Invisible contaminants and food security in former coal mined areas of Santa Catarina, southern Brazil

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Invisible contaminants and food security in former coal mined areas of Santa Catarina, southern Brazil

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Abstract

Background: Mining activities have environmental impacts due to sediment movement and contamination of areas, and also pose risks to people's food security. In Brazil, the major part of coal mining activities is done in the southern region, in the Santa Catarina Carboniferous region. In this region, former mined areas contaminated with heavy metals frequently occur nearby inhabited zones. Heavy metals are contaminants that does not have odor, color, or taste, and are therefore difficult to detect. We aimed to verify whether people use plants from contaminated mined areas, and to understand which factors influence plant use.

Methods: We did semi-structured interviews with residents from 14 areas nearby abandoned mines in the main municipalities of the Santa Catarina Carboniferous region.

Results: Out of the 196 interviewed residents, 127 (65%) reported collecting plants for medicinal and food use, directly from contaminated mined areas. Long-term residents, as well as those who noticed more environmental changes (positive and negative), cited more plants used, and had more detailed knowledge of plant use in their communities. When asked if they were aware of the possible contamination of mined areas, 85% said they knew about it. However, only 10% associated negative health effects with the use of plant species collected in contaminated mined areas.

Conclusions: Our study demonstrates that people living nearby contaminated areas use and consume plants, and also evidences a lack of information about contamination and a lack of participatory actions that include local communities in contaminated area restoration strategies. This situation poses a risk to the food security of the people living nearby former coal mined areas.

Key words Ethnoecology; food security; coal mining; local communities.

Background

The use and management of plant resources for medicinal or food purposes is an ancient practice present in all cultures of the world [1,2]. Through practices of harvesting, planting, and use of resources, traditional peoples and local communities maintain their link with the environment [3]. Local communities are human groups that are located in both, the same region and time period, developing a cultural identity and a unique relationship with the environment [3–5]. The interaction of local communities with the environment is directly related to their culture, and to the experiences and perceptions of past and present generations [6], and is reflected the use of local resources and dietary habits [7,8].

People perceive and categorize changes in the landscape over time [9,10]. The perception of changes in the landscape by local inhabitants (e.g. changes in species diversity-and species richness, and air pollution) assists in understanding why some changes occur and which are the possible factors that generate these changes (e.g. urbanization, deforestation, mineral extraction) [11,12]. Generally, individuals living for longer and closer to the resources are those who have the greater knowledge and use of the resources [10]. Coupled with this, women tend to have a greater knowledge and use of medicinal plants, as they are usually responsible for early health care in several local communities [13–16]. Women are also more vulnerable to food security issues than men due to gender inequalities. Food security is the term used to define the right that all people, at all times, should have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and preferences for an active and healthy life [17]. According to the FAO (2018), women often live in more unhealthy or contaminated areas than men, and, when they receive food from the government, it is of lower nutritional quality.

Around the world, contaminated areas have endangered people's food security [18–20]. Among the sources of contamination, mining activities, such as coal mining, have caused public health concerns, due to the release of heavy metals in the mining process [18,19,21]. Although the impact level of metal toxicity depends on the concentration at which it is ingested, chronic exposure to relatively low levels of heavy metals may also cause adverse effects [22]. Heavy metals can bioaccumulate in the food chain, therefore metals in the soil can be accumulated by plants that are consumed by humans, finally accumulating in humans [22,23]. The study of heavy metal impacts on food security of local communities has gained prominence in regions such as China, related to urban growth in mined areas [18,24], and northern Europe, related to increased mining activities and insecticide use in agriculture [25]. In Canada there has been an increase in heavy metals in some foods used by indigenous communities [26]. In Latin America, studies with indigenous peoples and fishers have observed the presence of heavy metals in fish and vegetable resources consumed by local communities [27–30].

