UNIVERSIDADE FEDERAL DE SANTA CATARINA
CENTRO DE CIENCIAS BIOLÓGICAS
DEPARTAMENTO DE ECOLOGIA E ZOOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA

Graziela Dias Blanco

Soberania, segurança alimentar e ecotoxicidade de alimentos e plantas medicinais consumidos por comunidades locais em áreas de mineração

Florianópolis
2022

Graziela Dias Blanco

Soberania, segurança alimentar e ecotoxicidade de alimentos e plantas medicinais consumidos por comunidades locais em áreas de mineração

Tese apresentada ao Programa de Pós-graduação em Ecologia da Universidade Federal de Santa Catarina, para obtenção de título de Doutora em Ecologia.

Orientadora: Natalia Hanazaki, Dra.
Coorientadora: Mari Lucia Campos, Dra.

Florianópolis
2022

Ficha de identificação da obra elaborada pelo autor,
através do Programa de Geração Automática da Biblioteca Universitária da UFSC.

Blanco, Graziela Dias
Soberania, segurança alimentar e ecotoxicidade de alimentos e plantas medicinais consumidos por comunidades locais em áreas de mineração / Graziela Dias Blanco ; orientador, Natalia Hanazaki, coorientador, Mari Lucia Campos, 2022.
217 p.

Tese (doutorado) - Universidade Federal de Santa Catarina, Centro de Ciências Biológicas, Programa de Pós Graduação em Ecologia, Florianópolis, 2022.

Inclui referências.

1. Ecologia. 2. Etnoecologia. 3. Mineração. 4. Carvão. 5. Povos e comunidades tradicionais. I. Hanazaki, Natalia. II. Campos, Mari Lucia. III. Universidade Federal de Santa Catarina. Programa de Pós-Graduação em Ecologia. IV. Título.

Graziela Dias Blanco

Soberania, segurança alimentar e ecotoxicidade de alimentos e plantas medicinais consumidos por comunidades locais em áreas de mineração

O presente trabalho em nível de doutorado foi avaliado e aprovado por banca examinadora composta pelos seguintes membros:

Prof. Eduardo L. Hettwer, Dr.

Universidade Federal de Santa Catarina

Profa. Sofia Zank, Dra.

Faculdade Municipal de Palhoça

Prof. Paulo Antunes Horta Jr., Dr.

Universidade Federal de Santa Catarina

Certificamos que esta é a **versão original e final** do trabalho de conclusão que foi julgado adequado para obtenção do título de Doutora em Ecologia.

ICP-Edu
Documento assinado digitalmente
Nei Kavaguichi Leite
Data: 18/02/2022 17:31:36-0300
CPF: 629.700.972-49
Verifique as assinaturas em https://v.ufsc.br

Prof. Dr. Nei Kavaguichi Leite

Coordenador do Programa

ICP-Edu
Documento assinado digitalmente
Natalia Hanazaki
Data: 18/02/2022 18:12:16-0300
CPF: 160.730.008-71
Verifique as assinaturas em https://v.ufsc.br

Profa. Dra. Natalia Hanazaki

Orientadora

Florianópolis, 16 de dezembro de 2021.

Dedico esta tese a todos os povos e
comunidades tradicionais e locais, à ciência e à
minha família.

AGRADECIMENTOS

A construção e desenvolvimento de uma tese, assim como de qualquer pesquisa, só é possível com apoio, incentivo e a constante troca de saberes com outros pesquisadores e olhares. E a construção da minha tese não foi diferente, por esta razão quero deixar registrada aqui todas as mãos, saberes e carinho que eu recebi ao longo da construção da presente pesquisa.

Primeiramente, aos meus pais Rosa Leamar Dias Blanco e Jose Blanco Fontes, que sempre depositaram a sua confiança, amor e incentivo na minha trajetória. A minha mãe, obrigada por sempre me incentivar a estudar e a batalhar, como mulher e pesquisadora, pelos meus direitos. Ao meu pai, obrigada por me ensinar a ser um ser humano melhor e com muito amor, e por sempre ter me apoiado em tudo. Sem eles eu nunca teria chegado no lugar que eu cheguei hoje. Tudo que eu tenho de melhor vem deles! Somente através do amor deles eu consegui finalizar a minha tese e superar tantos momentos desafiadores que surgiram durante estes dois últimos anos, que foram dedicados à pesquisa e escrita de uma tese em plena pandemia e diante de um cenário ambiental bastante desafiador. Obrigada! A vocês dedico o meu trabalho e agradeço ao destino por ter vocês como pais e exemplos de vida! A minha irmã Gabriela Dias Blanco, que além de ser um ser humano incrível e de um coração gigante, é uma excelente pesquisadora e co-autora de um dos capítulos da tese. Meu eterno carinho e admiração por você e agradeço por te ter na minha vida. Ao Antonio Dias Blanco, meu querido irmão! Obrigada por ter nos escolhido como a sua família, e por ser esse ser humano tão incrível, uma criança com tanto amor no coração e tanta alegria de viver! A cada dia aprendo mais com você sobre o amor, a felicidade e a vida! Obrigada por inundar as nossas vidas com tanta felicidade! E todos aqueles e aquelas pessoas queridas da nossa família que partiram cedo demais, mas que deixaram até hoje uma marca de muito carinho e amor nos nossos corações. Obrigada pelo amor e ensinamentos, com vocês aprendi muito sobre as plantas e a natureza, e acredito que a minha escolha por esta área se deve muito a tudo que vocês me ensinaram: vó Rafaela Marcelina Fontes Pereira, vó Ondina de Souza Dias, vô José Victorio Blanco Tejeira e vô Adiles Pereira Dias.

Quero deixar aqui registrado o meu carinho e admiração por duas pesquisadoras as quais eu admiro e respeito muito, e tive a sorte de ter elas como orientadoras: Natalia Hanazaki e Mari Lucia Campos. Natalia, ao longo destes 10 anos de trabalho juntas, só tenho a agradecer por toda a sua dedicação, carinho e orientação. Você me ensinou coisas que vão muito além da academia e pesquisa: a ética, dedicação, justiça e saber que tudo passa, que apesar da tese ser algo de extrema importância, ainda assim, é apenas uma tese, e o mais importante é a trajetória e todos os ensinamentos que vamos adquirindo ao longo desta caminhada. Todos estes conhecimentos e saberes podem não aparecer neste documento, mas eles influenciaram e moldaram a pessoa e pesquisadora que sou hoje. Obrigada por toda a sua dedicação e incentivo, em todos os momentos! Assim como, só tenho a agradecer a Mari! Mari muito obrigada por ter topado ser minha co-orientadora, por ter dedicado tanto do seu tempo em me ensinar sobre tantos aspectos que eu não conhecia, por ter aberto as portas do seu laboratório e, desde então, me orientado e ensinado.

Ao longo de toda esta trajetória tive a sorte de estar rodeada por amigos incríveis e tenho certeza, poderei levar para a vida toda. A Maiara Hayata e a Brisa Marciniak, duas mulheres, pesquisadoras, seres humanos e amigas incríveis que tive a sorte de ter na minha vida! Obrigada por todo o carinho e apoio, nos bons e maus momentos! Rafael BarbizanSühs, deixo aqui registrada toda a minha admiração e carinho por você, e agradeço a amizade e parcerias de trabalho. Ao Mario Sergio, parceiro de tantos momentos, agradeço a tua amizade e carinho ao longo destes cinco anos, e que venham muitos mais! A Aline Pereira Cruz, Anaide Wrublevsk Aued e Luiz Fernando Ferreira, deixo aqui registrado o meu carinho e admiração por vocês, não somente como pesquisadoras/es, mas também por serem seres humanos cheios de muita luz e amor. E a todos os colegas queridos do Programa de Pós-Graduação em Ecologia e do laboratório de Ecologia Humana e Etnobotânica, que tive a sorte de conhecer e compartilhar tantos momentos e saberes, obrigada! Um agradecimento especial aos queridos/as professores/as: Nivaldo Peroni, Eduardo L. Hettwer, Bárbara Segal e Michele Dechoum!

Assim como, agradeço imensamente às instituições de pesquisa, que ao longo destes cinco anos apoiaram e financiaram a minha pesquisa e possibilitaram que eu concluísse a tese. Obrigada Capes e CNPq! E um agradecimento especial a todas as comunidades e povos do Brasil e do mundo: esta tese é para vocês! Espero que este trabalho auxilie na nossa luta pela conservação e proteção das florestas, rios, Oceano e soberania e segurança alimentar!

Obrigada!

Enquanto isso, a humanidade vai sendo descolada de uma maneira tão absoluta desse organismo que é a terra. Os únicos núcleos que ainda consideram que precisam ficar agarrados nessa terra são aqueles que ficaram meio esquecidos pelas bordas do planeta, nas margens dos rios, nas beiras dos oceanos, na África, na Ásia ou na América Latina. São caiçaras, índios, quilombolas, aborígenes (...). Ailton Krenak (2020, p. 21).

RESUMO

As atividades de extração de minérios sólidos são praticadas em todos os continentes do mundo e desempenham um impacto na economia mundial. Entretanto, as atividades de mineração, desde a seleção de áreas, preparação para extração, extração do mineral até o abandono, impactam negativamente o ambiente e as pessoas, além de gerar conflitos socioambientais no mundo todo. Entre os impactos socioambientais causados, a remoção da vegetação, aumento da emissão de CO_2 e contaminação do solo e dos recursos hídricos por elementos-traço são as mais preocupantes, pois desequilibram a biodiversidade local e contaminam a cadeia alimentar. Os elementos-traço são elementos que são disponibilizados no ambiente devido ao processo de extração mineral, como, por exemplo, arsênio (As), cádmio (Cd), cromo (Cr) e chumbo (Pb). Alguns estudos têm mostrado impactos severos nas formas de polinização, taxa de reprodução dos organismos e alto potencial bioacumulador de elementos-traço em espécies que visitam ou se desenvolvem nestas áreas mineradas. O carvão é um dos minérios mais extraídos do mundo e considerado um dos mais impactantes ao meio ambiente. Ainda assim, há lacunas de conhecimento sobre as comunidades vegetais que se estabelecem em áreas que foram mineradas para extração de carvão mineral, seus impactos nas áreas vizinhas, na biodiversidade local e na soberania alimentar de grupos humanos de seu entorno. Desta forma o objetivo da presente tese foi avaliar os impactos da mineração de minérios sólidos na soberania e segurança alimentar de povos e comunidades tradicionais e locais, assim como o seu impacto na formação de comunidades vegetais que se estabelecem em áreas que foram mineradas e estão abandonadas. Assim, no Capítulo I avaliamos se fatores como mineração, contaminação por elementos-traço, desigualdade social, falta de políticas e ações ambientais e conflitos socioambientais impactam diretamente na segurança alimentar dos Povos Indígenas e Comunidades Locais (PICL) em todo o mundo. Por meio de uma revisão abrangente da literatura, mapeamos globalmente os problemas que PICL ao redor das áreas de mineração enfrentam em relação à segurança alimentar. Nossos resultados revelam que a combinação de mineração, desigualdade social e políticas ambientais insuficientes estão associadas a um impacto negativo significativo na segurança alimentar do PICL. Além disso, apresentamos evidências da contaminação dos sistemas alimentares de PICL como resultado direto da mineração. No Capítulo II, o nosso objetivo foi verificar se as comunidades locais que vivem próximas de áreas mineradas para extração de carvão em Santa Catarina usam espécies vegetais de áreas contaminadas pela mineração e buscamos entender quais fatores poderiam estar influenciando no uso desses recursos, mesmo em áreas visivelmente impactadas. Através de entrevistas, perguntamos sobre a percepção dos entrevistados acerca da qualidade do meio ambiente e quais espécies vegetais eram utilizadas e para qual finalidade. De todos os entrevistados, 127 (65%) relataram coletar plantas para uso medicinal e alimentar, diretamente de áreas contaminadas pela atividade mineradora. Nosso estudo demonstrou que as pessoas que vivem nas proximidades de áreas contaminadas pela mineração usam e consomem plantas destes ambientes e as pessoas sabem pouco sobre o perigo dessa contaminação em seus alimentos e o risco desses contaminantes para sua saúde. No Capítulo III, o objetivo foi descrever e compreender a riqueza, características ecológicas (*i.e.*, tipo de raiz, formas de dispersão de sementes e polinização, forma e ciclo de vida e via fotossintética), e o potencial bioacumulador das espécies que ocorrem ao longo do tempo em áreas que foram mineradas para extração de carvão. Através de um levantamento bibliográfico em estudos que analisaram a composição florística destas áreas compilamos uma lista das espécies presentes nelas e, considerando diferentes períodos temporais de abandono da atividade mineradora, observamos que ao longo do tempo estes ambientes concentram espécies com polinização por entomofilia, dispersão de sementes por anemocoria e zoocoria, tipo de raiz fasciculada e via fotossintética C4 nos primeiros anos e C3 nos anos seguintes. A riqueza diminui nas áreas mineradas abandonadas mais antigas e não restauradas, e a presença de espécies com potencial bioacumulador aumenta ao longo do tempo de abandono. As espécies, em sua maioria, apresentam uso medicinal associado. Por fim, no Capítulo IV, analisamos o teor de concentração de elementos-traço em uma espécie amplamente distribuída na região carbonífera do sul do Brasil e que apresenta uso tradicional medicinal, a *Baccharis sagittalis*. Combinando informações de entrevistas e da coleta de plantas e do solo na região carbonífera de Santa Catarina, analisamos se o consumo dessa planta representa um risco para a saúde humana. Entre os elementos analisados, Cd e Pb apresentaram níveis superiores aos recomendados por três agências globais de saúde. Cd e Pb apresentaram também níveis elevados nas projeções de ingestão diária recomendadas por agências internacionais de saúde, sendo citada como consumida por 53,8% dos entrevistados na forma de chá. Esses resultados indicam que o consumo de *B. sagittalis* contaminado com elementos-traço pode causar problemas de saúde, pois esses elementos se acumulam no organismo humano. Apresentamos dados que apontam para a urgência da criação de leis mais restritivas e de controle rigoroso sobre as atividades de mineração, a importância urgente da criação de protocolos nacionais e internacionais dos níveis de elementos-traço que representam um risco à saúde humana quando ingeridos através de alimentos contaminados. Os resultados desta tese também revelam a falta de informações sobre a contaminação para a população periférica às áreas, bem como a falta de ações que incluam as comunidades locais nas estratégias de restauração de áreas contaminadas. O povoamento de espécies em áreas de extração mineral para o carvão, que foram abandonadas, pode ser fortemente afetada pela presença de elementos-traço, como os metais pesados. Ao longo do tempo, estes elementos podem estar selecionando espécies com características funcionais específicas, impactando na riqueza de espécies e servindo como potenciais áreas de dispersão de elementos tóxicos para áreas que não foram mineradas. O estudo de espécies bioacumuladoras ainda é insuficiente e necessita maiores esforços, principalmente das espécies mais frequentes nestes ambientes e que apresentam uso alimentício ou medicinal associados.

Palavras-chave: Etnoecologia; mineração; carvão; povos e comunidades tradicionais.

ABSTRACT

Solid mineral extraction activities are carried out on all continents of the world and have an impact on the world economy. However, mining activities, from the selection of areas, preparation for extraction, extraction of the mineral to abandonment, negatively impact the environment and people, in addition to generating socio-environmental conflicts around the world. Among the social and environmental impacts caused, the removal of vegetation, increased CO_2 emissions and contamination of soil and water resources by trace elements are the most worrying, as they unbalance the local biodiversity and contaminate the food chain. Trace elements are elements that are made available in the environment due to the mineral extraction process, such as, for example, arsenic (As), cadmium (Cd), chromium (Cr) and lead (Pb). Some studies have shown severe impacts on the forms of pollination, rate of reproduction of organisms and high bioaccumulative potential of trace elements in species that visit or develop in these mined areas. Coal is one of the most extracted ores in the world and considered one of the most impactful on the environment. Even so, there are knowledge gaps about the plant communities that settle in areas that were mined for the extraction of coal, their impacts on neighboring areas, on local biodiversity and on the food sovereignty of human groups in their surroundings. Thus, the objective of this thesis was to evaluate the impacts of solid mineral mining on the sovereignty and food security of traditional peoples and local communities, as well as its impact on the formation of plant communities that settle in areas that have been mined and are abandoned. Thus, in Chapter I we assess whether factors such as mining, trace element contamination, social inequality, lack of environmental policies and actions, and socio-environmental conflicts directly impact the food security of Indigenous Peoples and Local Communities (IPLC) worldwide. Through a comprehensive literature review, we have globally mapped the issues that IPLC around mining areas face in relation to food security. Our results reveal that the combination of mining, social inequality and insufficient environmental policies are associated with a significant negative impact on the food security of the IPLC. In addition, we present evidence of the contamination of IPLC food systems as a direct result of mining. In Chapter II, our objective was to verify whether local communities living close to areas mined for coal extraction in Santa Catarina use plant species from areas contaminated by mining and we sought to understand what factors could be influencing the use of these resources, even in areas visibly impacted. Through interviews, we asked about the interviewees' perception about the quality of the environment and which plant species were used and for what purpose. Of all respondents, 127 (65%) reported collecting plants for medicinal and food use, directly from areas contaminated by mining activities. Our study showed that people living in the vicinity of areas contaminated by mining use and consume plants from these environments and that people know little about the danger of this contamination in their food and the risk of these contaminants to their health. In Chapter III, the objective was to describe and understand the richness, ecological characteristics (ie, root type, forms of seed dispersal and pollination, form and life cycle and photosynthetic pathway), and the bioaccumulative potential of the species that occur throughout of weather in areas that were mined for coal extraction. Through a bibliographic survey of studies that analyzed the floristic composition of these areas, we compiled a list of species present in them and, considering different temporal periods of abandonment of the mining activity, we observed that over time these environments concentrate species with pollination by entomophilia, dispersal of seeds by anemochory and zoochory, fasciculated root type and photosynthetic pathway C4 in the first years and C3 in the following years. Richness decreases in the oldest and unrestored abandoned mined areas, and the presence of species with bioaccumulative potential increases over time of abandonment. The species, for the most part, have an associated medicinal use. Finally, in Chapter IV, we analyze the concentration of trace elements in a species widely distributed in the coal region of southern Brazil and which has traditional medicinal use, *Baccharis sagittalis*. Combining information from interviews and from the collection of plants and soil in the Santa Catarina coal region, we analyzed whether the consumption of this plant represents a risk to human health. Among the elements analyzed, Cd and Pb presented levels higher than those recommended. Cd and Pb also showed high levels in the daily intake projections recommended by international health agencies, being cited as consumed by 53.8% of respondents in the form of tea. These results indicate that the consumption of *B. sagittalis* contaminated with trace elements can cause health problems, as these elements accumulate in the human body. We present data that point to the urgency of creating more restrictive laws and strict control over mining activities, the urgent importance of creating national and international protocols of the levels of trace elements that pose a risk to human health when ingested through contaminated food. The results of this thesis also reveal the lack of information about contamination for the population peripheral to the areas, as well as the lack of actions that include local communities in the restoration strategies of contaminated areas. The population of species in areas of mineral extraction for coal, which were abandoned, can be strongly affected by the presence of trace elements, such as heavy metals. Over time, these elements may be selecting species with specific functional characteristics, impacting species richness and serving as potential dispersal areas of toxic elements to areas that were not mined. The study of bioaccumulating species is still insufficient and requires greater efforts, especially of the most frequent species in these environments and which have associated food or medicinal use.

Keywords: Ethnoecology; mining; coal; traditional peoples and communities.

LISTA DE FIGURAS

INTRODUÇÃO

CAPÍTULO I

CAPÍTULO Ii

CAPÍTULO III

CAPÍTULO IV

LISTA DE TABELAS

CAPÍTULO I

CAPÍTULO II

CAPÍTULO III

CAPÍTULO IV

SUMÁRIO

APRESENTAÇÃO

A construção desta tese começou a partir de uma investigação sobre o uso de plantas medicinais e alimentos tradicionais, tema que eu sempre busquei estudar, através da etnobotânica e etnoecologia, desde a minha graduação. Ao longo de toda a minha formação profissional, sempre busquei compreender como as pessoas se relacionam, percebem e utilizam diferentes recursos vegetais. Os saberes tradicionais e uso de plantas para a medicina, alimentação e como forma de cura transcendental sempre estiveram presentes na minha vida, desde pequena: minha bisavó paterna era charrua, minha outra bisavó paterna era benzedeira, minhas avós eram curandeiras e meu pai é curandeiro.

Sendo assim, a busca por estudar e auxiliar na valorização do conhecimento tradicional, assim como, na conservação da biodiversidade, vão muito além de uma escolha profissional, e fazem parte da minha história e identidade. Movida por este sentimento, no meu doutorado, busquei compreender mais sobre o conhecimento tradicional e seus desafios. Neste sentido, me deparei com a temática da mineração de carvão no sul do Brasil, e seus impactos locais e globais, e busquei compreender como esta atividade poderia estar impactando o conhecimento tradicional, principalmente as populações locais que utilizam e consomem plantas para a sua alimentação e medicina. Importante destacar que eu tive muita orientação e apoio das minhas orientadoras, professores e colegas de trabalho ao longo da construção de toda a tese. Comecei então pensando, num nível local, se as pessoas utilizavam os recursos vegetais de áreas mineradas e quais seriam eles. A partir deste momento, comecei a me aprofundar no tema, buscando compreender, num nível global, os impactos diretos da mineração na segurança alimentar. Comecei a pensar, quais seriam as características das espécies que ocorrem nestas áreas, quais seriam as espécies e se elas estariam acumulando elementos-traço em seus tecidos. Será que poderiam colocar em risco a saúde das pessoas?

