = 8 varieties) from four species (S.D. = 3 species). High values of standard deviations reflect different individual strategies by the agriculturists (Emperaire and Pinton, 1999) and the heterogeneity on the maintenance of varieties among *caiçara*'s families, besides their common origin.

Diversity indices were calculated in order to compare the knowledge and the management of varieties among the agriculturists (Fig. 2). Agriculturists who manage the higher variety diversities played an important role in the regional system of swidden agriculture. They managed many varieties from many crops (e.g. agriculturists numbers 25, 10, 17, 6, 28, 26; Fig. 2). The average diversity measured by the Brillouin index was HB = 1.55 ranging from HB = 0.38 to 3.03 (Fig. 2).

Agriculturists with higher diversities (those on the left side of Fig. 2) fit into a profile of those who manage assemblages with more varieties within more species, and tend to have the better knowledge and skills about swidden systems, when compared to those on the right side of Fig. 2.

There are no key actors among *caiçaras* in the sense pointed out by Salick et al. (1997), who considered the Amuesha's shaman as the paramount keeper of cassava's diversity, because this person cultivated and managed 53 varieties, contrasting with the average of 5.9 varieties cultivated by other agriculturists. In the present study, among the main cited crops, cassava has an average of 5.4 varieties currently cultivated per agriculturist, while yams and sweet potato (*Ipomoea batatas* Poir.) have averages of 1.6 and 1.8 varieties per agriculturist, respectively. Among *caiçaras*, the figure of a shaman does not exist, yet the interchange of varieties among *caiçara* agriculturists seems to be more intense than among the Amuesha. Agriculturists who rely on a lower diversity of cultivars know that they depend on the other agriculturists as a source of new or lost varieties.

Some features are common among the high-diversity managers. First, they are agriculturists who own their land. The majority of the other agriculturists do not have this safety of having their own land to cultivate every new agricultural cycle. Second, they cultivate more than one plot per year, and they can rotate the plots inside their property from one year to another.

Some agriculturists rely just on a few varieties from a few crops (e.g. numbers 7, 21, 24, 19; Fig. 2). Lower diversities are pushed by changing factors simplifying the swidden system, which results in the choosing of a few species and the management of a few varieties per crop (often one). A remarkable agriculturist is number

19, who manages a low diversity, and closely reflects a market economy, producing cassava flour to be sold in the village of Icapara. Besides one variety of banana (*Musa paradisiaca* L.) planted for consumption, this agriculturist plants only one variety of cassava as a monocrop. The tendency to homogeneity in cultivation with increasing market dependence was also reported by Salick et al. (1997).

3.2. Species cultivated

The main species cultivated in plots were cassava, followed by yams, sweet potato, squash (*Cucurbita pepo* L.), sugarcane (*Saccharum officinarum* L.), and beans (*Phaseolus vulgaris* L.) (Table 2). Several agriculturists also cultivated bananas and fruits (such as cashew, *Anacardium occidentale* L., and avocado, *Persea americana* Mill.) on the borders of the main crops. Rice (*Oryza sativa* L.) was an important crop in the region until the end of the 19th century, but nowadays it is planted by few agriculturists. The percent of loss (30.6%) on Table 2 indicates the percent of varieties not cultivated by any agriculturist.

Peroni and Martins (2000) found 61 varieties of 12 different species cultivated by just one family of traditional farmers from southern São Paulo State, reflecting the high inter and intraspecific diversity cultivated. The great species richness reflects the agriculturist's skills in integrating varieties of different species in the same cultivation environment, reflecting the complexity of their crops system. The majority of the crops are of vegetative propagation, and the intraspecific diversity is high in each crop. Management features, such as the use of fallow areas, associated with life history components of these crops, such as seed dormancy, amplify this diversity (Peroni and Martins, 2000).