In Brazil, contamination of soil, plant, and fishery resources also pose a health risk to local communities [31,32]. In southern Brazil, 99.98% of the Brazil’s coal is mined [33,34]. The extraction of coal in the country began in the late nineteenth century, and continues to this day. It is estimated that in Santa Catarina state alone, there are more than 6,500 hectares of abandoned areas contaminated by heavy metals from coal mining activities [35]. Due to diminishing profitability in the late twentieth century, some mined areas were abandoned whilst local communities developed in these locations. Even after decades of inactivity, abandoned mined areas are still contaminated by heavy metals [36] and may pose a risk to the food security of local communities. Some open pit coal mined areas receive restoration treatment after abandonment, which consists in reconstructing the landscape and soil in order to create minimal conditions for vegetation development (Pinto, 1997). The restoration process of open pit coal mined areas consists basically in filling the pit with sterile pyrite and sandstone, covering this sterile layer with clayey regolith, and putting back previously stored soil; followed by planting species for soil fixation (Campos et al., 2003). However, this restoration process is usually deficient, especially due to the different mining processes employed by mining companies and the lack of inspection of mined areas by responsible authorities, resulting in contamination of the surface layers of the constructed soil with coal residues (Campos et al. 2003; Rocha-Nicoleite et al. 2017). Some plant species can survive and even thrive in these contaminated sites [37–40], and may be bioindicators of contamination and useful for bioremediation, if they have bioaccumulation potential [37,39]. Some of these species, however, also have associated medicinal or food use, which may pose a risk to human health [41]. Nevertheless, there are few studies investigating whether plant resources occurring in areas contaminated by heavy metals are being used by the local population [42].

Considering the growing risk of contamination of plant resources [8,28,43,44], we aimed to investigate whether local residents use plants obtained from contaminated mined areas, and to understand which factors influence plant use. Our hypothesis are that (1) the total number of species cited by interviewees will be influenced by their residence time, sex, locality and perception of landscape change, and area type (i.e. either abandoned or partially restored); and (2) the set of cited species will be influenced by interviewees' residence time, sex, locality and perception of landscape change, and area type (i.e. either abandoned or partially restored). We expect that women, older residents, residents neighboring restored mined areas, and residents who are unaware of the contamination, will use and know more plant species.

Methods

Study area

The study was conducted in municipalities of Criciuma, Forquilhinha, Siderópolis, Treviso, Urussanga, and Lauro Müller, in the state of Santa Catarina (Fig. 1). We selected 14 former coal mined areas with at least 1 ha, which were abandoned for at least 30 years, and with a history of heavy metals presence [36,45–47]. The sampled inhabited zones were located at an maximum distance of 300 m from the deactivated mined areas. Some of these abandoned mined areas underwent an initial restoration process, which consisted in filling the pit with pyrite and covering this layer with another layer of clay soil (30-50 cm) over the disturbed mine soil (Fig. 2a-b). The local communities of Vila Funil, Rio Carvão, Barreiros, Guaitá, Cidade Alta, Vila Visconde, and São Sebastião Alto are settled nearby abandoned mined areas; and the local communities of Vila Sao Jorge, Rio Fiorita, Volta Redonda, Campo Morozini, Santa Luzia, Santa Augusta, and São Sebastião are adjacent to partially restored mined areas.

Data collection

We did semi-structured interviews with residents of the communities located in inhabited areas near the mined areas, individually, between February and March 2018 (Table 1).

Table 1 General information of localities, total rural population of each municipality, total number of families per community living nearby mining areas and number of interviews

Municipality	Total rural population of the municipality	Locality	No. of families per local community near the mined areas	No. Interviews
Siderópolis	2,944	Vila Funil	35	16
		Vila São Jorge	20	7
		Rio Fiorita	36	20
Lauro Muller	3,261	Barreiros	27	16
		Guaitá	21	19
Criciúma	2,678	Santa Luzia	37	8
		Vila visconde	35	11
		São Sebastião alto	25	8
		Santa Augusta	14	10
		São Sebastião	25	12
Treviso	1,694	Volta Redonda	24	11
		Rio Morozini	26	16
Urussanga	8,818	Rio Carvão	32	25
Forquilhinha	4,122	Cidade Alta	23	16

Interview questions sought to understand: (1) whether plant species were collected or planted for consumption in areas contaminated by coal mining; (2) which were the main species collected and for what purpose; and (3) the interviewee's perceptions of landscape changes and the impacts of mining. For each interviewee, the following variables were noted: residence time, age, gender, locality, and their work relationship with the mining companies. To be sure of where the plant resources were obtained, the interviewee was asked for each species cited: whether they were collected from contaminated areas, collected in other areas, or planted in home gardens or other cultivated areas.