A partir deste momento, me aproximei mais da área de ecotoxicidade, e da necessidade de compreender melhor os impactos das áreas de mineração nas espécies e na saúde humana. A pandemia foi um fator que impactou a forma metodológica de algumas etapas da minha pesquisa, mas me possibilitou desenvolver novas habilidades científicas. Muitos desafios surgiram ao longo do caminho: coletas que não puderam ser realizadas, experimentos que tiveram que ser repetidos, expedições a campo que não deram certo, conceitos novos que exigiram horas e mais horas de estudos, análises estatísticas novas e desafiadoras, artigos rejeitados e os impactos psicológicos de desenvolver uma tese em uma pandemia e em um país com um governo totalmente desestruturado e negacionista da ciência e dos saberes tradicionais.

É importante destacar que neste documento não estão todos os desafios enfrentados e nem todos os aprendizados alcançados. A construção de uma tese passa por diferentes momentos, com altos e baixos, como uma montanha russa e, ainda que os resultados sejam apresentados de forma linear, muitas vezes os capítulos e ideias foram surgindo ao longo do doutorado. Quero através deste pequeno relato pessoal da construção da minha tese dizer que a pesquisa acadêmica pode ser muito desafiadora e que não existe um passo a passo único e que sirva para todas/os. Talvez mais importante do que aprender com o que deu certo, é aprendermos com o que deu "errado", e este "errado" faz parte da construção científica e é um dos melhores professores!

1. INTRODUÇÃO

A mineração é uma atividade realizada em praticamente todos os continentes do mundo e tem sido utilizada como uma forma de melhorar a economia local, a curto prazo (GITHIRIA; ONIFADE, 2020; HADDAWAY *et al.*, 2019). Em especial, países considerados subdesenvolvidos ou em desenvolvimento, tem buscado investir e desenvolver mais esta atividade nos últimos anos (ERICSSON; LÖF, 2019). Entretanto, as atividades de mineração, desde a seleção de áreas e extração do mineral até o abandono da atividade, impactam negativamente o ambiente, comunidades humanas e geram diversos conflitos socioambientais no mundo todo (NGUYEN; BORUFF; TONTS, 2018). Entre os principais impactos causados pelas atividades de mineração, os principais são a remoção da vegetação local, intensificação na emissão de CO_2 e contaminação do solo e recursos hídricos por elementos-traço, pois desequilibram a biodiversidade local e contaminam a cadeia alimentar (CONDE, 2017; FRENCH *et al.*, 2017; MILLER; VILLARROEL, 2011). Os elementos-traço são aqueles disponibilizados no ambiente devido ao processo de extração mineral como, por exemplo, arsênio (As), cromo (Cr), cádmio (Cd) e chumbo (Pb) (SAHA *et al.*, 2019).

Em 2015, a ONU estabeleceu os 17 Objetivos de Desenvolvimento Sustentável (ODS), iniciativa que identificou os principais desafios ambientais, sociais e econômicos que devem ser superados para garantir que as gerações presentes e futuras tenham acesso justo a ambientes saudáveis (V RELATÓRIO LUZ DA SOCIEDADE CIVIL DA AGENDA 2030, 2020). Dentre os principais desafios globais dos ODS, a recuperação de ecossistemas degradados, a contaminação de oceanos e solos, mudanças climáticas e soberania alimentar são temas prioritários e urgentes para proteger a biodiversidade e os recursos naturais e garantir a soberania alimentar para todos os povos (V RELATÓRIO LUZ DA SOCIEDADE CIVIL DA AGENDA 2030, 2020). Estes são desafios urgentes que todos os países devem se envolver e buscar soluções eficientes. Países como a China, Austrália, Estados Unidos, Rússia e Chile concentram 51% das áreas de extração mineral mundial (MAUS *et al.*, 2020). Entretanto, na última década a busca por áreas para extração mineral na América Latina cresceu (CINTRA, 2015; DE MEDEIROS; ONU, 2020). Isso se deve à riqueza de minérios que existem nesta região, menor controle legal, além de maior e mais barata mão de obra local (BERTHIER-FOGLAR; GAUDICHAUD; TOLAZZI, 2016). Entre os países da América Latina, Chile, Peru, Brasil e México são os maiores exportadores de minerais e metais (ARAUJO; CHAVES FERNANDES, 2016). Somente no Brasil o número de áreas de mineração cresceu mais de seis vezes entre 1985 e 2020 (MAPBIOMAS, 2021). A América Latina também é a região com o maior número de conflitos socioambientais relacionados à mineração em todo o mundo (EJATLAS, 2020). Isso ocorre principalmente pela realização ilegal da atividade ou a invasão de mineradoras em territórios que pertencem a comunidades locais, tradicionais ou dos povos originários (EJATLAS, 2020). No Brasil, o número de conflitos socioambientais entre comunidades tradicionais e mineradores cresceu exponencialmente na última década (MENTON *et al.*, 2021).

Outro impacto das atividades de mineração nestes locais é o abandono e a não restauração das áreas que foram mineradas. Estima-se que nos EUA, China e Canadá tenham, respectivamente, 390.000 (MITTAL, 2017), 12.000 (CUI *et al.*, 2020) e 10.139 (HOGAN; TREMBLAY, 2006) áreas mineradas conhecidas e que foram abandonadas. No Brasil, ainda se desconhece o número total de áreas mineradas e que foram abandonadas (ARAUJO, 2015). O aumento de áreas mineradas e abandonadas potencialmente aumenta também o volume de contaminantes liberados pela mineração no ambiente (EDRAKI *et al.*, 2014; GEORGE-LAURENTIU; FLORENTINA-CRISTINA; ANDREEA-LORETA, 2016) e a quantidade de barragens de rejeitos (LASCHEFSKI, 2019). Aliado a esta situação, muitos destes países apresentam poucas ou nenhuma legislação ambiental e social que controle ou minimizem os impactos das mineradoras, bem como, pouco se sabe sobre os impactos específicos que estas áreas podem causar ao meio ambiente e à saúde humana (CANDEIAS *et al.*, 2019). Entre esses impactos, é necessário compreender aqueles relacionados aos elementos-traço, pois uma vez liberados no ambiente, estes elementos podem se distribuir por diversas áreas, dificultar e alterar as relações ecológicas (ASGARI LAJAYER; GHORBANPOUR; NIKABADI, 2017) e contaminar os recursos medicinais e alimentares (YADAV; BHAGAT; YADAV, 2019).

Em países como a Bolívia, a contaminação de mercúrio foi registrada em peixes consumidos por povos originários (MILLER; VILLARROEL, 2011). No Brasil a contaminação chegou a ser identificada no leite materno de comunidades ribeirinhas (RAMOS; OLIVEIRA; RODRIGUES, 2020). Na Espanha, a contaminação tem sido observada em frutas que se desenvolvem em solos contaminados (FERNÁNDEZ *et al.*, 2016). Todas estas contaminações colocam em risco a soberania e segurança alimentar, principalmente dos povos originários e comunidades locais (BRIONES ALONSO; COCKX; SWINNEN, 2018). Entretanto ainda pouco se sabe sobre os alimentos e plantas medicinais utilizadas por grupos humanos em áreas mineradas ou que foram abandonadas sem restauração (FERNÁNDEZ-LLAMAZARES *et al.*, 2020), ou sobre o grau de contaminação e sua relação com a saúde de comunidades humanas (BRIONES ALONSO; COCKX; SWINNEN, 2018).

Esta situação representa um desafio à soberania e segurança das comunidades humanas no mundo (CANDEIAS *et al.*, 2019). A segurança alimentar é o termo usado para definir o direito que todas as pessoas, em todos os momentos, devem ter de acesso a fontes suficientes, seguras e nutritivas de alimentos, e que atendam às suas necessidades dietéticas e preferências por uma vida ativa e saudável (CONTI; COELHO-DE-SOUZA, 2014). Conectado com este conceito, a soberania alimentar é um princípio crucial para a garantia de segurança alimentar, abordando temas como participação das comunidades tradicionais e locais na definição de políticas públicas sobre alimentos, acesso a recursos seguros e saudáveis, autonomia sobre o que produzir, para quem produzir e em que condições produzir (ROCHA; LIBERATO, 2013a). Soberania alimentar significa garantir o direito de povos originários, extrativistas, pescadores e pescadoras, comunidades quilombolas, comunidades locais, entre outros grupos tradicionais, sobre sua cultura e sobre os bens da natureza (ROCHA; LIBERATO, 2013b; WEILER *et al.*, 2015).

Além destes riscos à saúde humana e à soberania e segurança alimentar, à medida que as áreas mineradas são abandonadas, os processos de repovoamento de espécies vegetais têm apresentado menor riqueza específica, favorecimento de espécies com características funcionais semelhantes (KIRMER *et al.*, 2008), aumento de espécies exóticas (LEMKE *et al.*, 2013) e diminuição nos serviços ecossistêmicos (e.g., diminuição na disponibilidade de recursos alimentares e culturais) (WU *et al.*, 2020). Todos estes fatores juntos fazem com que a estrutura ecológica das áreas mineradas seja fortemente impactada e tenha um desequilíbrio ecológico profundo (WU *et al.*, 2020).

Entre os minérios extraídos no mundo, o carvão é um dos principais, sendo responsáveis por sérios impactos ambientais e sociais (ZOCCHE *et al.*, 2017). A mineração de carvão no Brasil começou no final do século XIX e, hoje, praticamente todo o carvão produzido no Brasil é extraído na região sul (Figura 1) (BELLOLI; QUADROS; GUIDI, 2002). Desde a década de 1940, a região recebeu imigrantes alemães, italianos e portugueses para trabalharem na mineração (CORRÊA, 1934; KLANOVICZ, 2004). Antes da chegada de imigrantes europeus, a região era habitada por povos originários Guarani e Xokleng (ZANELATTO; JUNG; OZÓRIO, 2015). Atualmente ainda é possível encontrar estes e outros grupos tradicionais nestas regiões (Figura 1).

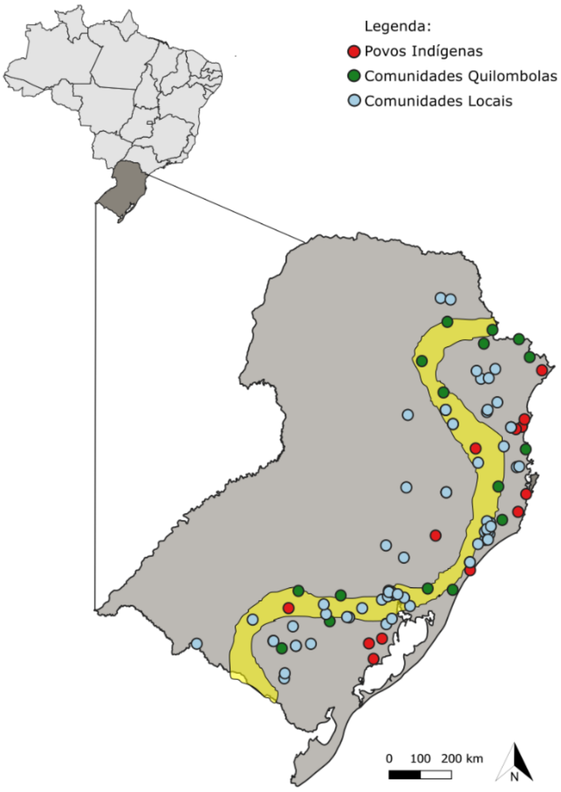


Figura 1 - Sobreposição da região carbonífera e de comunidades tradicionais no sul do Brasil. Em amarelo está indicada a região com maior atividade de extração mineral de carvão. Fonte: Graziela D. Blanco, com base nos dados do Ministério de Minas e Energia, IBGE e artigos (BECKER *et al.*, 2013; BLANCO *et al.*, 2020a; EJATLAS, 2020; GLAUSER *et al.*, 2005).

Ao longo do tempo, muitos destes locais deram origem às áreas urbanas da região, como Criciúma e Lauro Müller, ambas em Santa Catarina (SIZENANDO, 2011). A maioria dos habitantes atuais é descendente desses imigrantes europeus e do processo de formação de uma identidade brasileira que também mesclou outras culturas e etnias; mas dizimou ou reduziu os povos originários a pequenos grupos, a maioria deles restritos a poucos territórios (ZANELATTO; JUNG; OZÓRIO, 2015). O principal período de aumento e migração europeia para a região foi entre 1975 e 1985, levando a um crescimento urbano rápido (ZANELATTO; JUNG; OZÓRIO, 2015). Ainda hoje a mineração de carvão é uma das principais atividades econômicas, junto com a agricultura, na região carbonífera de Santa Catarina (Figura 1) (PAMPLONA; TRINDADE, 2015; SIZENANDO, 2011). O cordão carbonífero de Santa Catarina, devido a estas atividades de mineração e migração recente, levou a formação de um mosaico de áreas mineradas e abandonadas com presença de comunidades rurais e urbanas.

Um dos grandes desafios atuais desta região sul do Brasil, é devido a presença de elementos-traço, que tem sido detectada em diversas áreas da região (CAMPOS; ALMEIDA; SOUZA, 2003), assim como a perda de biodiversidade (CITADINI-ZANETTE; BOFF, 1992;

KLEIN, *et al.*, 2009a). A presença de comunidades humanas próximas destas áreas é uma situação alarmante e uma questão de saúde pública que deve ser melhor investigada, devido a ocorrência espontânea de espécies com uso associado nestes ambientes (Figura 2) (KLEIN *et al.*, 2009; SANTOS *et al.*, 2008).

Figura 2 - Áreas mineradas para extração de carvão e abandonadas de Santa Catarina, destacando o povoamento das espécies vegetais, coleta de recursos por moradores locais e proximidade das residências com as áreas mineradas. **A:** Área de extração mineral de carvão abandonada na localidade de Rio Carvão/Urussanga; **B:** Área abandonada após de extração mineral de carvão e presença de *Baccharis sagittalis* na localidade de Rio Fiorita/Criciúma; **C:** Lagoa Língua do Dragão contaminada pelas atividades de extração mineral na localidade de Siderópolis; **D:** Área abandonada após extração do carvão mineral na localidade de Barreiros/Lauro Müller; **E:** Coleta de espécies para uso medicinal em área de extração mineral de carvão abandonada na localidade de Rio Carvão/Urussanga; **F:** Presença de *Psidium guajava* e de casas em áreas abandonadas após extração mineral de carvão na localidade de Guaitá/Lauro Müller.

Estima-se que somente no estado de Santa Catarina existam mais de 6.500 ha de áreas que foram mineradas a céu aberto, estão abandonadas e com deposição de rejeitos e potencialmente contaminadas por elementos-traço da mineração de carvão (ROCHA-NICOLEITE; OVERBECK; MÜLLER, 2017). Nestas áreas é possível encontrar a presença de *Baccharis* spp. (carqueja) ocorrendo espontaneamente em áreas que foram mineradas a céu aberto (KLEIN, 2006; KLEIN, *et al.*, 2009; SANTOS *et al.*, 2008). Espécies deste gênero apresentam amplo uso medicinal por populações humanas do sul do Brasil até os Estados Unidos (ABAD; BERMEJO, 2007; FREIRE; URTUBEY; GIULIANO, 2007; MAZZELLA, 2012; PAULA *et al.*, 2016). Este gênero tem sido pesquisado devido ao seu alto potencial bioacumulador de elementos-traço e efeitos nocivos à saúde humana (AMERICAN *et al.*, 2016; MENEZES *et al.*, 2013; MORAES, 2014; PERON *et al.*, 2008; SILVA *et al.*, 2012). No Brasil, *Baccharis* tem espécies que são indicadas como um medicamento fitoterápico, e estão presentes na Relação Nacional de Plantas Medicinais de Interesse ao Sistema Único de Saúde (RENISUS), um programa do Sistema único de Saúde (SUS) (MARMITT *et al.*, 2017). O RENISUS é um programa nacional, que tem como objetivo difundir e incentivar o uso e conhecimento tradicional de plantas medicinais pelos brasileiros, por meio do sistema público de saúde (MARMITT *et al.*, 2017)

1.1 OBJETIVOS

1.1.1 Objetivo geral

Avaliar os impactos da mineração na soberania e segurança alimentar e medicinal de povos tradicionais e comunidades locais (PICL), assim como o seu impacto na formação de comunidades vegetais que se estabelecem em áreas que foram mineradas e estão abandonadas.

1.1.2 Objetivos específicos

a) Analisar, em nível global, as relações entre soberania alimentar, presença de atividades mineiras, baixo desenvolvimento humano, presença de elementos-traço do solo e baixo investimento e preocupação ambiental em países com presença de PICL;

b) Investigar, realizando extensa revisão da literatura, o nível de contaminação dos principais alimentos consumidos pelos PICL em áreas impactadas pela atividade de mineração;

c) Verificar se as comunidades locais que vivem próximas de áreas mineradas para extração de carvão em Santa Catarina usam espécies vegetais de áreas contaminadas pela mineração;

d) Compreender quais fatores podem estar influenciando no uso desses recursos vegetais, mesmo em áreas visivelmente impactadas;

e) Descrever a riqueza, as características (*i.e.*, tipo de raiz, formas de dispersão de sementes e polinização, forma e ciclo de vida e via fotossintética), distribuição (*i.e.*, nativa do Brasil ou exótica) e o potencial bioacumulador das espécies que ocorrem ao longo do tempo em áreas que foram mineradas para extração de carvão;

f) Compreender se as espécies que apresentam uso associado (*i.e.*, medicinal ou alimentício) apresentam potencial bioacumulador em áreas que foram mineradas para extração de carvão;

g) Analisar o teor de elementos-traço em uma espécie de uso medicinal e distribuída na região carbonífera do sul do Brasil;

1.2 HIPÓTESES

1.2.1 Hipótese geral

A mineração impacta negativamente a soberania e segurança alimentar das pessoas, devido a liberação de elementos-traço, ausência de políticas públicas socioambientais e abandono das áreas sem ações de restauração efetivas. As atividades de mineração impactam também asinterações ecológicas das espécies, diminuem a riqueza e abundância das espécies vegetais e selecionam espécies bioacumuladoras devido a presença de elementos-traço nessas áreas.

A tese está organizada na forma de quatro artigos que atendem aos objetivos e hipóteses especificas, formatados de acordo com as normas de cada revista-alvo. O primeiro artigo "*The impacts of mining on the food sovereignty and security of Indigenous Peoples and local communities: a global review*" encontra-se submetido para a *Science of Total Environment*. O segundo artigo "*Invisible contaminants and food security in former coal mining areas of Santa Catarina, southern Brazil*" foi publicado na revista *Journal of Ethnobiology and Ethnomedicine* em agosto de 2020. O terceiro artigo *"Descrição das características morfofisiologicas, de polinização, dispersão, bioacumulação e uso de espécies vegetais em áreas mineradas"* será submetido para *Perspectives in Ecology and Conservation* (PECON). O quarto artigo "*Is it safe to consume medicinal plants in mined areas? Impact of mining on* *consumption of a medicinal plant*" encontra-se submetido para a *Acta Botanica Brasilica*.

2 CHAPTER 1: THE IMPACTS OF MINING ON THE FOOD SOVEREIGNTY OF INDIGENOUS PEOPLES AND LOCAL COMMUNITIES: A GLOBAL REVIEW[1]

Graziela Dias Blanco[a*], Álvaro Fernadez-Llamazares[b], Gabriela Dias Blanco[c], Janelle Baker[d], Mario Sergio M. Tagliari[a], Maiara Albuquerque Hayata[a], Mari Lucia Campos[e], Natalia Hanazaki[a]

[a]Department of Ecology and Zoology, Federal University of Santa Catarina (UFSC), 88040-900, Florianópolis, Santa Catarina, Brazil
[b]Helsinki Institute of Sustainability Science (HELSUS), Faculty of Biological and Environmental Sciences, University of Helsinki, 00014, Helsinki, Finland
[c]Department of Sociology, Federal University of Rio Grande do Sul (UFRGS), 91509-900, Porto Alegre, Rio Grande do Sul, Brazil.
[d]Anthropology, Centre for Social Sciences, Athabasca University, Canada
[e]Department of Soils and Natural Resources, State University of Santa Catarina (UDESC), 88035-901, Lages, Santa Catarina, Brazil

ABSTRACT:

Mineral extraction areas are an environmental, social, and also a food sovereignty challenge for several countries. Indigenous Peoples and local communities (IPLC) are particularly vulnerable to the impacts of mining activities, particularly those that affect their lands and waters. At the global level, scientific evidence on the impacts of mining on the food sovereignty of IPLC is meager, scattered, and fragmented across disciplines and geographic regions. This study aims to assess whether factors such as mining, trace elements contamination, social inequality, lack of environmental deficitary environmental policy and practice, and socio-environmental conflicts directly impact the food sovereignty of IPLC worldwide. Through a comprehensive literature review of 403 articles, we mapped globally the impacts of mining activities on the food sovereignty of IPLC. Our results reveal that the combination of mining, social inequality and weak environmental strategies impinge negatively on the food sovereignty of IPLC. A hundred and six articles reviewed contained a detailed ecotoxicological analysis of food

---

[1] A formatação do texto e das referências do capítulo I seguem as normas da revista na qual foi submetida: Science of Total Environment.

resources used by IPLC in mining areas. Of all documented species, 52.9% were vascular plants, 40.3% were fish and 6.8% were mammals, presenting substantial scientific evidence of the contamination of food systems of IPLC as a direct result of mining. Given the magnitude of the evidence presented in this review, we propose strategic policy actions to address the impacts of mining on IPLC food sovereignty, such as the strengthening of social, cultural and environmental safeguards in the mining sector, which should include provisions for the protection of the food systems of IPLC and their culturally-valued food resources, as well as monitoring of contaminants' concentrations in the environment and in the resources potentially consumed.

Keywords: Mining, Food security, Ethnoecology, Rural communities, Ecotoxicology.