The relevance of cassava and of its intraspecific diversity was documented elsewhere, especially in the Amazonian region (Carneiro, 1983; Boster, 1983, 1984; Chernela, 1987; Salick et al., 1997). Among the Jivaro from Peru, Boster (1983) found that cassava is a highly dominant crop, and its number of varieties is far greater than of all other species combined. The Peruvian Aguaruna and Huambisa maintain more than 100 distinct cassava varieties each. This author also mentioned about 700 distinct names for cassava varieties cultivated by the Aguaruna (Boster, 1984). Among the Kuikuru from Brazilian Amazonia, Carneiro (1983) found 46 varieties of cassava, all bitter, but the six varieties most grown comprises over 95% of all the cassava varieties planted by Kuikuru. Chernela (1987) reported 137 bitter varieties cultivated by the Tukâno. Salick et al. (1997) found 204 varieties of cassava among the Peruvian Amuesha, which can be grouped in 39 phenotypes. These authors also pointed out that over 50% of the common names given to cassava varieties are unique to particular extended families cultivating the variety, often resulting in the same phenotype having distinct common names in different families (Salick et al., 1997).

The names given by *caiçaras* for the cassava varieties are quite homogeneous among the different households. The most cited varieties share the same morphological or agricultural features. For example, the main feature of "*aipim vassourinha*" (Table 3) is the leaf shape with narrow lobes; the variety "*Cascuda*" is characterized by its relatively high productivity in any conditions of soil and fertility; and the roots of "*aipim manteiga*" are yellow.

Analyzing genetically and morphologically the local varieties of cassava cultivated in Brazilian Atlantic Forest, Peroni (1998) and Peroni et al. (1999) showed that agriculturists are coherent in distinguishing and identifying the different varieties by morphology, but they underestimate the real genetic variability of cassava. Their results confirm the trend suggested by Quiros et al. (1990) with Andean potato, but with cassava the clones are like "genotypes' families", also showing an intravarietal variability.

The agriculturists consider each variety of cassava, yams, and sweet potato corresponding to clones, and each variety as corresponding to a different genotype. Quiros et al. (1990) and Peroni (1998) provide evidence for a higher number of genotypes and a higher level of variability, hence the number of varieties with different genotypes of the species in Table 2 is certainly higher than the diversity actually perceived by the agriculturists.

3.3. Lost diversity

Different species and varieties are under different degrees of risk of being lost in the whole assemblage of agriculturists. For example, the rice variety "*arroz amarelão*" was cited by 36.4% of the interviewees, but it has a high risk of being lost in the region (IL =

Table 3
Species, varieties and sub-varieties cited in 33 interviews in the southern coast of São Paulo State (Brazil)

Local name (species)	Percentage of citations	IL[a]
Aipim vassourinha (*Manihot esculenta* Crantz)	60.6	0.5
Mandioca cascuda (*Manihot esculenta* Crantz)	60.6	0.35
Aipim manteiga (*Manihot esculenta* Crantz)	60.6	0.3
Mandioca mandipóia (*Manihot esculenta* Crantz)	57.6	0.42
Cará de espinho (*Dioscorea cayenensis* Lam.)	57.6	0.32
Taioba (*Xanthosoma sagitifolium* Schott)	51.5	0.35
Batata doce branca (*Ipomoea batatas* Poir.)	48.5	0.31
Aipim cinco minutos (*Manihot esculenta* Crantz)	48.5	0.31
Arroz amarelão (*Oryza sativa* L.)	36.4	0.92
Cará frissura[b] (*Dioscorea bulbifera* L.)	36.4	0.67
Abóbora (*Cucurbita pepo* L.)	36.4	0.33
Batata doce roxa (*Ipomoea batatas* Poir.)	36.4	0.33
Banana nanica[c] (*Musa paradisiaca* L.)	36.4	0.08
Feijão carioquinha (*Phaseolus vulgaris* L.)	33.3	0.36
Mandioca imperial (*Manihot esculenta* Crantz)	33.3	0.27
Banana branca[d] (*Musa paradisiaca* L.)	33.3	0.18
Mangarito (*Xanthosoma* sp. 1)	30.3	0.8
Feijão (*Phaseolus vulgaris* L.)	30.3	0.7
Mandioca cascudinha (*Manihot esculenta* Crantz)	30.3	0.4
Cará guaçu (*Dioscorea* sp.)	27.3	0.67
Cará mirim (*Dioscorea trifida* L.)	24.2	0.88
Batata doce (*Ipomoea Batatas* Poir.)	24.2	0.75
Cará São João (*Dioscorea trifida* L.)	24.2	0.5
Cana (*Saccharum officinarum* L.)	24.2	0.25
Mandioca jurema (*Manihot esculenta* Crantz)	24.2	0.13
Feijão chumbinho (*Phaseolus vulgaris* L.)	21.2	1
Mandioca mata negro (*Manihot esculenta* Crantz)	21.2	0.57
Cana caiana (*Saccharum officinarum* L.)	21.2	0.14
Aipim branco[e] (*Manihot esculenta* Crantz)	21.2	0