To analyze the perception of landscape changes, the interviewee was asked if she/he was aware about what changes they had observed at the site since he/she began living there, and the responses were categorized a posteriori as: (1) positive (i.e., positive changes have been observed over time in the landscape, e.g., an increase in species richness or species diversity); (2) neutral (i.e., no change was observed); (3) negative (i.e., negative changes have been observed over time, e.g., a decrease in species richness or species diversity). They were also asked if they knew what the landscape looked like before mining, whether mining impacts have or had a negative impact on the health of residents, and whether they had been informed (either by a public or private institution) of contamination of the mined areas (full questionnaire is accessible at Additional file 1). Whenever possible, we did guided tours to collect botanical samples of the cited species for identification (collector numbers GD Blanco 90-120, vouchers deposited at EAFM herbarium). This project was approved by the UFSC Human Research Ethics Committee (80660217.1.0000.0121) and registered at SisGen, the Brazilian System of Genetic Heritage and Associated Traditional Knowledge Management (AB9A76B). Prior to the interviews, the consent of each interviewee was obtained and they signed a Free Informed Consent Form.

Data analysis

We built multivariate generalized linear models (GLMmv) to verify which variables could affect the set of cited species and generalized linear models (GLM) to verify which variables could affect the total number of citations. For both analyses we discarded information about plant species that were cited as cultivated only, and used data from the species cited as being collected from mined areas. The explanatory variables for both set of models were: residence time, gender, type of abandoned area (i.e., abandoned or partially restored) and the locality where the interviewee lives. However, locality and area type were never put together in the models, as both variables are related to geographic location, thus, highly correlated. For both models, the Poisson distribution family was used. Model selection was based on the Akaike Information Criterion (AIC) and validated using graphical residual analysis. For data visualization, a Principal Coordinate Analysis (PCoA) was performed. Analyses were performed in R environment with packages mvabund [48] for GLMmv, MASS [49] for GLM, and visreg [50] and vegan [51] for visualization of effects. The variables tested are listed in Additional file 2. For multivariate analysis, singletons and doubletons were removed. To analyze the importance of the plants mentioned in the interviews we used their frequency of citations and the Smith salience index (1993). This index ranges from 0 to 1, species with a value equal to or close to 1 are the species with the highest salience and species with values close to 0 are the less salient.

Results

We interviewed 195 residents, with an average of 14 residents (± 5.4) per locality. The residents' ages ranged from 15 to 86 years old, with an average age of 53 years (± 17.8). The majority of residents (115 or 59%) have lived in the community for more than 20 years (± 12.1), and 50 residents (26%) have always lived in the area, with the rest coming from other parts of the state. However, no respondents resided in the region prior to the coal mining. Among the residents, 130 were women (68%) and 66 were men (32%). All of the men, and none of the women, either work, or have worked, for the mining companies. Collecting or planting species for medicinal and/or food use was cited by 176 residents (90%), and 127 residents (65%) collected plants directly from areas contaminated by mining.

There were 176 species cited as planted and/or collected (Additional file 3), among which, 83 species were collected directly from areas contaminated by coal mining. From these, 18 species were obtained exclusively through collection in the mined areas (Table 2). The main species obtained exclusively by collecting from mined areas were *Psidium guajava, Plinia cauliflora* and *Eriobotrya japonica*. The main botanical families collected were Asteraceae and Lamiaceae, with 10 species (10%) each, and Myrtaceae and Fabaceae with 4 species (3.5%) each. For species collected in mined areas, 78% of residents cited medicinal uses, and 76% of residents cited food uses. The main use (54%) for medicinal species was for the treatment of digestive and infectious problems. Smith's salience index (1993) showed that among the species collected from mined areas, the species *Psidium cattleianum, Morus* sp., *Butia capitata, Plinia cauliflora* and *Psidium guajava* have the highest salience among residents (Table 2).

Table 2 Species cited only as collected by 195 interviewees, number of citations per species, uses, and salience (Smith's index)

Species	No. of Citations	Use	Salience
Psidium guajava L.	30	F	0.6758
Plinia cauliflora (DC.) Kausel	25	F	0.71321
Eriobotrya japonica (Thunb.) Lindl.	21	F/M	0.36364
Psidium cattleianum Sabine	18	F	0.87714
Equisetum giganteum L.	16	M	0.26825