2.1 INTRODUCTION:

Solid and precious minerals mining is an ancient practice that has become a significant economic source globally (Candeias *et al.*, 2019). Minerals mee many human commercial demands, including energy generation and manufactured materials' production (Conde, 2017). However, due to the lack of efficient public policies and greater knowledge dissemination about mineral extraction effects on landscapes by mining companies, mining activities are often carried out without sufficient oversight, causing several environmental consequences (Candeias *et al.*, 2019; Feng *et al.*, 2019). Among myriad environmental problems resulting from mining are landscape changes (e.g. vegetation removal, soil layer removal) and trace elements contamination (e.g. through the release of semi-metals such as arsenic and selenium, and heavy metals such as lead and mercury) (Campos *et al.*, 2003; Guan *et al.*, 2017). Given that trace elements concentration and their effects depend on their molecular form available in the environment, the technologies used for their extraction, and their deposition time (Brisbois *et al.*, 2019; Campos *et al.*, 2003), the levels of contamination and deleterious effects of mining on the environment are difficult to predict (Feng *et al.*, 2019), especially the cumulative toxicity capacity in the food chain.

Trace elements, when available in the environment, can represent a risk to the entire ecosystem (Campos *et al.*, 2003; Liu *et al.*, 2017) due to their toxicity and cumulative capacity within food chains. Still, there are many human settlements within mineral extraction areas considering local demand for labor and the globally rising exploitation of regions already occupied by local communities (Brisbois *et al.*, 2019; Candeias *et al.*, 2019; Wegenast and

Beck, 2019). The homelands of Indigenous Peoples and local communities (IPLC) have drawn particular attention from the mining sector in recent years, because these areas represent some of the world's last frontiers of resource extraction in the global economy (Brisbois *et al.*, 2019; Candeias *et al.*, 2019; Fernández-Llamazares *et al.*, 2020). IPLC are ethnic groups that descend from, and identify with, the original inhabitants of a given region, in contrast to groups that have settled, occupied or colonized the area more recently (Lyver *et al.*, 2019; Reyes-García *et al.*, 2019). Because they depend directly on their local environments and natural resources for their livelihoods, they tend to be largely affected by environmental changes. Hence, this situation makes IPLC particularly vulnerable to the impacts of mining, exposing them to trace elements contamination through water, air and/or contaminated food consumption (Brisbois *et al.*, 2019; Rai *et al.*, 2019; Wegenast and Beck, 2019). Trace elements can threat human health, affecting metabolism and in some cases resulting in a greater propensity for cancer development (Cortes-Ramirez *et al.*, 2018; Jenkins, 2014), however, studies on the use and frequency of consumption of food potentially contaminated from these areas are still scarce in the literature (Blanco *et al.*, 2020; Brisbois *et al.*, 2019).

IPLC have deep cultural and social connections with their lands and waters, depending on them to obtain food and raw materials, for religious rituals, for their cultural identity and their well-being, (Fernández-Llamazares *et al.*, 2020). Thus, mining in and around IPLC homelands poses several risks to the livelihoods and cultures of IPLC (Brisbois *et al.*, 2019; Fernández-Llamazares *et al.*, 2020). Nevertheless, we do not have a clear picture of how IPLCs' food sovereignty is threatened worldwide by mining and related factors, such as contamination by trace elements, combined with the absence of national environmental public policies. For this reason, it is paramount to better understand whether mining and related factors, such as contamination by trace elements, absence of national environmental public policies, significantly impact countries with an IPLC presence and may pose a risk to their food sovereignty. Food sovereignty is often described as the right to have physical, social, and economic access to sufficient and nutritious food at all times throughout one's life and taking into account one's cultural preferences (FAO, 2020). The food sovereignty of IPLC is not only threatened by the risks caused by environmental contamination from mining activities, but also by poor smallholders' marginalization, aggravated by the encouragement of land appropriation and structural changes in the labor market (Wegenast and Beck, 2019).

There is well-established evidence that the number of socio-environmental conflicts posed by mining on IPLC lands is rapidly increasing (EJAtlas, 2020; Lauda-Rodriguez and Ribeiro, 2019). Indeed, IPLC often find themselves in the frontlines of mining conflicts

(Hanaceck *et al.*, 2022; Martínez-Alier *et al.*, 2016). Socio-environmental conflicts are defined as local communities' mobilizations, or social movements, which may have national or international network support against specific activities that impact the environment (EJAtlas, 2020). Factors such as poverty, social inequality, foreign mining companies' presence, and lower investment in environmental protection, especially in low- and mid-income countries, bring up a greater number of socio-environmental conflicts in these areas (Castellares and Fouché, 2017; Lauda-Rodriguez and Ribeiro, 2019). The absence of effective public policies to protect the inherent rights of IPLC over their lands, waters and natural resources has been identified as a factor aggravating the number and intensity of mining conflicts in IPLC lands (Gallego Ríos *et al.*, 2018). For these reasons and partly as a result of the COVID-19 pandemic, in 2020 the International Commission on Human Rights (ICHR), through Resolution 1/2020, instructed countries to suspend all mineral extraction activities in areas with IPLC (CEPAL, 2020). However, many countries still do not have clear laws on the rights and socio-environmental effects of mining and have not ceased mineral extraction in areas with IPLC during the COVID-19 pandemic, as seen in Brazil and Argentina, for example (Santos *et al.*, 2017).

It is essential to understand the current panorama of global research on the impacts of mining on the food sovereignty of the IPLCs and to identify the factors that could aggravate this situation in the near future. In this study, we examine the impacts of mining on food sovereignty through two different analytical angles. First, we analyze, at a global level, the relationship between food sovereignty and the presence of mining activities, and other factors related to the subject in different countries with IPLC (human development index and countries' environmental performance, for example). Second, we explore impacts on specific IPLC, based on a comprehensive literature review. We believe that these two different angles provide us with complementary information about the impacts of mining activities on the food sovereignty of the IPLCs around the world. Therefore, the objectives of the study are: a) to analyze, at a global level, the relations between food sovereignty, presence of mining activities, low human development, presence of trace elements of soil and low investment and environmental concern in countries with presence of IPLCs; b) Investigate, carrying out an extensive literature review, the level of contamination of the main foods consumed by the IPLC in areas impacted by mining activities. The study hypothesis is that (i) high mineral exploration, low human development, and low environmental quality are negatively associated with food sovereignty; and (ii) that the absence of studies and policies on food sovereignty contribute to the increased exposure of the IPLCs to the impacts of mining. Finally, we propose a combined strategy to integrate the food sovereignty of IPLC into the social and environmental impact assessment processes of mining activities.

2.2 METHODS:

2.2.1 Selection of countries and indicators

To understand the impacts of mining and socio-environmental policies and actions on the food sovereignty and security of countries with IPLC, we have selected five indicators: the Global Food Security Index (GFSI, 2020) for food security; the International Council on Mining and Metals Index (ICMM, 2018) and the Trace elements Index (HMI, 2020) for mining activities; the Environmental Performance Index (EPI, 2020) for countries' sustainability level; and the Human Development Index (HDI, 2020), with a social indicator. The Global Food Security Index (GFSI) consists of 59 indicators, such as food quality, food availability, accessibility, and resilience (GFSI, 2020). It presents data for 113 countries, focusing on the factors that underpin food security, and it is widely used due to its reliability (Izraelov and Silber, 2019). The highest values correspond to the countries with better food security, and the lowest values are those countries with worse food security, where values range from 85.3 to 35.7 (GFSI, 2020).

Regarding mining indicators, the International Council on Mining and Metals (ICMM) synthesizes the contribution of the mining sector to a country's economy in a single value (ICMM, 2018). This index accounts for information on minerals and metals export values, increase/decrease in mineral extraction and metal export contribution, mineral production value (expressed as Gross Domestic Product (GDP) percentage), and production values minus costs (ICMM, 2018). The ICMM does not consider oil or gas extraction values, and its score ranges from 96 to 5.3, with the highest scores corresponding to countries with higher mining activity and mining economic impact on GDP (ICMM, 2018). This indicator has been used as a robust index by many authors to express the mining industry's economic and extraction impacts in countries (Ericsson and Löf, 2019). The Trace elements Index (HM) measures the direct impacts of exposure to trace element pollution on human health in each country, based on lead exposure (HMI, 2020). Values close to 100 indicate low rates of lead exposure, while a score of 0 indicates high rates of lead exposure within the country (HMI, 2020). Mining activities contribute to higher lead concentrations in soil and water resources (Rehman *et al.*, 2020).

The Environmental Performance Index (EPI) provides a summary of the sustainability levels worldwide (EPI, 2020). It uses 32 performance indicators divided into 11 categories, such as climate change, ecosystem services, environmental quality, and environmental policies (EPI, 2020). The EPI ranks 180 countries concerning their environmental health and ecosystem vitality, ranging from 82 to 22 points, and the highest scores imply better environmental quality (EPI, 2020). The EPI is developed by the United Nations and is linked to the 2030 Agenda, being widely used in studies regarding countries' sustainability and environmental quality (Hsu and Zomer, 2016).

Finally, the Human Development Index (HDI), given that it is one of the most widely used indexes (Ngoo and Tey, 2019), used to measure and assess countries' development according to their social and economic aspects. The HDI takes into consideration information such as per capita income, literacy and education level, life quality, and life expectancy (HDI, 2020). This index ranges from 0 to 1, with higher values meaning excellent human development and lower ones indicating poor human development within the country (HDI, 2020). In our analysis, we considered only countries with available values on all 5 indicators (Table 1) and only each indicators' most recent data was used.

Table 1: List of countries with social-environmental information used in the article. Global Food Security Index (GFSI), International Council on Mining and Metals (ICMM), Trace elements Index (HM), Environmental Performance Index (EPI) and Human Development Index (HDI).

Country	GFSI	ICMM	HM	EPI	HDI
Algeria	61.8	35.9	38.9	44.8	0.748
Angola	42.1	39.1	37.3	29.7	0.581
Argentina	62.7	58.4	73.1	52.2	0.845
Australia	71.3	69.8	77.2	74.9	0.944
Austria	79.4	35.5	91.7	79.6	0.922
Azerbaijan	62.3	49.5	41	46.5	0.756
Belarus	73.8	21.3	57.7	53	0.823
Belgium	75.2	29.7	67.4	73.3	0.931
Benin	46.2	38.4	36.8	30	0.545
Bolivia	60.0	84.5	43.7	44.3	0.718
Botswana	55.5	86.1	39.8	40.4	0.735
Brazil	64.1	55.3	58.9	51.2	0.765

Bulgaria	67.4	58.1	45.8	57	0.816
Burkina Faso	47.4	93.4	29.7	38.3	0.452
Burundi	37.1	74.5	35.8	27	0.433
Cameroon	44.7	58.4	36.1	33.6	0.563
Canada	77.2	55.1	96.6	71	0.929
Chad	39.4	59.4	29.1	26.7	0.398
Chile	70.2	69.1	97.8	55.3	0.851
China	69.3	53.1	37.6	37.3	0.761
Colombia	63.1	72.0	61.9	52.9	0.767
Congo. Dem. Rep.	40.7	96.4	36.1	36.4	0.480
Costa do Marfim	51.0	69.4	44.9	25.8	0.538
Costa Rica	72.3	33.4	53.8	52.5	0.810
Dominican Republic	65.2	78.3	30	46.3	0.756
Ecuador	57.9	53.7	63	51	0.759
Egypt. Arab Rep.	61.1	65.2	13.5	43.3	0.707
Ethiopia	37.0	64.7	35.8	34.4	0.485
Finland	85.3	57.3	100	78.9	0.938
France	76.5	34.5	84	80	0.901
Germany	77.0	36.5	90.7	77.2	0.947
Ghana	53.0	90.9	55.3	27.6	0.611
Greece	73.0	55.4	69.4	69.1	0.888
Guatemala	56.2	52.8	30.6	31.8	0.663
Guinea	39.5	94.3	32.9	26.4	0.477
Honduras	58.2	44.4	20.7	37.8	0.634
Hungary	70.1	36.1	68.2	63.7	0.854
India	56.2	56.9	21	27.6	0.645
Indonesia	59.5	58.8	34.6	37.8	0.718
Ireland	83.8	34.9	82.7	72.8	0.955
Israel	78.0	47.2	92.1	65.8	0.919

Italy	76.6	25.5	81.5	71	0.892
Japan	77.9	38.1	100	75.1	0.919
Jordan	60.4	38.1	46.7	53.4	0.729
Kazakhstan	70.8	76.7	52.8	44.7	0.825
Korea	72.1	38.3	89.4	66.5	0.916
Lao PDR	46.4	62.9	34.7	34.8	0.613
Madagascar	37.5	87.1	33	26.5	0.528
Malaysia	67.9	54.5	62.1	47.9	0.810
Mali	52.7	93.2	32.5	29.4	0.434
Mexico	66.2	53.2	45.7	52.6	0.779
Morocco	62.0	49.3	28.9	42.3	0.686
Mozambique	40.6	66.5	23.7	33.9	0.456
Nepal	53.0	10.9	27.2	32.7	0.602
Nicaragua	54.4	56.6	34.5	39.2	0.660
Niger	47.6	53.3	27.3	30.8	0.394
Norway	76.2	52.6	94	77.7	0.957
Pakistan	52.3	38.9	23	33.1	0.557
Panama	68.9	39.3	57.5	47.3	0.815
Peru	65.7	80.1	61.5	42.6	0.777
Philippines	55.7	56.2	48	38.4	0.718
Poland	73.5	49.1	65.3	60.9	0.880
Portugal	75.7	38.2	65.3	67	0.864
Romania	74.2	37.4	51.4	64.7	0.828
Russian Federation	73.7	77.0	72.2	50.5	0.824
Serbia	63.2	52.9	51.1	55.2	0.806
Sierra Leone	37.0	92.6	37.4	25.7	0.452
South Africa	57.8	65.1	58.8	43.1	0.709
Spain	73.4	39.2	71.3	74.3	0.904
Sudan	36.0	79.9	7.1	34.8	0.510

Sweden	78.1	48.4	98	78.7	0.945
Switzerland	77.7	45.4	95	81.5	0.955
Tajikistan	49.4	84.9	15.7	38.2	0.668
Tanzania	47.1	64.3	43.6	31.1	0.529
Thailand	64.0	53.0	81.6	45.4	0.777
Tunisia	61.4	43.2	36.5	46.7	0.740
Uganda	42.9	56.7	41.9	35.6	0.544
UK	78.5	46.9	94.6	81.3	0.932
Ukraine	63.0	61.4	69.3	49.5	0.779
United Arab Emirates	68.3	48.9	54.3	55.6	0.890
United States	77.5	41.0	75.9	69.3	0.926
Uruguay	71.4	36.3	62.3	49.1	0.817
Uzbekistan	50.9	89.1	27.8	44.3	0.720
Vietnam	60.3	43.4	47.8	33.4	0.704

2.2.2 Literature review

To better understand the impact of trace elements on Indigenous Peoples and local communities (IPLC) lands and waters in the countries mentioned in Table 1, we performed a survey on the databases of the United Nations High Commissioner for Refugees (UNHCR, 2021), The International Work Group for Indigenous Affairs (IWGIA, 2021), and the World Directory of Minorities and Indigenous Peoples (WDMI, 2021) to identify which countries presented information and/or recognized IPLC presence in their territory. Based on this information, we used ScienceDirect, Scopus, and Google Scholar databases (limited to the search in the first 15 pages) to find scientific articles reporting research on IPLC food contamination in mining areas. Different keyword combinations were used to find as many articles as possible regarding mining, food sovereignty and security, and traditional and local peoples and communities, such as *Indigenous peoples/ local peoples/communities, mining, food sovereignty and security in COUNTRY,* (Supplementary material Table S1). We pre-selected 403 articles through the analysis of the title and abstract, excluding those that were not strictly related to mining, food sovereignty and security, and/or IPLC. Only 106 articles had analyzed the quantified trace elements' levels in IPLC food systems. Based on the community's location data presented in each article, a heat map was plotted using the QGIS Development Team software (QGIS, 2017), allowing the visualization of regions with the highest number of scientific articles investigating the contamination of food consumed by IPLC in mining areas, and which were the foods with highest documentation of trace elements contamination.

We then used the global Environmental Justice Atlas (EJAtlas, 2020) to map socio-environmental conflicts within the countries in Table 1 with IPLC presence in mining areas. The EJAtlas is a dataset that systematizes information on social-ecological conflicts worldwide by drawing on inventories of conflicts reported upon by NGOs and activist organizations and is complemented with additional research (Temper *et al.* 2018). We used the EJAtlas' search engine to filter conflicts within the category "Indigenous Groups or Traditional Communities" and "mining" (EJAtlas, 2020). At last, a survey on food safety laws in the selected countries listed in Table 1 was carried out, using the Food and Agriculture Organization law database (FAO, 2020).

2.2.3 Data analysis

A Linear Regression model (LM) was used to verify which variables might affect food sovereignty and security, based on each country's Global Food Security Index (GFSI). The indicators International Council on Mining and Metals (ICMM), Trace elements (HM), Environmental Performance Index (EPI), and Human Development Index (HDI) were used as explanatory variables. Model validation used graphical analysis of residues and their constant variance (*i.e.* homoscedasticity). Data were log-transformed. Analysis was performed in R environment with vegan package to analyze the LM (Oksanen *et al.*, 2020). The tested variables and their values are listed in Table 1.

2.3 RESULTS

According to the Linear Regression Model, the International Council on Mining and Metals (ICMM), Trace elements (HM), Environmental Performance Index (EPI), and Human Development Index (HDI) do influence food sovereignty and security values of studied countries (Table 2). This result indicates that a country's food sovereignty and security is related to mining factors, trace elements presence, environmental performance, and human development. Countries with worse environmental performance and human development, higher trace element contamination, and greater investment in the mineral area exhibited lower food sovereignty and security levels.

Table 2: Analysis result of Linear Regression Model. Linear Regression Model (LM) results, showing the significance (p) and t values of the International Council on Mining and Metals (ICMM), Trace elements (HM), Environmental Performance Index (EPI) and Human Development Index (HDI) variables in relation to the Global Food Security Index (GFSI) of the countries.

Variables		
Linear Regression model (LM)	formula=Food_security~ log(HM) + log(MCI) + log(HDI) + log(EPI)	
	t value	**p value**
ICMM: index for the economic impact of mining in the country	-2.090	0.03981
EPI: index for the quality and investment of countries in the environmental area	3.125	0.00249
HM: index for the lead concentration in the soil of countries	2.147	0.03487
HDI: index for the human development of each country	7.035	6.4e-10

Among the 84 countries analyzed, 68 recognized IPLC presence in their territories and presented information about them (Supplementary material Table S2). It should be noted that during data collection, even though the databases of the United Nations High Commissioner for Refugees (UNHCR, 2021), The International Work Group for Indigenous Affairs (IWGIA, 2021) and the World Directory of Minorities and Indigenous Peoples (WDMI, 2021) reported IPLC occurrence in some countries, many of them did not recognize these human groups' presence in their territory, nor presented data on IPLC numbers or ethnic diversity. Thus, these countries were not included in this stage of the research.

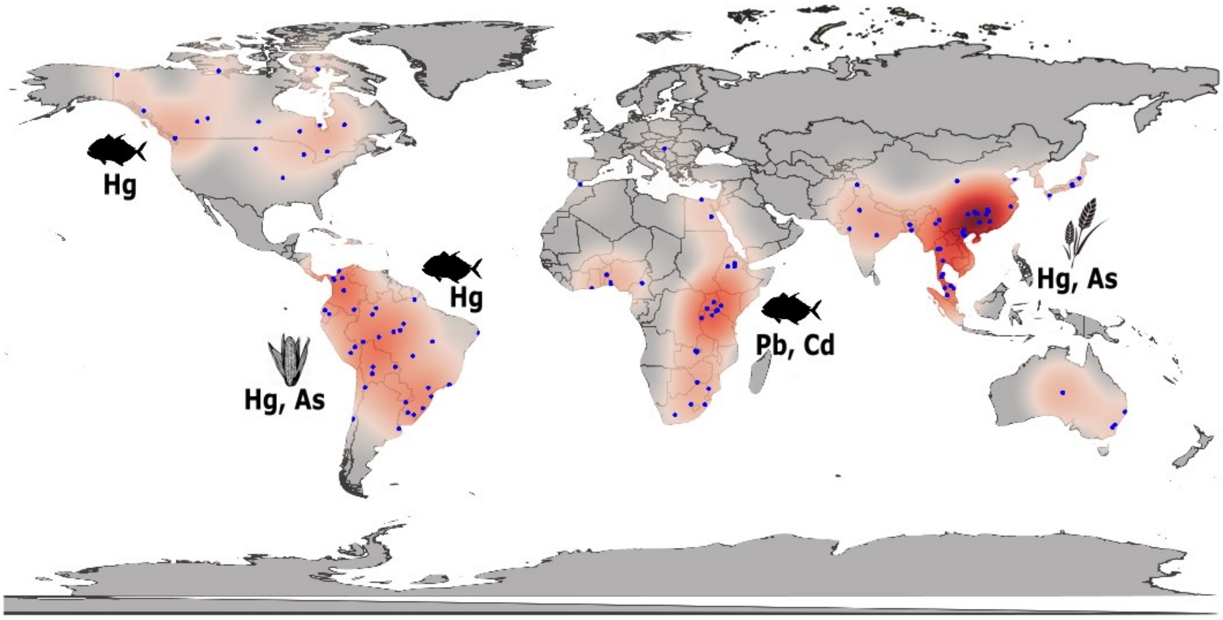
The EJAtlas documents the existence of at least 539 socio-environmental conflicts in relation to mining and involving IPLC (EJAtlas, 2020). Most of these conflicts were recorded in Latin America (15 countries) and Africa (6 countries), with Brazil and Peru exhibiting the highest numbers of conflicts (49 and 40 conflicts, respectively). The database reports numerous impacts associated with these mining conflicts, such as water and soil contamination, biodiversity loss, encroachment, and violence and repression against IPLC, among many others (Scheidel et al, 2020). Meanwhile, the main minerals extracted in the 68 countries were gold, iron, copper, and coal, according to the Central Intelligence Agency (CIA, 2020). Finally, among the 106 articles that analyzed the quantified trace elements levels in IPLC food systems, the countries with the highest number of studies were Brazil (15 articles), China (10 articles), and Canada (7 articles) (Supplementary material Table S2).