[a] Given by the number of varieties cited as lost divided by the total number of citations of each variety, ranging from 1 (totally lost) to 0 (still cultivated by some agriculturist); only for varieties with at least 20% of citations.
[b] Also called "*cará moela*" or "*do ar*".
[c] Also called "*caturra*".
[d] Also called "*prata*".
[e] Also called "*chileno*".

0.92). On the other hand, the most cited varieties are not necessarily the varieties with less risk of being lost. For example, the cassava variety "*aipim vassourinha*" is widely known (60.6% of the citations), but the IL was 0.5. Probably the high percentage of citations of "*aipim vassourinha*" is related to its conspicuous morphological features. In contrast, "*aipim manteiga*" was equally cited because of its agronomic and culinary features (easy to cook and highly productive). This latter variety had a lower IL when compared to other varieties widely known, and is preferred in flour processing, such as cassavas "*cascuda*" and "*mandipóia*".

There was a central group of cassava varieties, which were widely distributed among the agriculturists (Table 3). Some varieties of this group, such as "*mandipóia*" and "*cascuda*", have been managed in the region for decades (Pierson and Teixeira, 1947).

Also, the type of varieties planted is changing, with sweet varieties gradually replacing bitter ones, originally planted only to produce flour. The sweet varieties can be eaten cooked or used to produce flour, and are planted near the houses or in backyards.

An exception to the assemblage of the most cited varieties was the yam "*cará de espinho*" (57.6%; Table 3). This variety was rarely planted in the plots, and was occasionally consumed, but it is a ruderal species and can survive without direct human management. This was shown by its low IL (0.32). Besides, it was not properly cultivated, being associated mainly with human activity in environments near the houses and in secondary vegetation.

3.4. Buffer effects and resilience

The maintenance of the varieties followed the opportunist and individual strategy, as observed in Altamira (Pará State, Brazilian Amazon) with cassava (Emperaire and Pinton, 1999). In the present study, considering all the crops, the varieties kept by only one agriculturist family correspond to 35% of all the varieties cited. Adding the percentage of varieties lost (33%), a total of 68% of the cited varieties exists in only one locality or do not exist. The agriculturists argue that when they need more seeds or vegetative material to plant, they appealed to their neighbors' or to their relatives' stocks, building exchange webs of vegetative materials, such as cassava sticks or yam bulbs. Seeds were rarely bought in the nearby cities. These exchange webs were not restricted within the settlements, because frequently different settlements are connected by kin relationships. Exchange webs serve as a diversity buffer, and reinforce the importance of on-farm conservation in a regional level, connected to the local and household levels.

Resilience is the capacity of the system to absorb disturbances and this concept can be used to explain the transitions in behavior of social as well as ecological systems (Holling et al., 1998). The positive association of diversity and stability functions, such as resilience, is discussed by many authors (Walker, 1989; Pimm, 1994; Putman, 1994; Tilman, 1997), especially in agricultural systems (Boster, 1983; Kresovich and Mcferson, 1992; Swift and Anderson, 1994; Altieri, 1999; Trenbath, 1999). Cultural flexibility is often related to cultural behaviors, such as the use of the traditional and neo-traditional techniques, and might increase ecological resilience (Begossi, 1998). These techniques include diversified cropping and increasing manioc intraspecific diversity. Begossi (1998) argues that the traditional management of the *roças* is an example of attitudes that increase the ecological resilience of the *caiçara* communities, and the loss of knowledge about cultivated varieties may work against ecological resilience.