Morus sp.	14	F	0.87878
Foeniculum vulgare convar *azoricum* (Mill.) Holub	12	M	0.47881
Passiflora edulis Sims	12	F	0.53228
Inga edulis Mart.	11	M	0.66532
Baccharis spp.	9	M	0.3141
Chelidonium majus L.	7	M	0.39924
Campomanesia xanthocarpa Mart. ex O. Berg	6	F	0.54395
Bidens pilosa L.	6	M	0.3373
Butia capitata (Mart.) Becc.	4	F	0.82235
Fragaria vesca L.	4	F	0.61067
Justicia pectoralis Jacq.	3	M	0.42054
Aristolochia esperanzae Kuntze	3	M	0.50556
Achillea millefolium L.	3	M	0.23748

Legend: F food; *M* Medicinal

When questioned whether they were aware of the presence of contamination in abandoned mined areas, 166 residents (85%) said they did. However, when asked about harm to the environment or their lives, only 19 residents (10%) reported some type of discomfort. Air pollution and physical discomfort when ingesting the species *Baccharis* spp., *Plectranthus barbatus*, *Solanum paniculatum*, *Arnica montana*, and *Achillea millefolium* were cited among the annoyances. All residents moved to the area after the mining activity ended, and did not see what the landscape looked like before coal was mined; however, 172 residents (88%) said they had observed changes, 113 residents (58%) reported negative changes (i.e., forest loss, less animals, fewer plants), and 58 residents (30%) reported landscape improvements (i.e. more trees, more plants, cleaner air). Another issue raised by 147 of the residents (75%), was the lack of information from public agencies and mining companies, about the environmental impacts that mining may cause, and possible contamination of plant resources. Duration of residence time, gender, perceived changes in landscape (i.e., positive, neutral, negative), location, and type of abandoned area (i.e. either abandoned or partially restored), did not affect species diversity and richness cited by respondents (Additional file 4).

The same variables were analyzed in relation to the number of species cited. The locality, perception of changes in the landscape, and duration of residence time significantly influenced the total number cited species. The GLM model explained 27% of the variation in the total number of species used (Table 3, Fig. 3), of which locality explained 77%, perception of changes 15% and residence time 8%. Longer-term residents and residents who cited negative or positive landscape changes, cited more species collected than residents who had not observed landscape change over time. Locality also had a significant influence on the number of citations.

Table 3 Summary of models and variables tested with GLM.

Mod.	Int.	Loc	Tip	Perc.	Gend.	Time	df	LogLik	AIC	Delta	Weight
22	2.074	+		+		0.004711	17	677.842	1389.7	0	0.276
30	2.089	+		+	+	0.004885	18	677.064	1390.1	0.44	0.221
6	2.231	+		+			16	683.686	1399.4	9.69	0.002
14	2.245	+		+	+		17	683.281	1400.6	10.88	0.001
18	1.93	+				0.006767	15	693.262	1416.5	26.84	0
26	1.941	+			+	0.006944	16	692.789	1417.6	27.89	0

2	2.148	+					14	706.557	1441.1	51.43	0
10	2.152	+			+		15	706.524	1443	53.36	0
31	2.206		+	+	+	0.005626	6	769.991	1552	162.3	0
23	2.19		+	+		0.005439	5	771.065	1552.1	162.5	0
29	2.163			+	+	0.005814	5	771.186	1552.4	162.7	0
21	2.145			+		0.005621	4	772.312	1552.6	162.9	0
17	2.016					0.006696	2	781.196	1566.4	176.7	0
25	2.029				+	0.006896	3	780.429	1566.9	177.2	0
19	2.045		+			0.006546	3	780.473	1566.9	177.3	0
27	2.057		+		+	0.006744	4	779.747	1567.5	177.8	0
7	2.366		+	+			4	779.804	1567.6	177.9	0
15	2.382		+	+	+		5	779.256	1568.5	178.8	0
5	2.318			+			3	781.676	1569.4	179.7	0
13	2.335			+	+		4	781.111	1570.2	180.5	0
3	2.264		+				2	794.521	1593	203.4	0
1	2.23						1	796.017	1594	204.4	0
11	2.271		+		+		3	794.403	1594.8	205.1	0
9	2.238				+		2	795.888	1595.8	206.1	0

Legend: Mod. model number*; Int.* intercept value*; Loc.* Locality*; Tip* Type of *area (i.e. either abandoned or partially restored); Perc.* Perception of landscape changes*; Gend.* Gender*; Time* residence time*; df* degrees of freedom*; logLik* likely distribution of observed data*, AIC* Akaike Information Criterion*;* delta difference of each model in relation to the model selected by AIC, and *Weight* model weight.