We observed that some of the countries with the highest number of socio-environmental conflicts between mining companies and the IPLCs did not present data on the impacts of mining on the sovereignty and food security of the IPLCs. Countries such as Mexico (30 socio-environmental conflicts), Philippines (25 socio-environmental conflicts) and Indonesia (14 socio-environmental conflicts) fit this profile, that is, they have many socio-environmental conflicts and no studies on sovereignty and food security of IPLC in mining areas (Supplementary material Table S2).

In all, 438 species were studied in 106 articles found around the world, which investigated the contamination of IPLCs in foods. All studies of contamination in food consumed by the IPLC in mining areas were carried out between 1998 and 2021 (Supplementary material 3). Of all documented species, 52.9% were vascular plants, 40.3% were fish and 6.8% were mammals. Most comprised plant resources, such as vegetables, grains, medicinal plants, and legumes (54 articles), with analysis of the genus *Oryza* and *Brassica* being the most frequent (20 and 13 articles, respectively). Then came the fishery resources (45 articles) consumed by IPLCs, with *Oreochromis* being the most studied fish genus (6 articles), but we also found works from different regions of the world that analyzed the genera *Prochilodus* (5 articles), and *Hydrolycus* (3 articles) and detected trace elements in the organisms of the species of these genera. The main elements analyzed were Hg, Pb, As, Zn and Cd (35 articles), which have gold and coal mining as the central source of contamination. These studies focused mainly on Southeast Asia, East-Central Africa and the Congo Basin, South America, parts of Australia and between Canada and the United States.

Figure 1 shows a summary of the main food resources studied and the majority trace elements investigated in each of these regions. We can observe that the Asian region has investigated the contamination mainly in *Oryza* sp., the region of North America and the African continent has investigated the contaminants in fisheries resources, and South and Central America in the resource's vegetables and fisheries resources.

Fig. 1: World heat map showing countries that feature scientific articles on mining contamination in food consumed by indigenous peoples and local communities. Blue dots represent studied areas in the studies reviewed, while drawings represent the most cited type of food (*i.e.* corn, rice and fish products), per region. The most cited trace elements in the reviewed articles, by region, are presented: Hg (mercury), As (arsenic) Cd (cadmium), and Pb (lead).



Regarding the national legislation of each country on food sovereignty and security, only 32 of the 84 countries had some legal history and/or current laws on food safety in their territories (Table 3). Angola, Bolivia, Brazil, Panama, and Spain were the countries with the highest number of national food safety laws and decrees. Thailand was the only country in which reference to the creation of a committee to debate food safety laws implementation, with direct social action, at a national level, was found.

Table 3:Food safety laws. List of countries studied and their food safety laws.

Country	Legislation
Angola	Law Nº. 5/21 that approves the Plant Health Law (2021); Law Nº. 6/17 on Basic Forest and Wildlife Legislation (2017); Executive Decree Nº 47/11 that approves the Regulation of the National Directorate of Rural Development of the Ministry of Agriculture, Rural Development and Fisheries (DNDR) (2011).

Argentina	Law Nº. 27519 - Extension of the National Food Emergency (2020); Law Nº 25724 - Creates the National Nutrition and Food Program (2003).
Austria	Federal law amending the Health and Food Safety Act (2017); Federal Constitutional Act on sustainability, animal welfare, full protection of the environment, water and food grants, research (2013).
Azerbaijan	Law Nº. 759-IG "About food" (1999).
Belarus	Law Nº. 397-3 of 2000 on the introduction of modifications and amendments to the law on the health and epidemiological well-being of the population (2000).
Belgium	Law Nº. that repeals the law of February 19, 1999 that creates the Belgian Survival Fund and creates a Belgian Fund for Food Security.
Bolivia	Law Nº. 622 - School feeding law in the framework of sobriety, food and plural economy (2014); Law Nº 338 - Law of rural economic organizations, indigenous peoples and community economic organizations for the integration of sustainable family agriculture and food sobriety (2013); Law of Mother Earth and Integral Development for Living Well (2012).
Brazil	Decree No. 7775 that regulates the Food Acquisition Program (PAA) (2019); Law Nº. 11.346 of the National Food and Nutritional Security System (SISAN) (2006); Law Nº. 11,947 that institutes the School Feeding Program in Elementary Education in Brazil (PNAE) (2009); Law Nº. 10,689 that institutes the National Program for Access to Food (PNAA) (2003).
Canada	Law of Safe Food for Canadians (2012).
China	Law of Safe Food (2009).
Dominican Republic	Law Nº 589-16 - Creation of the National System for the Sovereignty and Security of Food and Nutrition (SINASSAN) of the Dominican Republic (2018).

Ecuador	Reform Organic Law to the Organic Law of the Food Sovereignty Regime (2009); Organic Law of the Food Sovereignty Regime (2009); Constituent Mandate N°. 16 - Food Sovereignty Program (2013).
France	Law Nº 2018-938 of October 30, 2018 for the balance of commercial relations that are not agricultural and feed a healthy food, sustainable and accessible to all.
Germany	Food Security and Supply Law.
Guatemala	Decree Nº 32/2005 - Law on the National System of Food and Nutritional Security (2005).
Honduras	Decree Nº 28-2015-PCM — Modifies Decree Nº. 25/11, Food and Nutritional Security Law (2015); Decree Nº 25-2011 — Food and nutritional security law (2011); Decree Nº 38/10 / PCM - Food and Nutrition Security Policy (PSAN) (2006).
India	National Food Security Law (2013).
Ireland	Irish Food Safety Authority Law (1998).
Nepal	Law on the Right to Food and Food Sovereignty, 2075 (2018).
Nicaragua	Law Nº 1005 - Law No. 881, Law of the Nicaraguan Legal Digest of Material Sovereignty and Security Food and Nutrition (SSAN) (2015); Law Nº 881 - Nicaraguan Legal Digest Law of the Materia Soberanía y Seguridad Alimentaria y Nutricional (SSAN) (2019).
Panama	Law Nº 17 - Which declares rice as a cultivation of national food security; Law Nº 36 - Creates the National Secretariat for the Food and Nutrition Security Plan (SENAPAN); Law Nº 89 - Incorporates the National Secretariat for the Food and Nutritional Security Plan (SENAPAN) to the Ministerio de Desarrollo Social.
Philippines	Law on the trade of rice (Law of the Republic Nº 11203) (2019).
Portugal	Decree-Law Nº 119/2012 that creates the Health and Food Security Plus Fund (2012); Decree-Law Nº 180/2000 that creates the Food Quality and Safety Service (2000).

Russian Federation	Federal Law FZ-29 on food quality and safety (2000).
Spain	Law Nº 9/2012 - Modifies Law Nº 17/2008, Law on Agrarian and Food Policy (2012); Law Nº 17/2011 - Law on food and nutrition security (2011); Law Nº 11/2001 - Creates the Spanish Agency for Food Safety (2001).
Sudan	Presidential Decree Nº 287 of 2015 to form the Superior Council for Food and Nutritional Security.
Tajikistan	Law Nº 671 "On food security", Law Nº 641 "On food security".
Tanzania	Tanzania Food and Nutrition Law, 1973 (Nº 24, 1973); Food Security Law of 1991 (Law Nº 10 of 1991).
Thailand	National Food Committee Law (2008).
United Arab Emirates	Law Nº 7 of 2019, which establishes the Abu Dhab Food and Agriculture Authority.
United States	Global Food Security Law 2016; Food Security Law 1985 (7 USC 2081); FDA Food Safety Modernization Law (21 USC 2201-2252).
Uzbekistan	Presidential Decree Nº UP-5503 "On measures to guarantee national food security" (2018); Presidential Decree Nº UP-1737 on State support for peasant families and agricultural companies and increasing their role in national food security (2006).

2.4 DISCUSSION

Our study revealed that the lack of social and environmental public policies, low Human development Index and control over mining activities in countries negatively impact the food sovereignty of countries. This situation can be even more worrying, as many countries still do not recognize the IPLC in their territory, which makes the real situation of food sovereignty of these groups unfeasible in many countries. Along with this, the high number of socio-environmental conflicts in mining areas with the presence of IPLCs has, as one of its direct effects, the increase in soil and water contamination and a greater occurrence of acts of violence against the IPLCs. Specifically, our study revealed four main elements related to the food sovereignty of Indigenous Peoples and local communities (IPLC) living in and around mineral extraction areas. Countries with minor mineral extraction, high human development index, high environmental performance, and lower lead contamination tend to have higher food sovereignty levels.

Mining areas are regions of financial instability, poverty, and social inequality, with insufficient laws to ensure human groups' rights and equality (Candeias *et al.*, 2019; Feng *et al.*, 2019). Over the last two decades, mining has grown exponentially, which has led to severe environmental impacts (Brisbois *et al.*, 2019; Candeias *et al.*, 2019). In 2000, 45% of all toxics emitted by anthropic activities were produced by mineral extraction, by contaminating the air, soil, and water resources (United States Environmental Protection Agency, 2000). Given the lack of research and full understanding of human health impacts caused by the consumption of food from mining areas, this situation only aggravates food sovereignty conditions (Wegenast and Beck, 2019), especially for vulnerable groups such as the IPLCs. In the long term, mining activities impact the availability of IPLC food and nutritional resources, as a result of deforestation and decreased species richness, for example (Yadav *et al.*, 2019). These data, along with the current food crisis and social inequality endured by countries in Latin America and Africa, worsen IPLC food insecurity in these regions (CEPAL, 2020; FAO, 2018).

One of the major concerns for both environmental issues and food sovereignty in mining areas is trace elements (Olumayowa Oluwasola *et al.*, 2021). When ingested at high levels and for a long period, trace elements can cause chronic diseases (Kumar *et al.*, 2020). Among these elements, lead is the most studied for its impacts on the environment and human health (Kumar *et al.*, 2020). Lead can be released into the environment in several ways: mineral extraction and smelting activities, pesticides and fertilizers, and use of leaded tetraethyl gasoline; still, human exposure to lead occurs mainly through the food chain (Ćwieląg-Drabek *et al.*, 2020). Our study results reveal that higher food sovereignty has been observed in environments with lower lead concentrations, disclosing an alarming impact of trace elements in countries' food sovereignty. In the articles found in the comprehensive literature review regarding contaminants in food consumed by IPLC, lead was one of the most mentioned elements, along with arsenic and mercury. Contamination by trace elements is one of the main challenges for the recovery and sustainability of degraded areas (Kumar *et al.*, 2020).

Among IPLC, women and children have been the ones most affected by diseases caused by contamination from trace elements related to mining activities (Adewumi and Laniyan, 2020; Vega *et al.*, 2018). For example, mercury contamination in Yanomami breast milk in the Brazilian Amazon has already been observed (Vega *et al.*, 2018), and analysis of hair and nails from children of local communities in Nigeria revealed high lead concentrations

(Adewumi and Laniyan, 2020; Bashwira and Cuvelier, 2019). Furthermore, growing numbers of women working in artisanal mineral sectors under poor conditions have increased exposure to contaminants and the development of diseases. In Africa, 40 to 50% of artisanal miners are women, while in Latin America this number varies between 10 to 20% (Hinton *et al.*, 2003). Meanwhile countries that present low HDI levels tend to exhibit greater social inequality and also exhibit worse environmental performance (Samimi *et al.*, 2011), favoring socio-environmental conflicts emergence (Samimi *et al.*, 2011). And as observed from the present study, this situation is directly linked to a worse performance in the countries' food sovereignty. This situation highlights the great socio-environmental vulnerability of women and children, even more so when we think of a scenario of overlapping mining and IPLC areas. We emphasize the urgency for countries to develop public policies that guarantee human rights and protect the health and food sovereignty of these groups.

The lack of knowledge concerning actual impacts of mining on public health, along with scarce study numbers regarding food consumed by IPLC, aggravate food insecurity in several countries (Blanco *et al.*, 2020; Villén-pérez *et al.*, 2020). As mentioned before, Brazil, China, and Canada were the countries that exhibited the highest number of studies on the impacts of mining on IPLC food systems. This might happen because these countries have a long history of mineral extraction (Aznar-Sánchez *et al.*, 2018; Lv *et al.*, 2019; Villén-pérez *et al.*, 2020), with well-documented environmental and social impacts in their territories (Lv *et al.*, 2019; Villén-Pérez *et al.*, 2018), and a prominent involvement of IPLC in resistance movements and grassroots mobilization (e.g., Temper *et al.*, 2018). For instance, the Indigenous Peoples of Canada (First Nations, Inuit and Métis) have historically been on the frontlines of numerous socio-environmental conflicts in relation to mining, with substantial implications in terms of food sovereignty (Batal *et al.*, 2021). However, Canada is also one of the countries that has invested most in scientific research on trace element contamination in the traditional foods consumed by such communities (Schwartz *et al.*, 2021).

In China, historic devastation of land by mining activities has led to notorious disasters and environmental impacts (e.g. soil and watersheds contamination) (Lv *et al.*, 2019). Still, the country has made considerable progress with guidelines and laws regarding contamination in foods consumed by different ethnic groups in the country (Robert, 2016). In contrast, Brazil continues to invest heavily in the mineral sector (Ferrante and Fearnside, 2020; Robert, 2016), despite the significant struggles concerning IPLC rights to a safe and healthy environment (Schwartz *et al.*, 2021). The country has records of historical socio-environmental crimes, such as the collapse of tailing dams contaminated with trace elements that devastated the cities of

Mariana and Brumadinho, resulting in the death of 289 people and environmental impacts beyond measure (Fabrício *et al.*, 2021).

The COVID-19 pandemic is yet another factor that has undoubtedly increased the social and health vulnerability of IPLC in Latin America and the Caribbean (Ferrante and Fearnside, 2020). In some countries, like Brazil, there was even a significant increase in mining activities in IPLC areas in 2020, most often without undertaking any process of Free, Prior and Informed Consent (Menton *et al.*, 2021). Public policies, laws, and socio-environmental guidelines on IPLC food sovereignty are still relatively recent and slowly developing (Candel and Biesbroek, 2018). There are increasing efforts by Indigenous Peoples' Organizations to develop frameworks to assess food sovereignty from an Indigenous perspective, based on their own knowledge systems, needs and views. A good example in this regard is the Inuit Food Security Conceptual Framework, developed by the Inuit Circumpolar Council of Alaska (ICC-AK, 2015).

Among the 84 countries analyzed in this study, only 32 presented national laws on food safety guidelines. Thailand, for instance, has been making considerable progress in its public health and food sovereignty policies since the 1990s (Rasanathan *et al.*, 2012). Some of its implemented strategies comprised local communities' involvement in the use and control of sustainable and safe resources, along with collaborative networks for food sovereignty (Chaoniruthisai *et al.*, 2018; Rasanathan *et al.*, 2012). Countries such as Bolivia, Ecuador, Kenya, China, and Brazil also exhibit some interesting strategies for the development of laws on food sovereignty with a strong participatory component (Conceição *et al.*, 2011; Schilling *et al.*, 2020). For instance, in Bolivia the right to Food Security and Sovereignty is enshrined in the country's constitution alongside the notion of "vivir bien" (living well), denoting an ethical, community-centric and ecologically balanced approach to development (Schilling *et al.*, 2020).

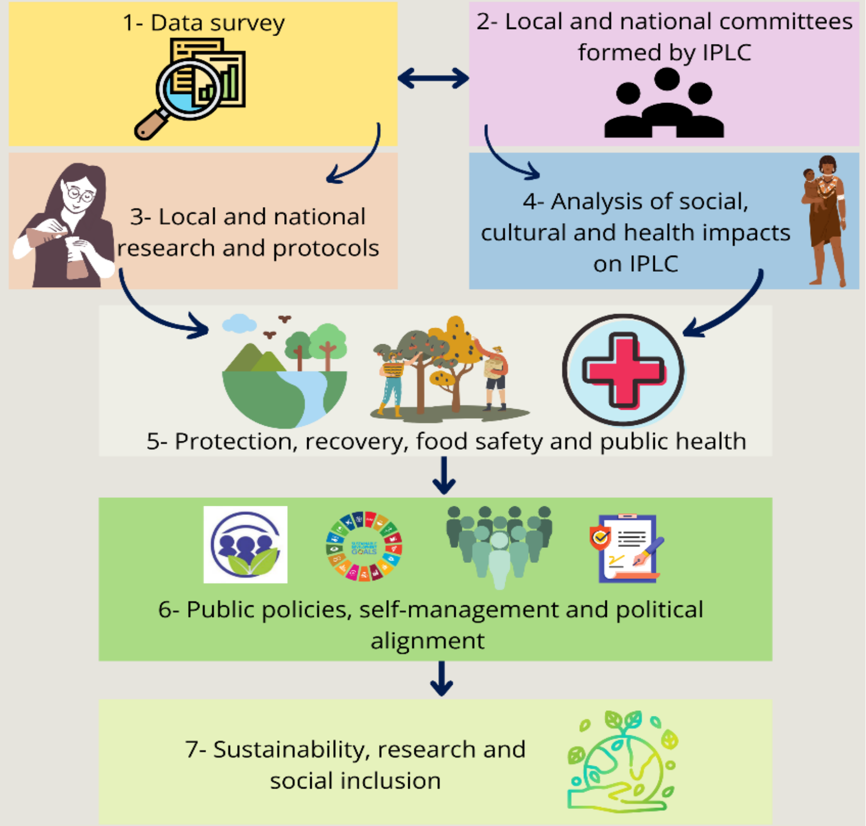
Regarding food consumed by IPLC and contaminated by mining activities, the consumption of contaminated fishery resources appeared as a global concern (Micheline *et al.*, 2019). Studies investigating freshwater and ocean water contamination by trace elements, such as mercury, have revealed alarming effects on human health (Gworek *et al.*, 2016). Even though fish contamination by mercury is gaining increasing research attention (Basu *et al.*, 2018), studies have also pointed to the bioaccumulation of cadmium, arsenic, and lead on these resources (Kortei *et al.*, 2020). Within plant-based foods, Rice (*Oryza* sp.) was the most studied in the reviewed articles, emphasizing its ability to bioaccumulate arsenic, cadmium, and mercury (Javaid *et al.*, 2020). Besides being one of the world's food staples, rice is a significant trace element bioaccumulator (Kortei *et al.*, 2020). Similar to rice, corn (*Zea mays*) also presented worrying data on its contaminant's levels, including cadmium (Shafaqat *et al.*, 2017). In Latin America, corn, in addition to its nutritional importance, also has a strong cultural significance, playing a major role in the religious and social practices of various IPLC (Hastorf and Johannessen, 1993). Along with food items, the consumption of medicinal plants by IPLC in mining areas has also been explored (e.g., Arquette *et al.*, 2002), and some species, like *Baccharis* sp., have revealed bioaccumulative potential of toxic elements for human health (Blanco *et al.*, 2020). During the COVID-19 pandemic, consumption of medicinal plants by IPLC has increased (Nugraha *et al.*, 2020), emphasizing the need for further studies of the use of medicinal plants in mining areas.

Here it is fundamental to acknowledge the importance of the knowledge systems of IPLC, as well as their views and perspectives, for furthering our understanding of food sovereignty issues in mining contexts. Indigenous and local knowledge systems can offer critical insights on the status and trends of culturally-valued food resources affected by mining extraction, and help to monitor the impacts of pollution on foods that are both nutritionally and culturally important for IPLCs (Fernández-Llamazares *et al.*, 2020). It is possible to identify information gaps, including insight on most consumed food resources, and what is important not only to a nutritional diet but also to local culture and biodiversity (Schilling *et al.*, 2020). Given that, 36% of the world's last remaining Intact Forest Landscapes intersect Indigenous Peoples' lands (Fa *et al.*, 2020), it becomes clear that the self-governance of Indigenous communities is inextricably linked to global efforts to safeguard biodiversity.

Ensuring IPLC access to information and participation in relation to environmental decision-making, as well as providing adequate protection of Indigenous land and environmental defenders, are central actions needed in order to build effective governance concerning food sovereignty in mining contexts (Assis, 2021). Moreover, international agreements have taken important steps towards this direction, such as the Escazú Agreement, which seeks to promote and guarantee such rights, and is valid for all UN member countries in Latin America (Beatrisse *et al.*, 2020). The Escazú Agreement emphasizes the importance of IPLC participation in local and national decisions regarding environmental, social, and political agreements, being crucial to achieving sustainability across scales (Assis, 2021). The creation of the 17 Sustainable Development Goals (SDGs) by the UN in 2015, also highlight the importance of creating inclusive and participatory strategies for different sectors of society, so that it is possible to guarantee effective sustainability (V Relatório Luz da Sociedade Civil sobrea Agenda 2030, 2020).

Overall, it is increasingly evident that environmental and social issues, along with human development and mining activity must be urgently reviewed and thoroughly debated, in order to understand their impacts on countries' food sovereignty, especially regarding IPLC. Thus, strategic actions are here proposed for governments at national and regional levels, based on seven steps to improve IPLC food sovereignty in mining areas, and reduce their exposure to trace elements contamination (Fig. 2). The first step involves data collection and mapping of mining activities in IPLC lands and waters, before creating national committees to identify the challenges related to the food sovereignty of these communities. Then, protocols such as the National Health Surveillance Agency protocols in Brazil (ANVISA, 2013) or Westman resolution in China (Godoy *et al.*, 2013) should be analyzed and/or created, providing information on unacceptable levels of contaminants in the environment and their effects on human health, as well as mapping these elements' concentration in foods consumed by IPLC. During all stages, the full and effective participation of IPLC is critical to identify the main challenges to ensure the food sovereignty of IPLC in mining areas. With the gathering of all information mentioned, along with increasing partnerships between IPLC, researchers, health professionals, and institutes, it will be possible to create efficient laws and political. Finally, legal supervision mechanisms are also necessary to provide greater control and more efficient penalties regarding mineral sector impacts on the environment and human health, which should be aligned with SDGs and Escazú Agreement international guidelines. This is needed to achieve more sustainable and inclusive societies, with effective IPLC involvement.