Crop diversity can be considered as a component of the resilience of an agricultural system as a whole (Trenbath, 1999). However, crop diversity is also related with a lower scale of analysis, the one concerning the resilience of the resource. Crop diversity avoids risks for the agriculturists because the maintenance of a large gene pool allows for future selection in response to environmental change (Boster, 1983; Kresovich and Mcferson, 1992). Crop diversity loss reduces the flexibility to face environmental changes. Sambatti (1998) pointed out that in *caiçara*'s systems under environmental law restrictions, agriculturists reduced the number of cassava varieties in plots, selecting varieties adapted to lower soil fertility. This happened because the fallow periods were shortened and the plots are now used during longer periods.

When diversity is reduced, the possibility of intraspecific gene flow is reduced, as well as interspecific gene flow with wild relatives (Peroni and Martins, 2000). Besides the conscious vegetative propagation of the main crops by the agriculturists, the sexual reproductive processes (unconscious) also occurs to amplify its diversity (Martins, 1994). Less intraspecific gene flow increases the possibility of inbreeding because of the clone propagation. In the case of cassava, it is also related to inbreeding depression (Kawano et al., 1978). These factors may reduce the selection possibilities and the adaptive success of the crops.

The reduction on the resource resilience can reduce the ecological and social resilience (Berkes and Folke, 1998) by affecting the biological flexibility to face changes (Fig. 3).

In the present study, it is clear that crop diversity is being lost. Fig. 3 presents a scheme that summarizes the main factors acting on the managed diversity. There are several factors indicated by the agriculturists that show on-farm diversity loss. Among them, environmental protection laws is one of the most cited. Agriculturists consider that these laws do not fit into the local reality of on-farm diversity management. Effects of restrictive environmental laws in the studied region were also mentioned by Winther et al. (1989). These components are not an isolated Brazilian case. DeJong (1997) observed that conservationist forest policies do not reflect the problems between the state and forest-dependent people in Indonesia. This author