Discussion

Residents living in local communities nearby abandoned or partially restored coal mined areas are consuming plant species from these areas for food and medicinal purposes, which puts their food security at risk. Among the species cited, 18 of them are obtained exclusively from areas contaminated by coal extraction. Location, duration of residence time, and perception of changes in the landscape, were the main factors linked to citing more species obtained in contaminated areas.

Residents who observed changes in the landscape, both positive and negative, cited more species than those who did not notice changes. Even when residents noted that there was a decrease in plant resources and negative landscape changes in areas contaminated by coal mining, they cited the use of plants collected in these areas for their food and medication. Similar observations are reported by Silvano and Begossi (2016), who found that although fishermen knew about mercury contamination in fishery resources, they continued to consume this resource. As well as some residents noticing negative changes in the environment due to mining, 85% of residents said they know about the contamination of the mined areas; however, they still collect and use plant species from these areas. This may be due to contaminants such as heavy metals being invisible, or due to psychological barriers [52,53].

Invisible contaminants are those that cannot be detected by human sensory abilities, i.e., cannot be seen, do not exude odor, taste or sound (Vyner 1988). Since they are not perceived, these contaminants can be unwittingly consumed and, in the case of heavy metals for example, can impact human health causing neurological damages and metabolic disorders [41,52,54]. Psychological barriers, on the other hand, are when people are aware of environmental impacts, but do not act emphatically against them [53,55]. People tend to think of environmental impacts as futuristic and distant from their reality, associated with governments failing to present more effective or participatory strategies, and within a framework of contemporary cultural and social issues [53,56]. Social understanding of risk, such as food security risk, is built on views and beliefs influenced by the social and cultural forces of each society or community [8,57]. The construction of this perception goes through a comparison stage. For a local community to perceive the risk to their own food security, it needs to see that a similar situation was identified as a risk, in another community that is culturally, socially, and historically similar to its own [57,58].

The use of plant species, from areas contaminated by coal mined areas, has also been observed in local communities in Europe; where these communities are among the most vulnerable to, and affected by, contamination of food resources [59]. Bolivia and other Latin American countries have warned of the risk to the food security of local communities near mined areas, primarily the consumption of fishery resources [60]. In China, foods that form the staple diet of local communities living near former coal mines (e.g., *Oryza* spp. and *Camellia sinensis*) are contaminated with heavy metals [61–64]. In Canada and the USA, rural and indigenous communities are twice as vulnerable to contamination of their food resources compared to the national average [65]. These communities have greater exposure and are in direct contact with contaminating sources [8,65], a situation similar to that faced by local communities in southern Brazil.

Lack of food security due to consumption of contaminated fishing resources has been reported in local fishing and river communities from the south, southeast, and northeast coasts of Brazil, as well as by indigenous Amazon communities [8,32,66]. In recent decades, the global return of incentives for coal extraction has raised concerns about the food security of local communities [36]. Coal is currently responsible for providing 29.6% of global energy needs and about 42% of all global electricity [36,67]. Resurgence of coal mining may increase the contamination of areas previously mined for coal and add to the number of areas impacted by heavy metal contamination. The low quality of the coal found in southern Brazil requires various stages in the extraction process which release high levels of contaminants, such as cadmium and zinc; and, if these metals are consumed frequently and at high levels, they may represent a risk to public health (ATSDR, 2018; Machado De Oliveira et al. 2019). In the far south of Brazil, children living in coal mined areas are at high risk of exposure leading to possible heavy metal poisoning [69].

No significant difference was observed in the species diversity and richness of species cited between men and women. This homogeneous distribution of knowledge across genders was also observed by Figueiredo et al. (1993) and Voeks (2007). This may be related to the different social roles of each gender. Men are the ones who work or worked in the mining areas, contributing to their knowledge of the plants that occur there. Even though women usually provide initial health care in communities and therefore have greater plant knowledge, in these localities men have a greater knowledge of the mined areas and of species found there, which seems to balance the knowledge about plant uses [15,16].