Fig. 2: Strategic actions to assist food sovereignty performance of IPLC affected by mining activities. 1- Organization of updated databases on overlapping, invasion, and presence of mining companies (e.g., projects such as EJAtlas, Instituto Socioambiental mapping projects, among others) in IPLC lands and waters; 2- Formation of local committees to gather information about the perceptions and situation of IPLC in mining areas; 3- Analysis of IPLC food, soil, and water, with the production of guidance protocols on unacceptable concentrations of elements and trace elements that may pose a risk to human health; 4- Analysis of the social, cultural and health impacts suffered by IPLC in mining areas; 5- Protection, recovery, food safety and public health working together, supported by scientific, traditional and legal knowledge; 6- Based on data from previous stages, this information should support public policies and local actions; 7- Sustainability, research, and social inclusion.



2.5 CONCLUSION

The IPLC must have a leading role in forums and policy discussions on food sovereignty and security and pollution control. However, across the world, IPLCs still face many barriers to effective participation in land and water policy and planning. The urgent need to increase the IPLC's involvement in environmental decision-making in relation to mining activities becomes more critical as evidence accumulates of myriad impacts that mining imposes on their food systems. We present disturbing data on the direct impact of mining activities on the health and sovereignty and food security of the IPLCs. The creation of efficient laws, policies and guidelines for the control, mitigation, and reduction of impacts arising from mining activities will only be possible through the effective participation of IPLCs in decision-making environments.

2.6 REFERENCES

Adewumi, A.J., Laniyan, T.A., 2020. Contamination, sources and risk assessments of metals in media from Anka artisanal gold mining area, Northwest Nigeria. Sci. Total Environ. 718, 137–235. https://doi.org/10.1016/j.scitotenv.2020.137235

ANVISA (2013). Resolução RDC nº 42, de 29 de agosto de 2013. Agência Nacional de Vigilância Sanitária. [https://bvsms.saude.gov.br/bvs/saudelegis/anvisa/2013/rdc0042_29_08_2013.html]. (accessed 7.5.21).

Arao, T., Ishikawa, S., Murakami, M., Abe, K., Maejima, Y., Makino, T., 2010. Heavy metal contamination of agricultural soil and countermeasures in Japan. Paddy Water Environ. 8, 247–257. https://doi.org/10.1007/s10333-010-0205-7

Archer, M.J.G., Caldwell, R.A., 2004. Response of six Australian plant species to heavy metal contamination at an abandoned mine site. Water Air Soil Pollut. 157, 257–267. https://doi.org/10.1023/B:WATE.0000038900.66771.bf

Arquette, M., Cole, M., Cook, K., LaFrance, B., Peters, M., Ransom, J., Sargent, E., Smoke, V., Stairs, A. 2002. Holistic risk-based environmental decision making: A native perspective. Environ Health Persp 110:259–264.

Assis, C.C., 2021. Environmental Democracy and the Invisibles: Breaking the barriers of socio-environmental exclusion. Cad. Der. Act. 15, 352–365.

Avigliano, E., Lozano, C., Plá, R.R., Volpedo, A., 2016. Toxic element determination in fish from Paraná River Delta (Argentina) by neutron activation analysis: Tissue distribution and accumulation and health risk assessment by direct consumption. J. Food Compost. Anal. 54, 27–36. https://doi.org/10.1016/j.jfca.2016.09.011

Aznar-Sánchez, J.A., García-Gómez, J.J., Velasco-Muñoz, J.F., Carretero-Gómez, A., 2018. Mining waste and its sustainable management: Advances in worldwide research. Min. 8, 284–310. https://doi.org/10.3390/min8070284

Barbieri, F.L., Cournil, A., Gardon, J., 2009. Mercury exposure in a high fis eating Bolivian Amazonian population with intense small-scale gold-mining activities. Int. J. Environ. Health Res. 19, 267–277. https://doi.org/10.1080/09603120802559342

Barbosa, S.C.T., Costa, M.F., Barletta, M., Dantas, D.V., Kehrig, H.A., Malm, O., 2011. Total mercury in the fish trichiuruslepturus from a tropical estuary in relation to length, weight, and season. Neotrop. Ichthyol. 9, 183–190. https://doi.org/10.1590/S1679-62252011000100018

Barmao, K.J., Cherutoi, J.K., Mitei, C.Y., Were, M.L.L., Kiprop, A., Achieng', O.G., 2019. Assessment of Fluoride and selected heavy metals in food chain around Fluorspar mining Plant, Kenya. J. Environ. Manage. Public Saf. 8, 15–24. https://doi.org/10.15580/gjemps.2019.1.020919029

Bashwira, M.R., Cuvelier, J., 2019. Women, mining and power in southeastern Democratic Republic of Congo: The case of Kisengo. Extr. Ind. 6, 960–967. https://doi.org/10.1016/j.exis.2019.02.010

Basu, N., Horvat, M., Evers, D.C., Zastenskaya, I., Weihe, P., Tempowski, J., 2018. A state-of-the- Science review of mercury biomarkers in human populations worldwide between 2000 and 2018. Environ. Health Perspect. 126, 1–14. https://doi.org/10.1289/EHP3904

Batal, M., Chan, H.M., Fediuk, K., Ing, A., Berti, P.R., Mercille, G., Sadik, T., Johnson-Down, L., 2021. First Nations households living on-reserve experience food insecurity: prevalence and predictors among ninety-two First Nations communities across Canada. Am. J. Public Health 112, 52–63. https://doi.org/10.17269/s41997-021-00491-x

Beatrisse, A., Queiroz Guerra, R., Lucas, A., Mata, S., 2020. Acordo de Escazú: A incidência de um aparato internacional de proteção aos direitos humanos e ambientais na américa latina e caribe. Cad. Eletr. Dir. Int. Fron. 2, 1–32. https://doi.org/10.5281/zenodo.4292445

Benefice, E., Luna-Monrroy, S., Lopez-Rodriguez, R., 2010. Fishing activity, health characteristics and mercury exposure of Amerindian women living alongside the Beni River (Amazonian Bolivia). Int. J. Hyg. Environ. Health. 213, 458–464. https://doi.org/10.1016/j.ijheh.2010.08.010

Bhattacharya, P., Samal, A.C., Majumdar, J., Santra, S.C., 2010. Arsenic contamination in rice, wheat, pulses, and vegetables: A study in an arsenic affected area of West Bengal, India. Water Air Soil Pollut. 213, 3–13. https://doi.org/10.1007/s11270-010-0361-9

Blanco, G.D., Sühs, R.B., Brizola, E., Corrêa, P.F., Campos, M.L., Hanazaki, N., 2020. Invisible contaminants and food security in former coal mined areas of Santa Catarina, southern Brazil. J. Ethnobiol. Ethnomed. 16, 1–11. https://doi.org/10.21203/rs.2.19425/v1

Bortey-Sam, N., Nakayama, S.M.M., Ikenaka, Y., Akoto, O., Baidoo, E., Yohannes, Y.B., Mizukawa, H., Ishizuka, M., 2015. Human health risks from metals and metalloid via consumption of food animals near gold mines in Tarkwa, Ghana: Estimation of the daily intakes and target hazard quotients (THQs). Ecotoxicol. Environ. Saf. 111, 160–167. https://doi.org/10.1016/j.ecoenv.2014.09.008

Boudou, A., Maury-Brachet, R., Coquery, M., Durrieu, G., Cossa, D., 2005. Synergic effect of gold mining and damming on mercury contamination in fish. Environ. Sci. Technol. 39, 2448–2454. https://doi.org/10.1021/es049149r

Brisbois, B.W., Reschny, J., Fyfe, T.M., Harder, H.G., Parkes, M.W., Allison, S., Buse, C.G., Fumerton, R., Oke, B., 2019. Mapping research on resource extraction and health: A scoping review. Extr. Ind. 8, 250–259. https://doi.org/10.1016/j.exis.2018.10.017

Bui, A.T.K., Nguyen, H.T.H., Nguyen, M.N., Tran, T.H.T., Vu, T. v., Nguyen, C.H., Reynolds, H.L., 2016. Accumulation and potential health risks of cadmium, lead and arsenic in vegetables grown near mining sites in Northern Vietnam. Environ. Monit. Assess. 188. https://doi.org/10.1007/s10661-016-5535-5

Campos, M.L., Almeida, J.A., Souza, L.S., 2003. Avaliação de três áreas de solo construído após mineração de carvão a céu aberto em Lauro Müller, Santa Catarina. Rev. Bras. Cienc. Solo. 27, 1123–1137. https://doi.org/10.1590/s0100-06832003000600017

Candeias, C., Ávila, P., Coelho, P., Teixeira, J.P., 2019. Mining activities: Health impacts. Ency. Environ. Health. 415–435. https://doi.org/10.1016/B978-0-12-409548-9.11056-5

Candel, J.J.L., Biesbroek, R., 2018. Policy integration in the EU governance of global food security. Food Secur. 10, 195–209. https://doi.org/10.1007/S12571-017-0752-5

Castellares, R., Fouché, M., 2017. The Determinants of Social Conflicts in Mining Production Areas the Determinants of Social Conflicts in Mining Production Areas. Econpapers. 1–26.

Ceccatto, A.P.S., Testoni, M.C., Ignácio, A.R.A., Santos-Filho, M., Malm, O., Díez, S., 2016. Mercury distribution in organs of fish species and the associated risk in traditional subsistence villagers of the Pantanal wetland. Environ. Geochem. Health. 38, 713–722. https://doi.org/10.1007/s10653-015-9754-4

CEPAL (Comisión Económica para América Latina), 2020. El impacto del COVID-19 enlospueblos indígenas de América Latina-Abya Yala Entre lainvisibilización y laresistenciacolectiva. [https://www.cepal.org/sites/default/files/publication/files/46543/S2000817_es.pdf]. (accessed 7.5.21).

Chaoniruthisai, P., Punnakitikashem, P., Rajchamaha, K., 2018. Challenges and difficulties in the implementation of a food safety management system in Thailand: A survey of BRC certified food productions. Food Control. 93, 274–282. https://doi.org/10.1016/j.foodcont.2018.06.004

Chungu, D., Mwanza, A., Ng'andwe, P., Chungu, B.C., Maseka, K., 2019. Variation of heavy metal contamination between mushroom species in the Copperbelt province, Zambia: are the people at risk? J. Sci. Food Agric. 99, 3410–3416. https://doi.org/10.1002/jsfa.9558

Conceição, P., Conceição, C., Fuentes-Nieva, R., Horn-Phathanothai, L., Ngororano, A., 2011. Food Security and Human Development in Africa: Strategic Considerations and Directions for Further Research. African Develo. Rev. 23, 237–246. https://doi.org/10.1111/j.1467-8268.2011.00283.x

Conde, M., 2017. Resistance to mining: A review. Ecol. Econ. 132, 80–90. https://doi.org/10.1016/j.ecolecon.2016.08.025

Correia, J., Cesar, R., Marsico, E., Diniz, G.T.N., Zorro, M.C., Castilhos, Z., 2014. Mercury contamination in alligators (Melanosuchusniger) from Mamirauá Reservoir (Brazilian Amazon) and human health risk assessment. Environ. Sci. Pollut. Res. 21, 13522–13527. https://doi.org/10.1007/s11356-014-3282-0

Cortes-Ramirez, J., Naish, S., Sly, P.D., Jagals, P., 2018. Mortality and morbidity in populations in the vicinity of coal mining: A systematic review. BMC Public Health. 18, 721–734. https://doi.org/10.1186/s12889-018-5505-7

Ćwieląg-Drabek, M., Piekut, A., Gut, K., Grabowski, M., 2020. Risk of cadmium, lead and zinc exposure from consumption of vegetables produced in areas with mining and smelting past. Sci. Rep. 10, 1–9. https://doi.org/10.1038/s41598-020-60386-8

Diab, H.M., Alkahtani, M.A., Ahmed, A.S., Khalil, A.M., Alshehri, M.A., Ahmed, M.A.A., Rehan, I.F., Elmansi, A.A., Ahmed, A.E., 2020. Coexistence of diverse heavy metal pollution magnitudes: Health risk assessment of affected cattle and human population in some rural regions, Qena, Egypt. J. Adv. Vet. Anim. Res. 7, 345–359. https://doi.org/10.5455/JAVAR.2020.G428

Diaz, O.P., Arcos, R., Tapia, Y., Pastene, R., Velez, D., Devesa, V., Montoro, R., Aguilera, V., Becerra, M., 2015. Estimation of arsenic intake from drinking water and food (Raw and cooked) in a rural village of Northern Chile. urine as a biomarker of recent exposure. Int. J. Environ. Res. Public Health. 12, 5614–5633. https://doi.org/10.3390/ijerph120505614

Egler, S.G., Rodrigues-Filho, S., Villas-Bôas, R.C., Beinhoff, C., 2006. Evaluation of mercury pollution in cultivated and wild plants from two small communities of the Tapajós gold mining reserve, Pará State, Brazil. Sci. Total Environ. 368, 424–433. https://doi.org/10.1016/j.scitotenv.2005.09.037

EJatlas, 2021. Atlas of Environmental Justice. [https://ejatlas.org/]. (accessed 7.5.21).

Elhamri, H., Idrissi, L., Coquery, M., Azemard, S., elAbidi, A., Benlemlih, M., Saghi, M., Cubadda, F., 2007. Hair mercury levels in relation to fish consumption in a community of the Moroccan Mediterranean coast. Food Addit. Contam. 24, 1236–1246. https://doi.org/10.1080/02652030701329611

El-Sayed, E.-S., Khater, Z., El-Ayyat, M., Nasr, E.-S., 2011. Assessment of heavy metals in water, sediment and fish tissues, from, Sharkia province, Egypt. Egypt. J. Aquat. Biol. Fish. 15, 125–144. https://doi.org/10.21608/ejabf.2011.2097

EPI, 2020. Environmental Performance Index [https://epi.yale.edu/]. (accessed 7.5.21).

Ericsson, M., Löf, O., 2019. Mining's contribution to national economies between 1996 and 2016. Miner. Econ. 32, 223–250. https://doi.org/10.1007/s13563-019-00191-6

Fa, J.E., Watson, J.E.M., Leiper, I., Potapov, P., Evans, T.D., Burgess, N.D., Molnár, Z., Fernández-Llamazares, Á., Duncan, T., Wang, S., Austin, B.J., Jonas, H., Robinson, C.J., Malmer, P., Zander, K.K., Jackson, M. v., Ellis, E., Brondizio, E.S., Garnett, S.T., 2020. Importance of Indigenous Peoples' lands for the conservation of Intact Forest Landscapes. Front. Ecol. Environ. 18, 135–140. https://doi.org/10.1002/fee.2148

Fabrício, S.A., Ferreira, D.D.M., Borba, J.A., 2021. Panorama of Mariana and Brumadinho disasters: what do we know. Rev. Eletrôn. Adm. 27, 128–152. https://doi.org/10.1590/1413-2311.310.102806

FAO, 2018. State of Food and Agriculture in Africa: Future Prospects and Emerging. [https://www.fao.org/3/mv737en/MV737EN.pdf]. (accessed 7.5.21).

FAO, 2020. Food and Agriculture Organization of the United Nations. [http://www.fao.org/faolex/en/]. (accessed 7.5.21).

Feng, X., Li, P., Qiu, G., Wang, S., Li, G., Shang, L., Meng, B., Jiang, H., Bai, W., Li, Z., Fu, X., 2008. Human exposure to methylmercury through rice intake in mercury mining areas, Guizhou province, China. Environ. Sci. Technol. 42, 326–332. https://doi.org/10.1021/es071948x

Feng, Y., Wang, J., Bai, Z., Reading, L., 2019. Effects of surface coal mining and land reclamation on soil properties: A review. Earth-Sci. Rev. 191, 12–25. https://doi.org/10.1016/j.earscirev.2019.02.015

Fernández-Llamazares, Á., Garteizgogeascoa, M., Basu, N., Brondizio, E.S., Cabeza, M., Martínez-Alier, J., McElwee, P., Reyes-García, V., 2020. A State-of-the-Art Review of Indigenous Peoples and Environmental Pollution. Integr. Environ. Assess. Manag. 16, 324–341. https://doi.org/10.1002/ieam.4239

Ferrante, L., Fearnside, P.M., 2020. Brazil threatens Indigenous lands. Sci. 368, 481–482. https://doi.org/10.1126/Sci..abb6327

Flores-Ramírez, R., Berumen-Rodríguez, A.A., Martínez-Castillo, M.A., Alcántara-Quintana, L.E., Díaz-Barriga, F., Díaz de León-Martínez, L., 2021. A review of Environmental risks and vulnerability factors of indigenous populations from Latin America and the Caribbean in the face of the COVID-19. Glob. Public Health. 8, 975–999. https://doi.org/10.1080/17441692.2021.1923777

Gallego Ríos, S.E., Ramírez, C.M., López, B.E., Macías, S.M., Leal, J., Velásquez, C.M., 2018. Evaluation of Mercury, Lead, Arsenic, and Cadmium in Some Species of Fish in the Atrato River Delta, Gulf of Urabá, Colombian Caribbean. Water Air Soil Pollut. 229, 275–289. https://doi.org/10.1007/s11270-018-3933-8

Gallego Ríos, S.E., Ramírez, C.M., López, B.E., Macías, S.M., Leal, J., Velásquez, C.M., 2018. Evaluation of Mercury, Lead, Arsenic, and Cadmium in Some Species of Fish in the Atrato River Delta, Gulf of Urabá, Colombian Caribbean. Water Air Soil Pollut. 229. https://doi.org/10.1007/s11270-018-3933-8

Gammons, C.H., Slotton, D.G., Gerbrandt, B., Weight, W., Young, C.A., McNearny, R.L., Cámac, E., Calderón, R., Tapia, H., 2006. Mercury concentrations of fish, river water, and sediment in the Río Ramis-Lake Titicaca watershed, Peru. Sci. Total Environ. 368, 637–648. https://doi.org/10.1016/j.scitotenv.2005.09.076

Garrido, A.E., Strosnider, W.H.J., Wilson, R.T., Condori, J., Nairn, R.W., 2017. Metal-contaminated potato crops and potential human health risk in Bolivian mining highlands. Environ. Geochem. Health. 39, 681–700. https://doi.org/10.1007/s10653-017-9943-4

GFSI, 2020. Global Food Security Index [https://foodsecurityindex.eiu.com/]. (accessed 7.5.21).

Godoy, R.C.B., Deliza, R., Gheno, L.B., Licodiedoff, S., Frizon, C.N.T., Ribani, R.H., 2013. Consumer perceptions, attitudes and acceptance of new and traditional mate tea products. Int. Food Res. J. 53:801–817.

Golzadeh, N., Barst, B.D., Basu, N., Baker, J.M., Auger, J.C., McKinney, M.A., 2020. Evaluating the concentrations of total mercury, methylmercury, selenium, and selenium: mercury molar ratios in traditional foods of the Bigstone Cree in Alberta, Canada. Chemosphere. 250, 126285. https://doi.org/10.1016/j.chemosphere.2020.126285

Gomes, A.M., Hauser-davis, R.A., Nunes, A., Souza, D., Pierre, A., 2016. Metal phytoremediation: General strategies, genetically modified plants and applications in metal nanoparticle contamination. Ecotoxicol. Environ. Saf. 134, 133–147.

Guan, Y., Chu, C., Shao, C., Ju, M., Dai, E., 2017. Study of integrated risk regionalisation method for soil contamination in industrial and mining area. Ecol. Indic. 83, 260–270. https://doi.org/10.1016/j.ecolind.2017.08.003

Gworek, B., Bemowska-Kałabun, O., Kijeńska, M., Wrzosek-Jakubowska, J., 2016. Mercury in Marine and Oceanic Waters—a Review. Water Air Soil Pollut. 227, 1–19. https://doi.org/10.1007/S11270-016-3060-3

Habiba, G., Abebe, G., Bravo, A.G., Ermias, D., Staffan, Bishop, K., 2017. Mercury Human Exposure in Populations Living Around Lake Tana (Ethiopia). Biol. Trace Elem. Res. 175, 237–243. https://doi.org/10.1007/s12011-016-0745-9

Hanaceck, K., Kröger, M., Scheidel, A., Rojas, F., Martinez-Aliera, J. 2022. On thin ice – The Arctic commodity extraction frontier and environmental conflicts. Ecolog. Econ. 191, 1–15. https://doi.org/10.1016/j.ecolecon.2021.107247

Hanning, R.M., Sandhu, R., MacMillan, A., Moss, L., Tsuji, L.J.S., Nieboer, E., 2003. Impact on blood Pb levels of maternal and early infant feeding practices of First Nation Cree in the Mushkegowuk Territory of northern Ontario, Canada. J. Environ. Monit. 5, 241–245. https://doi.org/10.1039/b208220a

Hansen, M.D., Nøst, T.H., Heimstad, E.S., Evenset, A., Dudarev, A.A., Rautio, A., Myllynen, P., Dushkina, E. v., Jagodic, M., Christensen, G.N., Anda, E.E., Brustad, M., Sandanger, T.M., 2017. The impact of a Nickel-Copper smelter on concentrations of toxic elements in local wild food from the Norwegian, Finnish, and Russian border regions. Int. J. Environ. Res. Public Health. 14, 1–16. https://doi.org/10.3390/ijerph14070694

Hashim, R., Song, T.H., Muslim, N.Z.M., Yen, T.P., 2014. Determination of heavy metal levels in fishes from the lower reach of the kelantan river, Kelantan, Malaysia. Trop. Life Sci. Res. 25, 21–39.