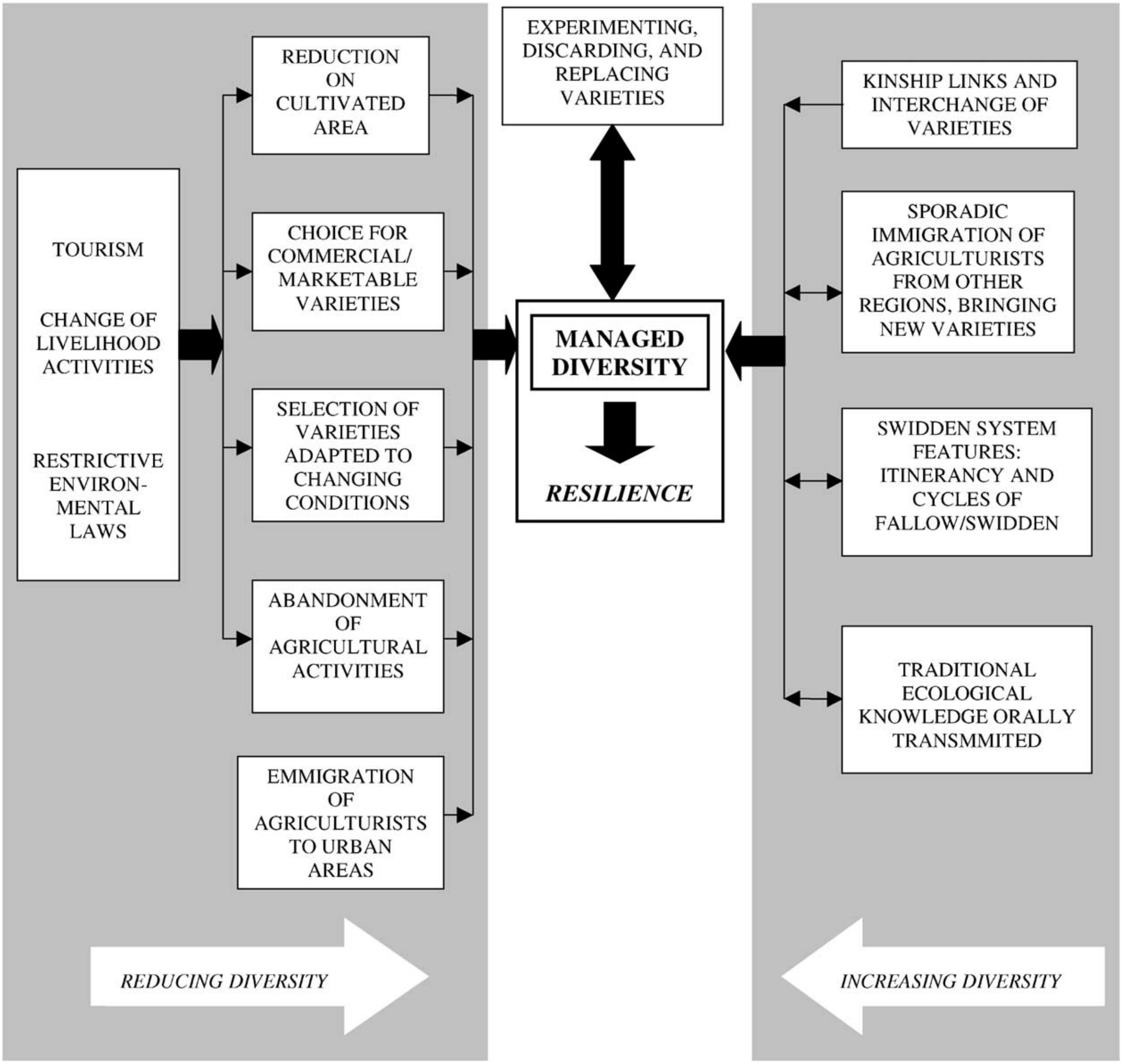

Fig. 3. Factors that influence the diversity maintenance and loss among the *caiçaras* from Atlantic Forest.

observed that the official schemes towards converting swidden agriculturists into sedentary cultivators result in reduction of biodiversity in the agricultural landscape.

Other factors pointed out by agriculturists also contribute to the reduction of managed diversity. These factors are related to rural exodus, increasing tourism, and changing of livelihood activities, which is also related to the loss of knowledge about the varieties (Fig. 3). Among the interviewed agriculturists, 87% of them have sons and daughters who do not continue the agricultural activity. Hanazaki and Begossi (2000) suggested the same trends among *caiçaras* from the northern coast of São Paulo State. As stressed by Emperaire and Pinton (1999), the loss of the learning process about the local varieties makes the crop diversity more vulnerable than the loss of the biological material by itself.

4. Conclusions

Caiçara's swidden systems were characterized by the management of a high inter and intraspecific diversity of crops. This diversity has important effects on the resilience of the resources managed and on the resilience of the agricultural system as a whole. However, there was a trend toward the loss of the crop diversity, along with the traditional knowledge associated.

There was evidence that one of the shortcomings of the environmental protection laws is the resulting reduction of species and varieties cultivated, and the associated loss of knowledge about an agricultural system adapted to tropical conditions. It benefits the Atlantic Forest cover, but at the same time has negative consequences to on-farm biodiversity.

In the long term, the continuity of the swidden agriculture among *caiçaras* depends on the maintenance of this activity by a pool of agriculturists. However, many constraints to swidden agriculture make its continuity an unlikely event. The loss of crop diversity indicates the urgency for the development of strategies and policies towards the maintenance of the diversity and knowledge tied to the agricultural systems of *caiçara* communities, to avoid the loss of their agricultural legacy.

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