The species *Psidium guajava*, *Plinia cauliflora*, and *Eriobotrya japonica* were most cited as collected, and had a high salience index. These species are also bioaccumulators of heavy metals [70–73]. *Citrus sinensis*, *Plectranthus barbatus*, *Mentha arvensis*, and *Cymbopogon citrates* were the species most cited as both collected and planted, and they are also bioaccumulators of heavy metals [39,40,62,74]. Native and pioneer species, such as *Inga edulis* and species of the genus *Baccharis* were obtained only through collection from contaminated areas. These both have high growth rates and are widely distributed in the environment, they are eaten or used medicinally and also have bioaccumulation potential [38,75,76]. Some of these species are being studied as phytoremediators (i.e., species used to restore degraded areas due to their ability to bioaccumulate heavy metals).

The longer the time a person had resided in the area correlated with more species cited: older residents use a greater wealth of plant species, collected or planted, and they also perceive more changes in the landscape, both due to the length of time of living and learning in these environments [10]. The variable locality indicated that there is a difference in the citation of plant species use between the communities. This may be due to the high cultural diversity of peoples who colonized this region, including indigenous peoples such as Guarani and recent German, and Italian immigrants (Seyferth 2013; Santa et al. 2018). Santa Catarina state, as well as several Brazilian areas in South and Southeast, is culturally heterogeneous, which may influence plant knowledge and use. The influence of different cultures and the mixture of knowledge have impact mainly in the most recent generations that ends up absorbing from different sources of knowledge (Abreu et al. 2015). This cultural influence may have a greater weight than, for example, the resource availability itself in the environment (Abreu et al. 2015; Menendez-Baceta et al. 2015).

Conclusion

Traditional knowledge is an important tool for identifying and locating areas and resources that can pose a risk to the food security of local communities. Consumption of plant species collected from abandoned mined sites in southern Brazil, coupled with a lack of information, is a reality and a concern. Potential bioaccumulator species that occur in these areas are being used locally as food or therapeutic resources. This situation is aggravated by the fact that these contaminants are invisible, and because of psychological barriers to recognizing the risks associated with the contamination of a living environment. In view of this scenario, it is necessary and urgent to inform the population about the risk of invisible contaminants in order to reduce their vulnerability to food insecurity, combined with studies that quantify the extent of heavy metal contamination in plant resources resulting from mining activity.

Declarations

Ethics approval and consent to participate

In order to carry out the present research, the necessary authorizations were obtained with CEPSH (Ethics Commitee on Research with Human Beings of Universidade Federal de Santa Catarina, processes number 80660217.1.0000.0121). All interviewees signed a free informed consent term.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors contributed substantively to the research; GDB and NH designed the research project. GDB, RBS, EB and PFC collected the samples and performed sample analyses. Blanco, GDB, RBS, PFC, MLC and NH wrote the manuscript.

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Legend

Fig. 1 Study area. Each number corresponds to a local community: 1- Barreiros; 2-Guaitá; 3-Rio Carvão; 4-Volta Redonda; 5- Rio Morozini; 6- Vila Funil; 8-Vila São Jorge; 9-Rio Fiorita; 10-Santa Luzia; 11-São Sebastião Alto; 12-Santa Augusta; 13- São Sebastião; 14- Cidade Alta

Fig. 2 Coal mined areas. a Lauro Müller mining area abandoned 35 years ago. b Lauro Müller mining area with 30 years old that has been undergoing an initial restoration process 7 years ago

Fig. 3 Graphical representation of the explanatory variables of the selected GLM model in relation to the number of species citations according to locality (1 to 14), residence time and perception of landscape changes (i.e., 1-positive, 2-neutral and 3-negative)

Additional file 1 .pdf. Model of the applied interview [interviewer's orientations between brackets]

Additional file 2 .xls. Explanatory variables analyzed in lm and GLM

Additional file 3 .xls. List of species cited as used by residents. C: Collected, P: Planted.

Additional file 4 .tiff. PCoA showing that there was no difference in the set of species collected from mined areas between local communities, perceptions of landscape changes (i.e. positive, neutral and negative), types of abandoned areas (i.e. either abandoned or partially restored) and gender (i.e. men and women)