Hastorf, C.A., Johannessen, S., 1993. Mudança política pré-hispânica e o papel do milho na região central dos Andes do Peru. Amer. Anthrop. 95, 115–138.

HDI, 2020. Human Development Index [http://hdr.undp.org/en/data]. (accessed 7.5.21).

Hinton, J., Veiga, M., Beinhoff, C., 2003. Women and artisanal mining: Gender roles and the road ahead. In The Socio-Economic Impacts of Artisanal and Small-Scale Mining in Developing Countries, edited by G Hilson and A Balkema. Netherlands: Swets Publishers. 1–29.

HMI, 2020. Heavy Metals Index [https://epi.yale.edu/epi-results/2020/component/hmt]. (accessed 7.5.21).

Hsu, A., Zomer, A., 2016. Environmental Performance Index. Electron. J. Stat. 1–5. https://doi.org/10.1002/9781118445112.STAT03789.PUB2

Hu, Y., Cheng, H., Tao, S., 2016. The Challenges and Solutions for Cadmium-contaminated Rice in China: A Critical Review. Environ. Int. 92–93, 515–532. https://doi.org/10.1016/j.envint.2016.04.042

ICMM, 2018. International Council on Mining and Metals [https://www.icmm.com/en-gb/research/social-performance/mci-4-2018]. (accessed 7.5.21).

Ikingura, J.R., Akagi, H., 1996. Monitoring of fish and human exposure to mercury due to gold mining in the Lake Victoria goldfields, Tanzania. Sci. Total Environ. 191, 59–68. https://doi.org/10.1016/0048-9697(96)05178-9

ICC-AK. Inuit Circumpolar Council-Alaska. 2015. Alaskan Inuit food security conceptual framework: How to assess the Arctic from an Inuit perspective. Anchorage (AK). 29 p.

Islam, M.S., Ahmed, M.K., Habibullah-Al-Mamun, M., 2015a. Metal speciation in soil and health risk due to vegetables consumption in Bangladesh. Environ. Monit. Assess. 187. https://doi.org/10.1007/s10661-015-4533-3

Islam, M.S., Ahmed, M.K., Raknuzzaman, M., Habibullah-Al-Mamun, M., Masunaga, S., 2015b. Metal Speciation in Sediment and Their Bioaccumulation in Fish Species of Three Urban Rivers in Bangladesh. Arch. Environ. Contam. Toxicol. 68, 92–106. https://doi.org/10.1007/s00244-014-0079-6

Ismail, B.S., Farihah, K., Khairiah, J., 2005. Bioaccumulation of heavy metals in vegetables from selected agricultural areas. Bull. Environ. Contam. Toxicol.74, 320–327. https://doi.org/10.1007/s00128-004-0587-6

IWGIA, 2021. The International Work Group for Indigenous Affairs [https://iwgia.org/en/]. (accessed 7.5.21).

Izraelov, M., Silber, J., 2019. An assessment of the global food security index. Food Secur. 11, 1135–1152. https://doi.org/10.1007/S12571-019-00941-Y

Javaid, S., Zaman, Q., Sultan, K., Riaz, U., Aslam, A., Sharif, S., Ehsan, N., Aslam, S., Jamil, A., Ibraheem, S., 2020. Heavy metals stress, mechanism, and remediation techniques in rice (Oryza sativa L.): A review. J. Pure Appl. Biosci. 9, 403-426. https://doi.org/10.19045/bspab.2020.90045

Jenkins, K., 2014. Women, mining, and development: An emerging research agenda. Extr. Ind. 1, 329–339. https://doi.org/10.1016/j.exis.2014.08.004

Juric, A.K., Batal, M., David, W., Sharp, D., Schwartz, H., Ing, A., Fediuk, K., Black, A., Tikhonov, C., Chan, L.H.M., 2017. A total diet study and probabilistic assessment risk assessment of dietary mercury exposure among First Nations living on-reserve in Ontario, Canada. Environ. Res. 158, 409–420. https://doi.org/10.1016/j.envres.2017.06.025

Kasozi, K.I., Hamira, Y., Zirintunda, G., Alsharif, K.F., Altalbawy, F.M.A., Ekou, J., Tamale, A., Matama, K., Ssempijja, F., Muyinda, R., Kawooya, F., Pius, T., Kisakye, H., Bogere, P., Matovu, H., Omadang, L., Etiang, P., Mbogua, J., Ochieng, J.J., Osuwat, L.O., Mujinya, R., Batiha, G.E.S., Otim, O., 2021. Descriptive Analysis of Heavy Metals Content of Beef from Eastern Uganda and Their Safety for Public Consumption. Front. Nutr. 8, 1–10. https://doi.org/10.3389/fnut.2021.592340

Kerfoot, W.C., Urban, N.R., McDonald, C.P., Zhang, H., Rossmann, R., Perlinger, J.A., Khan, T., Hendricks, A., Priyadarshini, M., Bolstad, M., 2018. Mining legacy across a wetland landscape: High mercury in Upper Peninsula (Michigan) rivers, lakes, and fish. Environ. al Science: Proc. Imp. 20, 708–733. https://doi.org/10.1039/c7em00521k

Khidkhan, K., Imsilp, K., Poapolathep, A., Poapolathep, S., Tanhan, P., 2017. Potential human health risk from consumption of metallic elements-contaminated benthic mollusks from Don Hoi Lot sandbar, Thailand. Sci. Total Environ. 584–585. https://doi.org/10.1016/j.scitotenv.2017.01.188

Kortei, N.K., Heymann, M.E., Essuman, E.K., Kpodo, F.M., Akonor, P.T., Lokpo, S.Y., Boadi, N.O., Ayim-Akonor, M., Tettey, C., 2020. Health risk assessment and levels of toxic metals in fishes (Oreochromis noliticus and Clariasanguillaris) from Ankobrah and Pra basins: Impact of illegal mining activities on food safety. Toxicol. Rep. 7, 360–369. https://doi.org/10.1016/j.toxrep.2020.02.011

Kortei, N.K., Heymann, M.E., Essuman, E.K., Kpodo, F.M., Akonor, P.T., Lokpo, S.Y., Boadi, N.O., Ayim-Akonor, M., Tettey, C., 2020. Health risk assessment and levels of toxic metals in fishes (Oreochromis noliticus and Clariasanguillaris) from Ankobrah and Pra basins: Impact of illegal mining activities on food safety. Toxicol. Rep. 7, 360–369. https://doi.org/10.1016/j.toxrep.2020.02.011

Kuhnlein, H. v., Chan, H.M., 2000. Enviroment and Contaminants in Traditional Food Systems of Northern Indigenous Peoples. Annu. Rev. Nutr. 20, 595–626. https://doi.org/10.1146/annurev.nutr.20.1.595

Kumar, A., Kumar, A., Cabral-Pinto, M., Chaturvedi, A.K., Shabnam, A.A., Subrahmanyam, G., Mondal, R., Gupta, D.K., Malyan, S.K., Kumar, S.S., Khan, S.A., Yadav, K.K., 2020. Lead toxicity: Health hazards, influence on food Chain, and sustainable remediation approaches. Int. J. Environ. Res. Public Health. 17, 21-79. https://doi.org/10.3390/ijerph17072179

Langeland, A.L., Hardin, R.D., Neitzel, R.L., 2017. Mercury levels in human hair and farmed fish near artisanal and small-scale gold mining communities in the madre de dios River Basin, Peru. Int. J. Environ. Res. Public Health. 14. https://doi.org/10.3390/ijerph14030302

Lauda-Rodriguez, Z.L., Ribeiro, W.C., 2019. Risk, precautionary principle, and environmental justice in mining conflicts. Desenvolv. Meio Ambiente. 51, 154–179. https://doi.org/10.5380/dma.v51i0.59821

Le, Q., Bach, L., Arai, T., 2015. Monitoring Heavy Metal Contamination Using Rocky Oyster (Saccostrea glomerata) in Haiphong-Halong Coastal Area, North Vietnam. Int. J. Environ. Res. 9, 1373–1378. https://doi.org/10.22059/ijer.2015.1031

Li, M.S., Yang, S.X., 2008. Heavy metal contamination in soils and phytoaccumulation in a manganese mine Wasteland, South China. Air Soil Water Res. 1, 31–41. https://doi.org/10.4137/aswr.s2041

Li, Y., Wang, Y. bin, Gou, X., Su, Y.B., Wang, G., 2006. Risk assessment of heavy metals in soils and vegetables around non-ferrous metals mining and smelting sites, Baiyin, China. J. Environ. Sci. 18, 1124–1134. https://doi.org/10.1016/S1001-0742(06)60050-8

Lino, A.S., Galvão, P.M.A., Longo, R.T.L., Azevedo-Silva, C.E., Dorneles, P.R., Torres, J.P.M., Malm, O., 2016. Metal bioaccumulation in consumed marine bivalves in Southeast Brazilian coast. J. Trace Elem. Med. Biol. 34, 50–55. https://doi.org/10.1016/j.jtemb.2015.12.004

Lino, A.S., Kasper, D., Guida, Y.S., Thomaz, J.R., Malm, O., 2018. Mercury and selenium in fishes from the Tapajós River in the Brazilian Amazon: An evaluation of human exposure. J. Trace Elem. Med. Biol. 48, 196–201. https://doi.org/10.1016/j.jtemb.2018.04.012

Liu, B., Ai, S., Zhang, W., Huang, D., Zhang, Y., 2017. Assessment of the bioavailability, bioaccessibility and transfer of heavy metals in the soil-grain-human systems near a mining and smelting area in NW China. Sci. Tot. Environ. 609, 822–829. https://doi.org/10.1016/j.scitotenv.2017.07.215

Liu, B., Ai, S., Zhang, W., Huang, D., Zhang, Y., 2017. Assessment of the bioavailability, bioaccessibility and transfer of heavy metals in the soil-grain-human systems near a mining and smelting area in NW China. Sci. Total Environ. 609, 822–829. https://doi.org/10.1016/j.scitotenv.2017.07.215

Liu, J., Zhang, X.H., Li, T.Y., Wu, Q.X., Jin, Z.J., 2014. Soil characteristics and heavy metal accumulation by native plants in a Mn mining area of Guangxi, South China. Environ. Monit. Assess. 186, 2269–2279. https://doi.org/10.1007/s10661-013-3535-2

Lizardi, N., Aguilar, M., Bravo, M., Fedorova, T.A., Neaman, A., 2020. Human Health Risk Assessment from the Consumption of Vegetables Grown near a Copper Smelter in Central Chile. J. Soil Sci. Plant Nutr. 20, 1472–1479. https://doi.org/10.1007/s42729-020-00226-w

Lv, X., Xiao, W., Zhao, Y., Zhang, W., Li, S., Sun, H., 2019. Drivers of spatio-temporal ecological vulnerability in an arid, coal mining region in Western China. Ecol. Indic. 106. https://doi.org/10.1016/j.ecolind.2019.105475

Lyver, P.O.B., Timoti, P., Davis, T., Tylianakis, J.M., 2019. Biocultural Hysteresis Inhibits Adaptation to Environmental Change. TrendsEcolEvol. 34, 771–780. https://doi.org/10.1016/j.tree.2019.04.002

Machado De Oliveira, C., Gesser Müller, T., Patricio Ferreira, L., Prado Cechinel, M.A., Peterson, M., Raupp-Pereira, F., 2019. Valorization of iron pyrite from coal mining in southern Brazil. J. Environ. Chem. Eng. 7, 102931. https://doi.org/10.1016/j.jece.2019.102931

Maharia, R.S., Dutta, R.K., Acharya, R., Reddy, A.V.R., 2010. Heavy metal bioaccumulation in selected medicinal plants collected from Khetri copper mines and comparison with those collected from fertile soil in Haridwar, India. J. Environ. Sci. Health - B Pestic. Food Contam. Agric. Wastes. 45, 174–181. https://doi.org/10.1080/03601230903472249

Marrugo-Negrete, J., Verbel, J.O., Ceballos, E.L., Benitez, L.N., 2008. Total mercury and methylmercury concentrations in fish from the Mojana region of Colombia. Environ. Geochem. Health. 30, 21–30. https://doi.org/10.1007/s10653-007-9104-2

Martínez-Alier, J., Temper, L., Bene, D.D., Scheidel, A. *et al.* 2016. Is there a global environmental justice movement? J. Peas. Stud. 731-755. https://doi.org/10.1080/03066150.2016.1141198

Md Yunus, S., Hamzah, Z., Ariffin, N.A.N., Muslim, M.B., 2014. Cadmium, chromium, copper, lead, ferum and zinc levels in the cockles (Anadaragranosa) from Kuala Selangor, Malaysia | Tahapkadmium, kromium, kuprum, plumbum, ferum dan zink di dalamkerang (Anadaragranosa) dari Kuala Selangor, Malaysia. Malaysian J. Anal. Sci. 18, 514–521.

Meharg, A.A., Williams, P.N., Adomako, E., Lawgali, Y.Y., Deacon, C., Villada, A., Cambell, R.C.J., Sun, G., Zhu, Y.G., Feldmann, J., Raab, A., Zhao, F.J., Islam, R., Hossain, S., Yanai, J., 2009. Geographical variation in total and inorganic arsenic content of polished (white) rice. Environ. Sci. Technol. 43, 1612–1617. https://doi.org/10.1021/es802612a

Menton, M., Milanez, F., Souza, J.M. de A., Cruz, F.S.M., 2021. The COVID-19 pandemic intensified resource conflicts and indigenous resistance in Brazil. World Dev. 138, 105222. https://doi.org/10.1016/J.WORLDDEV.2020.105222

Micheline, G., Rachida, C., Céline, M., Gaby, K., Rachid, A., Petru, J., 2019. Levels of Pb, Cd, Hg and As in Fishery Products from the Eastern Mediterranean and Human Health Risk Assessment due to their Consumption. Int. J. Environ. Res. 13, 443–455. https://doi.org/10.1007/S41742-019-00185-W

Moagi, L., 2016. Sulphur and heavy metals contents in soils and Grewia bicolor leaves around the SelibePikwe Cu-Ni mine (BCL), Botswana. J. Environ. Chem. Ecotox. 8, 73–81. https://doi.org/10.5897/jece2013.0306

Montcho, S.A., Koudouvo, K., Yehouenou, A.P.E., Guedenon, P., Koumolou, L., Sopoh, M.O., Dougnon, V., Gbéassor, M.F., Creppy, E.E., Boko, M., Edorh, A.P., 2014. Sanitary risks connected to the consumption of infusion from Senna rotundifolia L. contaminated with lead and cadmium in Cotonou (Benin). J. Toxicol. https://doi.org/10.1155/2014/376503

Morshdy, A.E.M.A., elBayomi, R.M., Abd El Galil, G.M., Mahmoud, A.F.A., 2018. Heavy metal concentrations and their risk assessment in marketed slaughtered animals in Sharkia Governorate, Egypt. Slov. Vet. Res. 55, 103–112. https://doi.org/10.26873/SVR-635-2018

Moslen, M., Miebaka, C.A., 2017. Concentration of Heavy Metals and Health Risk Assessment of Consumption of Fish (Sarotherodonmelanotheron) from an Estuarine Creek in the Niger Delta, Nigeria. J. Environ. Sci. Tox. Food Tech. 11, 68–73. https://doi.org/10.9790/2402-1103026873

Nawab, J., Khan, S., Shah, M.T., Qamar, Z., Din, I., Mahmood, Q., Gul, N., Huang, Q., 2015. Contamination of soil, medicinal, and fodder plants with lead and cadmium present in mine-affected areas, Northern Pakistan. Environ. Monit. Assess. 187. https://doi.org/10.1007/s10661-015-4807-9

Ngoc, N.T.M., Chuyen, N. van, Thao, N.T.T., Duc, N.Q., Trang, N.T.T., Binh, N.T.T., Sa, H.C., Tran, N.B., Ba, N. van, Khai, N. van, Son, H.A., Han, P. van, Wattenberg, E. v., Nakamura, H., Thuc, P. van, 2020. Chromium, Cadmium, Lead, and Arsenic Concentrations in Water, Vegetables, and Seafood Consumed in a Coastal Area in Northern Vietnam. Environ. Health Ins. https://doi.org/10.1177/1178630220921410

Ngoo, Y.T., Tey, N.P., 2019. Human Development Index as a Predictor of Life Satisfaction. J. Popul. Soc. Stud. 27, 70–86.

Ngure, V., Kinuthia, G., 2020. Health risk implications of lead, cadmium, zinc, and nickel for consumers of food items in Migori Gold mines, Kenya. J. Geochem. Explor. 209, 106430. https://doi.org/10.1016/j.gexplo.2019.106430

Ngure, V., Lelo, F., Obwanga, B., 2017. Heavy Metal Pollution from Migori Gold Mining Area, Kenya: Health Implications for Consumers of Fish and Water. J. Nat. Sci. Res. 7, 46–53.

Nguyen, N., Boruff, B., Tonts, M., 2018. Fool's gold: Understanding social, economic and Environ. al impacts from gold mining in Quang Nam province, Vietnam. Sustainability. 10. https://doi.org/10.3390/su10051355

Noubissié, E., Ngassoum, M.B., Ali, A., Castro-Georgi, J., Donard, O.F.X., 2016. Contamination of market garden soils by metals (Hg, Sn, Pb) and risk for vegetable consumers of Ngaoundéré (Cameroon). EuroMediterr J. Environ. Integr. https://doi.org/10.1007/s41207-016-0009-2

Nugraha, R.V., Ridwansyah, H., Ghozali, M., Khairani, A.F., Atik, N., 2020. Traditional Herbal Medicine Candidates as Complementary Treatments for COVID-19: A Review of Their Mechanisms, Pros and Cons. Evid. Complementary Altern. Med. 1–12. https://doi.org/10.1155/2020/2560645

Nyanza, E.C., Dewey, D., Thomas, D.S.K., Davey, M., Ngallaba, S.E., 2014. Spatial distribution of mercury and arsenic levels in water, soil, and cassava plants in a community with long history of gold mining in Tanzania. Bull. Environ. Contam. Toxicol. 93, 716–721. https://doi.org/10.1007/s00128-014-1315-5

Obiajunwa, E.I., Adebajo, A.C., Omobuwajo, O.R., 2002. Essential and trace element contents of some Nigerian medicinal plants. J. Radioanal. Nucl. Chem. 252, 473–476. https://doi.org/10.1023/A:1015838300859

Okem, A., 2014. Heavy metals in South African medicinal plants with reference to safety, efficacy, and quality. [https://ukzn-dspace.ukzn.ac.za/bitstream/handle/10413/12216/Okem_Ambrose_2014.pdf?sequence=1&isAllowed=y]. (accessed 7.5.21).

Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., Mcglinn, D., Minchin, P.R., O'hara, R.B., Simpson, G.L., Solymos, P., Henry, M., Stevens, H., Szoecs, E., Maintainer, H.W., 2020. Package "vegan" Title Community Ecology Package Version 2.5-7.

Oliveira, D.F., Bastos, W.R., Recktenval, M.C.N.N., Castro, B.S., Alves, C.L.M., Froehlich J.D., Sora G.T.S., Ott A.M.T., 2018. Risk Assessment to the Health of Amazonian Indigenous for the Consumption of Fish, Meat of Hunts and Vegetables Containing Metylmercury. Int. J. Adv. Eng. Res. Sci.5, 194–208. https://doi.org/10.22161/ijaers.5.9.23

Olivero-Verbel, J., Caballero-Gallardo, K., Torres-Fuentes, N., 2009. Assessment of mercury in muscle of fish from Cartagena Bay, a tropical estuary at the north of Colombia. Int. J. Environ. Health Res. 19, 343–355. https://doi.org/10.1080/09603120902749090

Olivero-Verbel, J., Johnson-Restrepo, B., Baldiris-Avila, R., Güette-Fernández, J., Magallanes-Carreazo, E., Vanegas-Ramírez, L., Kunihiko, N., 2008. Human and crab exposure to mercury in the Caribbean coastal shoreline of Colombia: Impact from an abandoned chlor-alkali plant. Environ. Int. 34, 476–482. https://doi.org/10.1016/j.envint.2007.10.009

Olivero-Verbel, J., Johnson-Restrepo, B., Mendoza-Marín, C., Paz-Martinez, R., Olivero-Verbel, R., 2004. Mercury in the aquatic Environ. of the village of Caimito at the Mojana Region, North of Colombia. Water Air Soil Pollut. 159, 409–420. https://doi.org/10.1023/B:WATE.0000049162.54404.76

OlumayowaOluwasola, H., Oluoye, O., Mohammad Bashir, S., Odewole, O.A., OnyekaAbugu, H., Akpomie, K.G., Kolade David, M., InumidunFagorite, V., Aishatu Umar, M., 2021. Geochemical and health risk assessment of heavy metals concentration in soils around Oke-Ere mining area in Kogi State, Nigeria. J. Environ. Anal. Chem. https://doi.org/10.1080/03067319.2020.1862817

Otero, X.L., Tierra, W., Atiaga, O., Guanoluisa, D., Nunes, L.M., Ferreira, T.O., Ruales, J., 2016. Arsenic in rice agrosystems (water, soil, and rice plants) in Guayas and Los Ríos provinces, Ecuador. Sci. Total Environ. 573, 778–787. https://doi.org/10.1016/j.scitotenv.2016.08.162

Passos, C.J.S., da Silva, D.S., Lemire, M., Fillion, M., Guimarães, J.R.D., Lucotte, M., Mergler, D., 2008. Daily mercury intake in fish-eating populations in the Brazilian Amazon. J. Exp. Sci. Environ. Epid. 18, 76–87. https://doi.org/10.1038/sj.jes.7500599

Patel, K.S., Shrivas, K., Brandt, R., Jakubowski, N., Corns, W., Hoffmann, P., 2005. Arsenic contamination in water, soil, sediment, and rice of central India. Environ. Geochem. Health. 27, 131–145. https://doi.org/10.1007/s10653-005-0120-9

Phimol, P., Visuthismajarn, P., Lin, C., Rukkur, S., 2017. Assessment of Arsenic Concentrations and Estimated Daily Intake of Arsenic from Rice (Oryza sativa) in Ron Phibun District, Southern Thailand. Int. J. Environ. Sci. Develop. 8, 517–520. https://doi.org/10.18178/ijesd.2017.8.7.1007

Plessl, C., Jandrisits, P., Krachler, R., Keppler, B.K., Jirsa, F., 2017. Heavy metals in the mallard Anas platyrhynchos from eastern Austria. Sci. Total Environ. 580, 670–676. https://doi.org/10.1016/j.scitotenv.2016.12.013

QGIS, 2017. QGIS Development Team [https://qgis.org/en/site/]. (accessed 7.5.21).

Rahman, M.A., Rahman, M.M., Reichman, S.M., Lim, R.P., Naidu, R., 2014. Heavy metals in Australian grown and imported rice and vegetables on sale in Australia: Health hazard. Ecotoxicol. Environ. Saf. 100, 53–60. https://doi.org/10.1016/j.ecoenv.2013.11.024

Rai, P.K., Lee, S.S., Zhang, M., Tsang, Y.F., Kim, K.H., 2019. Heavy metals in food crops: Health risks, fate, mechanisms, and management. Environ. Int. 125, 365–385. https://doi.org/10.1016/j.envint.2019.01.067

Ramos, A.R.A., Oliveira, K.A. de, Rodrigues, F. dos S., 2020. Mercury-Based Mining in Yanomami Indigenous Lands and Accountabilities. Ambiente Soc. 23, 1–22. https://doi.org/10.1590/1809-4422asoc20180326r2vu2020L5AO

Rasanathan, K., Posayanonda, T., Birmingham, M., Tangcharoensathien, V., 2012. Innovation and participation for healthy public policy: The first National Health Assembly in Thailand. Health Expect. 15, 87–96. https://doi.org/10.1111/j.1369-7625.2010.00656.x

Rehman, A., Liu, G., Yousaf, B., Zia-ur-Rehman, M., Ali, M.U., Rashid, M.S., Farooq, M.R., Javed, Z., 2020. Characterizing pollution indices and children health risk assessment of potentially toxic metal(oid)s in school dust of Lahore, Pakistan. Ecotoxicol. Environ. Saf. 190, 110059. https://doi.org/10.1016/J.ECOENV.2019.110059

Reyes-García, V., Fernández-Llamazares, Á., McElwee, P., Molnár, Z., Öllerer, K., Wilson, S.J., Brondizio, E.S., 2019. The contributions of Indigenous Peoples and local communities to ecological restoration. Restor. Ecol. 27, 3–8. https://doi.org/10.1111/REC.12894

Robert, P., 2016. Legal Assessment of Indigenous Peoples' Rights to Lands and Natural Resources over Transboundary Aquifers Contaminated by Mining Production within the Lake Titicaca Region. [https://strathprints.strath.ac.uk/68391/1/Robert_SCELG_2016_A_legal_assessment_of_indigenous_peoples_rights_to_lands_and_natural_resources.pdf]. (accessed 7.5.21).

Rodríguez González, S., Elena, X., Rojas, F., 2019. Evolution of the multidimensionality of food and nutritional safety (SAN) in the Latin American countries Costa Rica and Brazil: proposal for a system of indicators. [https://strathprints.strath.ac.uk/68391/1/Robert_SCELG_2016_A_legal_assessment_of_indigenous_peoples_rights_to_lands_and_natural_resources.pdf]. (accessed 7.5.21).

Rosli, M.N.R., Samat, S.B., Yasir, M.S., Yusof, M.F.M., 2018. Analysis of heavy metal accumulation in fish at terengganu coastal area, Malaysia. SainsMalays. 47, 1277–1283. https://doi.org/10.17576/jsm-2018-4706-24

Ruiz-Guzmán, J.A., Marrugo-Negrete, J.L., Díez, S., 2014. Human Exposure to Mercury Through Fish Consumption: Risk Assessment of Riverside Inhabitants of the Urrá Reservoir, Colombia. Hum. Ecol. Risk Assess. 20, 1151–1163. https://doi.org/10.1080/10807039.2013.862068

Russell, S., Sullivan, C.A., Reichelt-Brushett, A.J., 2015. Aboriginal consumption of estuarine food resources and potential implications for health through trace metal exposure; A study in Gumbaynggirr Country, Australia. PLoS ONE. 10, 1–17. https://doi.org/10.1371/journal.pone.0130689

Ryan, B., Martin, P., Iles, M., 2005. Uranium-series radionuclides in native fruits and vegetables of northern Australia. J. Radioanal. Nucl. Chem. 264, 407–412. https://doi.org/10.1007/s10967-005-0729-2

Samimi, A.J., Kashefi, A., Salatin, P., Lashkarizadeh, M., 2011. Environmental Performance and HDI: Evidence from Countries Around the World. J. Sci. Ind. Res. 10, 294–301.

Santasnachok, C., Kurniawan, W., Hinode, H., 2015. The use of synthesized zeolites from power plant rice husk ash obtained from Thailand as adsorbent for cadmium contamination removal from zinc mining. J. Environ. Chem. Engin. 3, 2115–2126. https://doi.org/10.1016/j.jece.2015.07.016

Santos, L.M.G. dos, Vicentini Neto, S.A., Iozzi, G., Jacob, S. do C., 2017. Arsenic, cadmium and lead concentrations in Yerba mate commercialized in Southern Brazil by inductively coupled plasma mass spectrometry. Cienc. Rural. 47. https://doi.org/10.1590/0103-8478cr20170202

Santos, M. dos, da Silva Júnior, F.M.R., Zurdo, D.V., Baisch, P.R.M., Muccillo-Baisch, A.L., Madrid, Y., 2019. Selenium and mercury concentration in drinking water and food samples from a coal mining area in Brazil. Environ. Sci. Pollut. Res. 15510–15517. https://doi.org/10.1007/s11356-019-04942-4

Schenone, N.F., Avigliano, E., Goessler, W., Fernández Cirelli, A., 2014. Toxic metals, trace and major elements determined by ICPMS in tissues of Parapimelodusvalenciennis and Prochiloduslineatus from Chascomus Lake, Argentina. Microchem. J. 112, 127–131. https://doi.org/10.1016/j.microc.2013.09.025

Schilling, J., Schilling-Vacaflor, A., Flemmer, R., Froese, R., 2020. A political ecology perspective on resource extraction and human security in Kenya, Bolivia, and Peru. Extr. Ind. Soc. https://doi.org/10.1016/j.exis.2020.10.009

Schmitt, C.J., Brumbaugh, W.G., May, T.W., 2007. Accumulation of metals in fish from lead-zinc mining areas of southeastern Missouri, USA. Ecotoxicol. Environ. Saf. 67, 14–30. https://doi.org/10.1016/j.ecoenv.2006.11.002

Schwartz, H., Marushka, L., Chan, H.M., Batal, M., Sadik, T., Ing, A., Fediuk, K., Tikhonov, C., 2021. Metals in the drinking water of First Nations across Canada. Am. J. Public Health. 112, 113–132. https://doi.org/10.17269/s41997-021-00497-5

Shafaqat, R., Muhammad, A., Yong, F.Q., Muhammad, S.O., Rehman, Z., Abbas, Z., Muhammad, F.H., 2017. Use of Maize (Zea mays L.) for phytomanagement of Cd-contaminated soils: a critical review. Environ. Geochem. Health. 39, 259–277. https://doi.org/10.1007/s10653-016-9826-0

Silva Brabo, E., de Oliveira Santos, E., Maura De Jesus, I., Fernando Silva Mascarenhas, A., de Freitas Faial, K., 2000. Mercury contamination of fish and exposures of an indigenous community in Para state, Brazil. Environ. Res. 84, 197–203. https://doi.org/10.1006/enrs.2000.4114

Sindayigaya, E., van Cauwenbergh, R., Robberecht, H., Deelstra, H., 1994. Copper, zinc, manganese, iron, lead, cadmium, mercury, and arsenic in fish from Lake Tanganyika, Burundi. Sci. Total Environ. 144, 103–115. https://doi.org/10.1016/0048-9697(94)90431-6

Smolders, A.J.P., Guerrero Hiza, M.A., van der Velde, G., Roelofs, J.G.M., 2002. Dynamics of discharge, sediment transport, heavy metal pollution and Sábalo (Prochiloduslineatus) catches in the lower Pilcomayo River (Bolivia). River Res. Appl. 18, 415–427. https://doi.org/10.1002/rra.690

Souza-Araujo, J., Giarrizzo, T., Lima, M.O., Souza, M.B.G., 2016. Mercury and methyl mercury in fishes from Bacajá River (Brazilian Amazon): evidence for bioaccumulation and biomagnification. J. fish bio. 89, 249–263. https://doi.org/10.1111/jfb.13027

Sudsandee, S., Tantrakarnapa, K., Tharnpoophasiam, P., Limpanont, Y., Mingkhwan, R., Worakhunpiset, S., 2017. Evaluating health risks posed by heavy metals to humans consuming blood cockles (Anadaragranosa) from the Upper Gulf of Thailand. Environ. Sci. Pollut. Res. 24, 14605–14615. https://doi.org/10.1007/s11356-017-9014-5

Suwatvitayakorn, P., Ko, M.S., Kim, K.W., Chanpiwat, P., 2020. Human health risk assessment of cadmium exposure through rice consumption in cadmium-contaminated areas of the Mae Tao sub-district, Tak, Thailand. Environ. Geochem. Health 42, 2331–2344. https://doi.org/10.1007/s10653-019-00410-7

Temper, L., Demaria, F., Scheidel, A., Bene, D., Martinez-Alier, J., 2018. The Global Environmental Justice Atlas (EJAtlas): ecological distribution conflicts as forces for sustainability. Sustain. Sci. https://doi.org/10.1007/s11625-018-0563-4

Tran, T.S., Dinh, V.C., Nguyen, T.A.H., Kim, K.W., 2020. Heavy metals and arsenic concentrations in water, agricultural soil, and rice in Ngan Son district, Bac Kan province, Vietnamo Title. J. Food Eng. 3, 270–282.

UNHCR, 2021. United Nations High Commissioner for Refugees [https://www.unhcr.org/]. (accessed 7.5.21).

United States Environmental Protection Agency, 2000. National Water Quality Inventory Report to Congress. [https://www.epa.gov/waterdata/national-water-quality-inventory-report-congress]. (accessed 7.5.21).

V Relatório Luz Da Sociedade Civil Da Agenda 2030 De Desenvolvimento Sustentável Brasil [https://brasilnaagenda2030.files.wordpress.com/2021/07/por_rl_2021_completo_vs_03_lowres.pdf]. (accessed 7.5.21).

Vega, C.M., Orellana, J.D.Y., Oliveira, M.W., Hacon, S.S., Basta, P.C., 2018. Human mercury exposure in yanomami indigenous villages from the Brazilian Amazon. Int. J. Environ. Res. Public Health. 15. https://doi.org/10.3390/ijerph15061051

Villén-Pérez, S., Mendes, P., Nóbrega, C., Gomes Córtes, L., de Marco, P., 2018. Mining code changes undermine biodiversity conservation in Brazil. Environ. Conserv. 45, 96–99. https://doi.org/10.1017/S0376892917000376

Villén-pérez, S., Moutinho, P., Nóbrega, C.C., Marco, P. de, 2020. Brazilian Amazon gold: indigenous land rights under risk. Elementa Sci. Anthropol. 8, 31.

WDMI, 2021. World Directory of Minorities and Indigenous Peoples [https://www.refworld.org/docid/49749d3bc.html]. (accessed 7.5.21).

Wegenast, T., Beck, J., 2019. Mining, rural livelihoods and food security: A disaggregated analysis of sub-Saharan Africa. World Dev. 130, 104921. https://doi.org/10.1016/j.worlddev.2020.104921

Wong, K.W., Yap, C.K., Yaacob, A., Nulit, R., Omar, H., Aris, A.Z., Sharifinia, M., Bakhtiari, A.R., Al-Shami, S.A., Saleem, M., Okamura, H., 2021. Bioaccumulation of zinc in edible tropical vegetables in Peninsular Malaysia and its human health risk assessment based on various ethnicities in Malaysia. Environ. Sci. Pollut. Res. https://doi.org/10.1007/s11356-021-13361-3

Yadav, A.K., Bhagat, R.B., Yadav, V., 2019. Does coal mining affect household food security? An empirical study of Dhanbad, India. Agric. Food Secur. 8. https://doi.org/10.1186/s40066-018-0244-7

Yamashita, Y., Omura, Y., Okazaki, E., 2005. Total mercury and methylmercury levels in commercially important fishes in Japan. Asian Fish. Sci. 71, 1029–1035. https://doi.org/10.1111/j.1444-2906.2005.01060.x

Yu, X., Khan, S., Khan, A., Tang, Y., Nunes, L.M., Yan, J., Ye, X., Li, G., 2020. Methyl mercury concentrations in seafood collected from Zhoushan Islands, Zhejiang, China, and their potential health risk for the fishing community: Capsule: Methyl mercury in seafood causes potential health risk. Environ. Int. 137, 105420. https://doi.org/10.1016/j.envint.2019.105420

Zhang, H., Feng, X., Larssen, T., Qiu, G., Vogt, R.D., 2010. In inland China, rice, rather than fish, is the major pathway for methylmercury exposure. Environ. Health Perspec. 118, 1183–1188. https://doi.org/10.1289/ehp.1001915

Zhao, F.J., Ma, Y., Zhu, Y.G., Tang, Z., McGrath, S.P., 2015. Soil contamination in China: Status, and mitigation strategies. Environ. Sci. Technol. 49, 750–759. https://doi.org/10.1021/es5047099

Zhuang, P., Lu, H., Li, Z., Zou, B., McBride, M.B., 2014. Multiple exposure and effects assessment of heavy metals in the population near mining area in South China. PLoS ONE. 9, 1–11. https://doi.org/10.1371/journal.pone.0094484

Zocche, J.J., Rohr, P., Damiani, A.P., Leffa, D.D., Martins, M.C., Zocche, C.M., Teixeira, K.O., Borges, G.D., de Jesus, M.M., dos Santos, C.E.I., Dias, J.F., de Andrade, V.M., 2017. Elemental composition of vegetables cultivated over coal-mining waste. An. Acad. Bras. Cienc. 89, 2383–2398. https://doi.org/10.1590/0001-3765201720170234

2.7 SUPLEMENTARY MATERIAL

Table S1: Keywords used in the research. Keywords used in the survey of articles regarding analysis of contaminated food consumed by IPLC in mining areas.

Keywords used
“Indigenous peoples mining and food sovereignty and security in COUNTRY” “Quilombola communities, mining and food security in COUNTRY” “Mining communities and Food Security in COUNTRY” “Indigenous peoples and food sovereignty and security” in COUNTRY” “Quilombola communities and food security in COUNTRY” “Traditional communities” OR “mining” “food security” "Ethnobotany" "Plants use" "Plants used" "Uses of plants" "Local Knowledge about plants" "Traditional Knowledge about plants" “Indigenous peoples mining” “food security” “COUNTRY” “Local communities”

Table S2: Social-environmental conflicts between mining companies and IPLC. Information on number of socio-environmental conflicts (Conflicts Number), articles number on IPLC food contamination information (References Number), and the main minerals extracted (Minerals) by country. INF: Information not found; *Atlas of Environmental Justice (EJAtlas, 2021); **Central Intelligence Agency (CIA, 2020).

Country	**Conflicts Number***	**Number of references**	**Minerals****
Algeria	0	0	Gold, zinc, copper, lead, uranium and phosphate
Angola	0	0	Diamond, iron, phosphate, feldspar, bauxite, uranium and gold
Argentina	31	2	Iron, uranium, lead, zinc, silver, copper, manganese and tungsten
Australia	5	4	Bauxite, iron ore, site, gold, lead, diamond, uranium and zinc
Austria	0	1	Iron
Bangladesh	7	3	Iron
Belgium	1	0	Diamond, pig iron and raw steel
Benin	1	1	Gold and iron
Bolivia	18	4	Tin, silver and iron
Botswana	1	1	Diamonds, copper, nickel, coal, iron and silver
Brazil	49	15	Iron, gold, bauxite, nickel and manganese
Bulgaria	5	0	Coal, silver, steel, zinc, copper and lead
Burundi	INF	1	Gold, copper, uranium, tungsten, nickel, tin, peat, platinum, limestone, vanadium, tantalum, niobium, kaolin and cobalt
Cameroon	0	1	Aluminum
Canada	12	7	Gold, coal, potsh, iron ore and copper^b
Chad	0	0	Gold, natron and uranium
Chile	27	2	Copper and lithium
China	33	10	Coal, iron, steel and aluminum
Colombia	25	7	Gold, coal, emeralds
Congo Dem. Rep.	3	0	Copper, cobalt, gold, diamonds, coltan, zinc, tin and tungsten
Cote d’Ivoire	0	0	Gold

Costa Rica	4	0	Bauxite and copper
Dominican Republic	5	0	Gold
Ecuador	14	2	Gold and silver
Egypt Arab Rep.	0	3	Gold, copper, silver, zinc, platinum
El Salvador	1	0	Gold and silver
Ethiopia	1	2	Gold, copper and platinum
Finland	1	1	Gold and platinum
Ghana	4	2	Aluminum
Guatemala	11	0	Uranium, nickel, coal, gold, silver, copper, iron ore and cobalt
Guinea	5	0	Bauxite and gold
Haiti	0	0	Bauxite, copper and gold
Honduras	6	0	Cadmium, cement, coal, copper, gold and gypsum
Hungary	1	0	Coal, perlite and bauxite
India	51	3	Diamond, iron and granite
Indonesia	14	0	Gold, coal, nickel and copper
Ireland	0	0	Zinc and lead
Japan	5	2	Lead, nickel, copper and zinc
Jordan	0	0	Phosphate
Kenya	4	3	Aluminum, steel and lead
Lao PDR	0	0	Copper, tin and gold
Madagascar	7	0	Ilmenite, sapphire, nickel and cobalt
Malawi	1	0	Coal and uranium
Malaysia	0	5	Copper, tin, bauxite and iron
Mexico	30	0	Gold, silver, copper and zinc
Morocco	0	1	Phosphate
Mozambique	0	1	Aluminum
Nepal	0	1	Iron, copper, lead, zinc, cobalto and nickel
Nicaragua	2	0	Gold
Niger	0	2	Uranium
Norway	2	0	Zinc, steel, copper, cobalt, cadmium and aluminum
Pakistan	1	1	Iron, low-quality coal, copper and limestone
Panama	4	0	Copper
Paraguay	1	0	Iron and manganese
Peru	40	2	Gold, copper, silver, iron ore, coal, zinc, phosphate and potassium

Philippines	25	0	Copper, nickel, silver, gold and cobalt
Russian Federation	8	0	Coal
South Africa	18	2	Coal, platinum, gold and diamonds
Sweden	5	0	Iron
Tanzania	2	3	Diamonds, gold and iron
Thailand	2	6	Coal, zinc, iron, gold and copper
Tunisia	0	0	Phosphate and ferrof
Uganda	1	1	Copper and cobalt
Ukraine	0	0	Coal, manganese, uranium, sulfur, potassium and nickel
United States	11	2	Coal, copper, lead, uranium, molybdenum, nickel, phosphates, silver, bauxite, gold, iron, mercury, zinc, potassium and tungsten
Uruguay	1	0	Gold
Vietnam	7	4	Coal
Zambia	2	1	Copper

Table S3: **Bibliographical survey of articles on food sovereignty and security of IPLC in mining areas**. The table presents information about the country where the work was carried out, which type of ore was extracted, the species that was analyzed and found trace elements, the trace element found in the species, and the reference of the article that found this result. INF: Information not found.