Figures

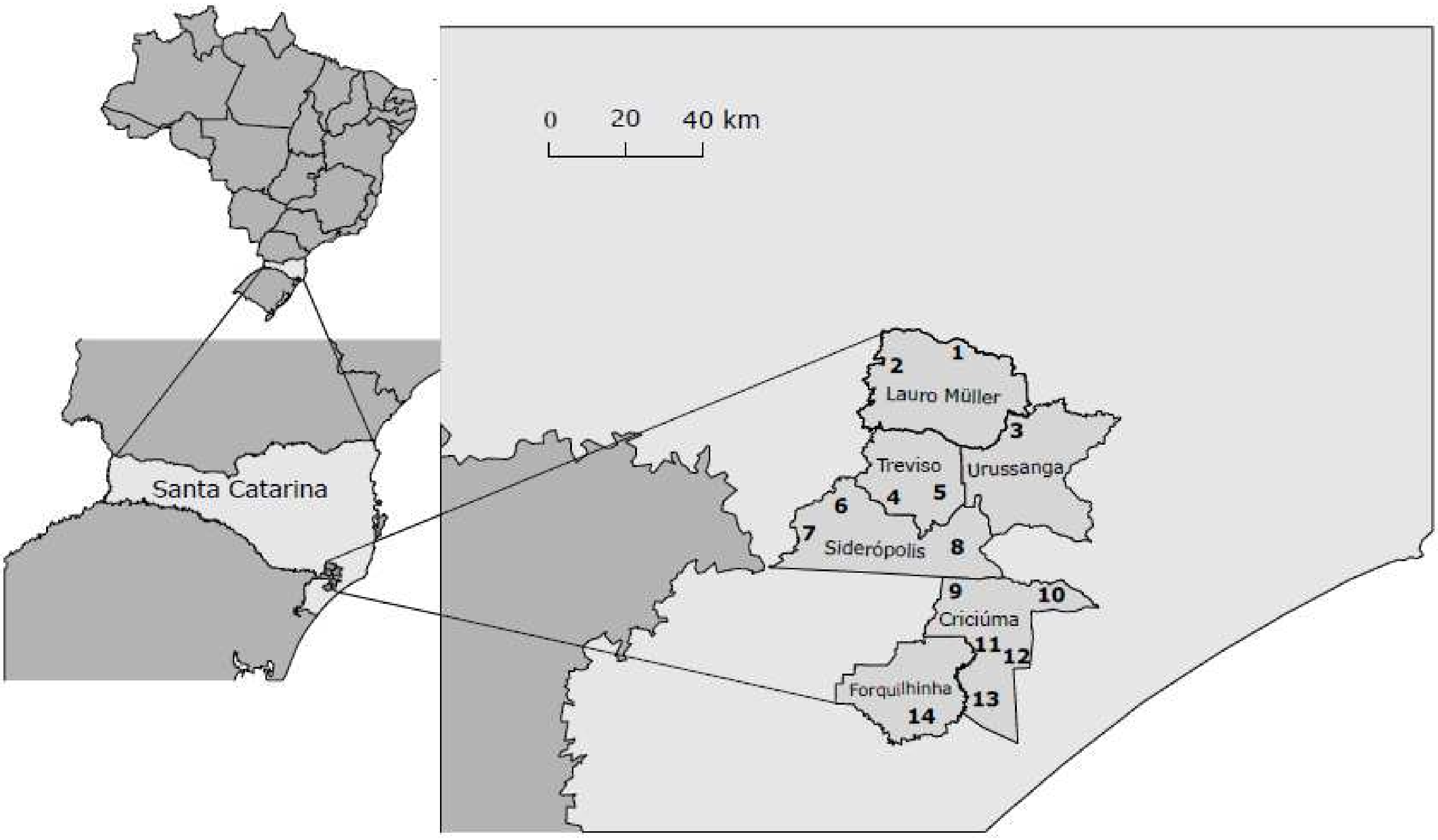

Figure 1

Study area. Each number corresponds to a local community: 1- Barreiros; 2-Guaitá; 3-Rio Carvão; 4-Volta Redonda; 5- Rio Morozini; 6- Vila Funil; 8-Vila São Jorge; 9-Rio Fiorita; 10-Santa Luzia; 11-São Sebastião Alto; 12-Santa Augusta; 13- São Sebastião; 14- Cidade Alta

Figure 2

Coal mined areas. a Lauro Müller mining area abandoned 35 years ago. b Lauro Müller mining area with 30 years old that has been undergoing an initial restoration process 7 years ago

Figure 3

Graphical representation of the explanatory variables of the selected GLM model in relation to the number of species citations according to locality (1 to 14), residence time and perception of landscape changes (i.e., 1-positive, 2-neutral and 3-negative)

Supplementary Files

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