Country	**Mineral**	*Species*	**Popular name**	**Trace element**	**Article**
Argentina	Various minerals	*Prochilodus lineatus* (Valenciennes, 1837) *Parapimelodus valenciennes* (Lütken, 1874)		Various minerals	(Schenone *et al.*, 2014)
Argentina	Various minerals	*Odontesthes bonariensis* (Valenciennes, 1835) *Lycengraulis grossidens* (Spix & Agassiz, 1829)		As Co Fe Hg Zn	(Avigliano *et al.*, 2016)
Australia	Uranium mines	*Buchanania obovata Engl.*		Po Ra	(Ryan *et al.*, 2005)
		Persoonia falcote (R.Br.) Kuntze			
		Terminalia ferdinandiana Exell			
		Syzygium eucalyptoides (F. Muell.) B. Hyland			
		Ficus racemosa L.			
		Dioscorea bulbifera L.			
		Eriosema chinense Vogel			
		Dioscorea transversa R.Br.			
		Vigna lanceolata Benth.			
		Cartonema parviflorum Hassk.			
		Brachystelma glabriflorum (F. Muell.) Schltr.			
Australia	Various minerals	*Myxus elongatus* (Günther, 1861) *Saccostrea glomerata* (Gould, 1850)		As Zn Pb Cd Cu Se	(Russell *et al.*, 2015)
Australia	Iron	*Oryza* spp.		Cd Co Cr Cu Mn Ni Pb Zn	(Rahman *et al.*, 2014)
Australia	Silver	*Juncus usitatus* L.	Common Rush Spiny-Headed Mat Rush	Pb Cd	(Archer and Caldwell, 2004)
		Cynodon dactylon (L.) Pers.			
		Lomandra longifolia Labill. *Cynodon dactylon* (L.) Pers.	Couch		
		Pteridium esculentum (Kaulf.) Thomson			
		Acacia decurrens Willd.			
		Melaleuca alternifolia Cheel.			
Austria	Various minerals	*Anas platyrhynchos* (Linnaeus, 1758)		Cr Cu Zn Ag Cd Hg Pb	(Plessl *et al.*, 2017)
Bangladesh	Various minerals	*Oryza* spp.		As	(Meharg *et al.*, 2009)

Bangladesh	Pb	*Channa punctatus* (Bloch, 1793) *Heteropneustes fossilis* (Bloch, 1794) *Trichogaster fasciata* (Bloch & Schneider, 1801)		Cr Ni Pb Cu As Cd	(Islam *et al.*, 2015a)
Bangladesh	Various minerals	*Solanum melongena* L.	Green Ama-Ranth	Cr Ni Cu As Cd Pb	(Islam *et al.*, 2015b)
		Amaranthus hybridus L.	Red Amaranth		
		Amaranthus gangeticus L.	Bottle Gourd		
		Lagenaria siceraria L.	Tomato		
		Cucurbita maxima Duchesne			
		Solanum lycopersicum L.	Pumpkin		
		Capsicum annuum L.	Chili		
		Daucus carota L.	Carrot		
		Phaseolus vulgaris L.	Bean		
		Allium cepa L.	Onion		
		Solanum tuberosum L.	Potato		
		Lens culinaris Moench.	Lentil		
Benin	Various minerals	*Senna rotundifolia* Pers.		Pb Cd	(Montcho *et al.*, 2014)
Bolivia	Ag	*Potato tubers* L.		As Cd Pb Zn	(Garrido *et al.*, 2017)
Bolivia	Various minerals	*Musa paradisiaca* L. *Manihot esculenta* Crantz *Colossoma macropomum* (Cuvier, 1816) *Pseudoplatystoma fasciatum* (Linnaeus, 1776)		Hg	(Benefice *et al.*, 2010)
Bolivia	Gold	*Brycon* spp.		Hg	(Barbieri *et al.*, 2009)
Bolivia	Gold	*Prochilodus lineatus* (Valenciennes, 1837)		Hg	(Smolders *et al.*, 2002)
Botswana	Copper	*Grewia bicolor* Juss.		Cu Ni	(Moagi, 2016)
Brazil	Gold		Tucunaré Pacu Jaraqui Trairá Aarcu Matrichã Caratinga	Hg	(da Silva Brabo *et al.*, 2000)
Brazil	Gold	*Brassica oleracea* L. *Allium fistulosum* L. *Mangifera indica* L. *Anacardium occidentale* L. *Ipomea batatas* L. *Dioscorea cayenensis* Lam.		Hg	(Egler *et al.*, 2006)

Brazil	Gold	*Manihot esculenta* Crantz *Ageneiosus inermis* (Linnaeus, 1766) *Tocantinsia piresi* (Miranda Ribeiro, 1920) *Myloplus rubripinnis* (Müller & Troschel, 1844) *Myloplus rhomboidalis* (Cuvier, 1818) *Serrasalmus manueli* (Fernánde, Yépez & Ramírez, 1967) *Serrasalmus rhombeus* (Linnaeus, 1766) *Boulengerella cuvieri* (Spix & Agassiz, 1829) *Cynodontidae* *Hydrolycus armatus* (Jardine & Schomburgk, 1841) *Hydrolycus scomberoides* (Cuvier, 1819) *Hydrolycus tatauaia* (Toledo-Piza, Menezes & Santos, 1999) *Hoplierythrinus unitaeniatus* (Spix & Agassiz, 1829) Pimelodidae *Hemisorubim platyrhynchos* (Valenciennes, 1840) *Phractocephalus hemioliopterus* (Bloch & Schneider 1801) *Pimelodus blochii* (Valenciennes, 184) *Pimelodus ornatus* (Kner, 1858) *Pinirampus pirinampu* (Spix & Agassiz, 1829) *Pseudoplatystoma punctifer* (Castelnau, 1855) Prochilodontidae *Prochilodus nigricans* (Spix & Agassiz, 1829) *Semaprochilodus brama* (Valenciennes, 1850) Sciaenidae *Plagioscion* sp.		Hg Me-Hg	(Souza-Araujo *et al.*, 2016)
Brasil	Gold	*Melanosuchus niger* (Spix, 1825)		Hg	(Correia *et al.*, 2014)
Brasil	Coal		Beans Garlic Tomato Lettuce Orange Eggs Yolks	Se Hg	(Santos *et al.*, 2019)

			White		
Brasil	Gold	*Krobia guianensis* (Regan, 1905) *Triportheus rotundatus* (Jardine, 1841) *Sternopygus macrurus* (Bloch & Schneider, 1801) *Poptella brevispina* (Reis, 1989) *Pimelodella cristata* (Müller & Troschel, 1849) *Myleus ternetzi* (Norman, 1929) *Moenkhausia oligolepis* (Günther, 1864) *Leporinus lebaili* (Géry, J. & Planquette, P., 1983) *Leporinus friderici* (Bloch, 1794) *Hoplias aimara* (Valenciennes, 1847) *Bryconops melanurus* (Bloch, 1794) *Ancistrus hoplogenys* (Günther, 1864) *Acestrorhynchus guianensis* (Menezes, 1969)		Hg	(Boudou *et al.*, 2005)
Brasil	Gold	*Curimata cyprinoides* (Linnaeus, 1766) *Crenicichla lepidota* (Heckel, 1840) *Pygocentrus nattereri* (Kner, 1858) *Semaprochilodus insignis* (Jardine, 1841) *Schizodon vittatus* (Valenciennes, 1850) *Myleus schomburgki* (Jardine, 1841) *Leporinus friderici* (Bloch, 1794)		Hg	(Ceccatto *et al.*, 2016)
Brasil	Gold	Rhytides sp. *Geophagus proximus* (Castelnau, 1855) *Plagioscion squamosissimus* (Heckel, 1840) *Serrulatus calmoni* (Spix & Agassiz, 1829) *Psectrogaster rutiloides* (Kner, 1858) *Leiarius marmoratus* (Gill, 1870) *Hemigrammus marginatus* (Ellis, 1911) *Plagioscion squamosissimus* (Heckel, 1840) *Prochilodus nigricans* (Spix & Agassiz, 1829) *Hypophthalmus edentatus* (Spix, 1829)		Hg Se	(Lino *et al.*, 2018)

		Piaractus brachypomus (Cuvier, 1818) *Colossoma macropomum* (Cuvier, 1816) *Semaprochilodus taeniurus* (Valenciennes, 1817) *Salarias fasciatus* (Bloch, 1786) *Pseudoplatystoma fasciatum* (Linnaeus, 1776)		
Brasil	Coal	*Lactuca sativa* L. *Beta vulgaris* L. *Brassica oleracea* L. *Brassica oleracea* L.	Si P K Fe Zn	(Zocche *et al.*, 2017)
Brasil	Coal	*Ilex paraguariensis* St. Hil.	As Cd Pb	(Santos *et al.*, 2017)
Brasil	Gold	*Schizodon* sp. *Cichla monoculus* (Spix, 1831) *Plagioscion squamosissimus* (Heckel, 1840) *Cichla temensis* (Humboldt, 1821) *Curimata inornata* (Vari, 1989) *Liposarcus pardalis* (Castelnau, 1855) *Hemiodus unimaculatus* (Bloch, 1794) *Auchenipterus nuchali* (Spix & Agassiz, 1829) *Rhaphiodon vulpinus* (Spix & Agassiz, 1829) *Pseudoplatystoma* sp. *Pellona castelnaeana* (Valenciennes, 1847) *Prochilodus nigricans* (Spix & Agassiz, 1829) *Geophagus proximus* (Castelnau, 1855) *Mylossoma* sp. *Semaprochilodus insignis* (Jardine, 1841) *Pygocentrus* sp. *Pachypops furcraea* (Fowler, 1914)	Hg	(Passos *et al.*, 2008)
Brasil	Various minerals	*Trichiurus lepturus* (Linnaeus, 1758)	Hg	(Barbosa *et al.*, 2011)
Brasil	Various minerals	*Perna perna* (Linnaeus, 1758) *Nodipecten nodosus* (Linnaeus, 1758)	Zn Fe Cu Mn Cr Cd Ni Pb	(Lino *et al.*, 2016)
Brasil	Gold	*Pygocentrus nattereri* (Kner, 1858) *Pseudoplatystoma corruscans* (Spix & Agassiz, 1829)	Hg	(De. *et al.*, 2018)

Brasil	Gold	*Phractocephalus hemioliopterus* (Bloch & Schneider, 1801) *Serrasalmus marginatus* (Valenciennes, 1837) *Pinirampus pirinampu* (Spix & Agassiz, 1829) *Ageneiosus brevifilis* (Valenciennes, 1840) *Pseudoplatystoma fasciatum* (Linnaeus, 1776) *Zungaro jahu* (Ihering, 1898) *Cichla kelberi* (Kullander & Ferreira, 2006) *Acestrorhynchus falcirostris* (Cuvier, 1819) *Potamorhina altamazonica* (Cope, 1878) *Prochilodus nigricans* (Spix & Agassiz, 1829) *Callichthys callichthys* (Linnaeus, 1758) *Mylossoma aureum* (Agassiz, 1829) *Piaractus brachypomus* (Cuvier, 1818) *Leporinus friderici* *Colossoma macropomum* (Cuvier, 1818) *Brassica oleracea var. acephala* L. *Allium fistulosum* L. *Mangifera indica* L. *Anacardium occidentale* L. *Ipomea batatas* L. *Dioscorea cayenensis* L. *Manihot esculenta* Crantz Cyperaceae sp. Poaceae spp. *Hypolytrum* spp.	Hg	(Egler *et al.*, 2006)
Burundi	Various minerals	*Stolothrissa tanganyika* (Regan, 1917)	Cu Zn Mn Fe Pb Cd Hg As	(Sindayigaya *et al.*, 1994)
Camaron	Various minerals	*Amaranthus hybridus* L. *Corchorus olitorius* L. *Lactuca sativa* L.	Hg Sn Pb	(Noubissié *et al.*, 2016)
Canada	Various minerals	*Branta canadensis* (Linnaeus, 1758) *Salvelinus fontinalis* (Mitchill, 1814) *Coregonus artedi* (Lesueur, 1818) *Salvelinus namaycush (Walbaum, 1792)* *Exos lucius* (Linnaeus, 1758)	As Cd Pb Hg	(Kuhnlein and Chan, 2000)

		Coregonus clupeaformis (Mitchill, 1818) *Rangifer tarandus* (Linnaeus, 1758) *Alces alces* (Linnaeus, 1758) *Lota lota* (Linnaeus, 1758) *Delphinapterus leucas* (Pallas, 1776) *Zea mays* L. *Atriplex canescens* (Pursh) Nutt. *Salvelinus naresi* (Linnaeus, 1758) *Monodon monoceros* (Linnaeus, 1758) *Phoca hispida* (Schreber, 1775) *Stizostedion vitreum* (Mitchill, 1818) *Uria lomvia* (Linnaeus, 1758) *Chen canagica* (Sevastianov, 1802) *Esox lucius* (Linnaeus, 1758) *Catostomus catostomus* (Lesueur, 1817) *Salvelinus namaycush*			
Canada			Walrus species of seals Species of whales Several local fish species Artic Char Bearded Seal Beluga Cod Lake Trout Murre Mussels Walrus	Pb Hg Me-Hg	(Kuhnlein and Chan, 2000)
Canada	Pb		Milk	Pb	(Hanning *et al.*, 2003)
Canada	Various minerals		Fish Canned Fish Fresh Water Poultry Chicken Turkey Shellfish	MeHg	(Juric *et al.*, 2017)

Canada	Oil sands	Nymphaeaceae spp. *Rhododendron groenlandicum* (Oeder) Kron & Judd *Vaccinium vitis-idaea* L. *Vaccinium* spp. *Rosa canina* L. *Viburnum trilobum* Marshall *Cornus canadensis* L. *Cyanococcus* spp. *Vaccinium oxycoccos* L. *Amelanchier alnifolia* (Nutt.) Nutt. *Acorus calamus* L. *Sorbus aucuparia* L. *Mentha* spp. *Usnea* spp. *Coregoninae clupeaformis* (Mitchill, 1818) *Anas platyrhynchos* (Linnaeus, 1758) *Bonasa umbellus* (Linnaeus, 1758) *Falcipennis canadensis* (Linnaeus, 1758) *Lepus americanus* (Erxleben, 1777) *Alces alces* (Linnaeus, 1758) *Ursus americanos* (Linnaeus, 1758)	Whitefish Caribou Meat Pickerel-Walleye Canada Goose	Hg MeHg Se	(Golzadeh *et al.*, 2020)
Chile	Iron		Rice Tomatoes Lettuce Quinoa	As	(Diaz *et al.*, 2015)
Chile	Various minerals		Lettuce Chard Cabbage Potato Carrot Beetroot	As	(Lizardi *et al.*, 2020)
China	Non-ferrous metals mining	*Cucumis sativus* L. *Lagenaria siceraria* (Mol.) Standi. *Capsicum annuum* L. *Solanum melongena* L. *Brassica oleracea* var. *capitata* L.		Cu Zn As Cd Pb Cr	(Li *et al.*, 2006)

China	Coal	*Brassica campestris var. olegera* L. *Spinacia oleracea* L. *Brassica pekinensis* Lour. *Schima superba* Gardner & Champ. *Pinus massoniana* Lamb. *Imperata cylindrica* (L.) P. Beauv. *Solanum nigrum* L. *Amaranthus tricolor* L. *Prunus persica* L. *Castanea molíssima* Blume *Erigeron acer* L. *Panicum repens* L. *Prunus persica* L. *Phytolacca acinosa* L. *Imperata cylindrica* (L.) P. Beauv. *Hedyotis auricularia* L.		Mn Pb Zn Cu Cr Cd	(Li and Yang, 2008)
China	Coal		Rice Grain Chicken Bean	Cd Oh Cu Zn	(Zhuang *et al.*, 2014)
China	Mn	*Miscanthus floridulus* *Erigeron acer* L. *Paspalum orbiculare* G. Forst. *Pteris vittata* L. *Kummerowia striata* (Thunberg) Schindler *Polygonum perfoliatum* L. *Polygonum pubescens* Blume *Dicranopteris linearis* (Burm.f.) Underw. *Solanum nigrum* L. *Eleusina indica* (L.) Gaertn. *Glycine soja* (Soybean) Oil *Celosia argentea* L. *Camellia oleífera* C. Abel		Mn Cr Cd Zn Pb Cu	(Liu *et al.*, 2014)
China	Various minerals		Rice	Cd	(Zhao *et al.*, 2015)
China	Various minerals		Rice	Cd	(Hu *et al.*, 2016)
China	Copper		Spring Wheat Maize Rice	Cd Cu Pb Zn Cr Ni	(Liu *et al.*, 2017)
China	Coal	*Pseudosciaena crocea* (Richardson, 1846) *Larimichthys polyactis* (Bleeker, 1877)		MeHg	(Yu *et al.*, 2020)

		Trichiurus japonicus (Temminck & Schlegel, 1844) *Metasepia pfefferi* (Hoyle, 1885) *Scomberomorus niphonius* (Cuvier and Valenciennes, 1832) *Muraenesox cinereus* (Forsskål, 1775) *Scomber japonicus* (Linnaeus, 1758) *Navodon septentrionalis* (Linnaeus, 1758) *Portunus trituberculatus* (Miers, 1876) *Bullacta exarata* (Linnaeus, 1758) *Loligo chinensis* (Gray, 1849) *Ruditapes philippinarum* (Linnaeus, 1758)			
China	Zn		Rice Corn Fish Meat	Hg MeHg	(Zhang *et al.*, 2010)
China	Hg		Rice	MeHg	(Feng *et al.*, 2008)
Colombia	Hg	*Callinectes sapidus* (Rathbun, 1896) *Callinectes bocourti* (A. Milne-Edwards, 1879)		Hg	(Olivero-Verbel *et al.*, 2008)
Colombia	Gold	*Hoplias malabaricus* (Bloch, 1794) *Ageneiosus pardalis* (Lütken, 1874) *Pimelodus blochii* (Steindachner, 1879) *Prochilodus magdalenae* (Steindachner, 1879)		Hg	(Ruiz-Guzmán *et al.*, 2014)
Colombia	Various minerals	*Prochilodus magdalenae* (Steindachner, 1879)		Hg	(Olivero-Verbel *et al.*, 2004)
Colombia	Gold	*Caquetaia kraussii* (Steindachner, 1878) *Hoplias malabaricus* (Bloch, 1794) *Plagioscion surinamensis* (Bleeker, 1873)		Hg	(Marrugo-Negrete *et al.*, 2008)
Colombia	Various minerals	*Centropomus undecimalis* (Bloch, 1792) *Caranx hippos* (Linnaeus, 1766) *Scomberomorus brasiliensis* (Collette, Russo & Zavala-Camin, 1978) *Lutjanus purpureus* (Cuvier, 1828) *Caranx crysos* (Mitchill, 1815)		Fe Cd As Hg	(Gallego Ríos *et al.*, 2018)

Colombia	Gold	*Megalops atlanticus* (Valenciennes, 1847) *Elops saurus* (Linnaeus, 1766) *Epinephelus itajara* (Lichtenstein, 1822) *Prochilodus reticulatus* (Valenciennes, 1850) *Triportheus magdalena* (Steindachner, 1878) *Curimata magdalenae* (Steindachner, 1878) *Petenia kraussii* (Steindachner, 1878) *Aequidens pulcher* (Gill, 185) *Plagioscion surinamensis* (Bleeker, 1873) *Hoplias malabaricus* (Bloch, 1794)		Hg	(Ramos *et al.*, 2020)
Colombia	Gold	*Chloroscombrus chrysurus* (Linnaeus, 1766) *Salmão Corvinata* (Linnaeus, 1758) *Hipopótamos Caranx* (Linnaeus, 1766) *Lutjanus synagris* (Linnaeus, 1758) *Centropomus undecimalis* (Bloch, 1792) *Trichiurus lepturus* (Linnaeus, 1758) *Dactylopterus volitans* (Linnaeus, 1758) *Gerres cinereus* (Walbaum, 1792) *Elops saurus* (Linnaeus, 1758) *Eugerres plumieri* (Cuvier, 1830) *Haemulon steindachneri* (Jordan & Gilbert, 1882) *Oligoplites saliens* (Linnaeus, 1758) *Sciades herzbergii* (Bloch, 1794) *Triportheus magdalenae* (Steindachner, 1878) *Archosargus rhomboidalis* (Linnaeus, 1758) *Mugil cephalus* (Linnaeus, 1758)		Hg	(Olivero-Verbel *et al.*, 2009)
Ecuador	Various minerals		Rice	As	(Otero *et al.*, 2016)
Ecuador	Various minerals		Rice	As	(Angélica *et al.*, 2016)
Egypt Arab Rep.	Various minerals	*Oreochromis niloticus* (Linnaeus 1758) *Clarias gariepinus* (Burchell, 1822) *Bagrus bayad* (Bosc, 1816)		Zn Co Fe Co Cd Al MgNi Co	(El-Sayed *et al.*, 2011)

Egypt Arab Rep.	Gold		Milk	Al As NiPb Cd	(Diab *et al.*, 2020)
Egypt Arab Rep.	lead, cadmium, mercury		Buffalo Sheep	Co Zn	(Morshdy *et al.*, 2018)
Ethiopia	Various minerals	*Oreochromis niloticus* (Linnaeus 1758) *Clarias gariepinus* (Burchell, 1822)		Zn Cd Co Cu Fe Mn Ni Pb	
Ethiopia	Various minerals	*Labeobarbus intermedius* (Rüppell, 1835) *Clarias gariepinus* (Burchell, 1822) *Oreochromis niloticus* (Linnaeus 1758)		Hg	(Habiba *et al.*, 2017)
Finland	Ni, Cu	*Vaccínium myrtíllus* L. *Vaccinium vítis-idaea* L. *Rubus chamaemorus* L. *Empetrum nigrum* L. *Vaccínium uliginósum* L. *Leccinum versipelle* L. *Leccinum aurantiacum* (Bull. ex St. Amans) *Leccinum scabrum* (Bull.) Gray (1821) *Cortinarius caperatus* (Pers.) Fr. (1838) *Lactarius rufus* (Scop.) Fr. *Lactarius torminosus* (Schaeff.) Gray (1821) *Lactarius resimus* (Fr.) Fr. (1838) *Russulaceae* *Coregonus lavaretus* (Linnaeus, 1758) *Perca fluviatilis* (Linnaeus, 1758) *Esox Lucius* (Linnaeus, 1758) *Salvelinus alpinus* (Linnaeus, 1758) *Salmo trutta* (Linnaeus, 1758) *Rangifer tarandus* (Linnaeus, 1758) *Alces alces Alces alces* *Lagopus lagopus* (Linnaeus, 1758)		Ni Cu C As Pb Cd Hg	(Hansen *et al.*, 2017)
Ghana	Gold	*Oreochromis niliticus* (Linnaeus, 1758) *Clarias anguillaris* (Linnaeus, 1758)		Hg Pb Cd As	(Kortei *et al.*, 2020)
Ghana	Various minerals		Free-Range Chicken Goat Sheep	Cr Mn Fe Co Ni Cu	(Bortey-Sam *et al.*, 2015)

				Zn As Cd Pb	
India	Various minerals		Rice Grain Wheat Pea Lentil Mustard Seed Potato Tuber Cauliflower Onion Bulb Brinjal Spinach Bitter Gourd Garlic Radish Green Chili Arum Amaranth Cabbage Papaya Lady's Finger Pumpkin Beans Tomato Lemon Turmeric	As	(Bhattacharya *et al.*, 2010)
India	Various minerals	*Ocimum sanctum* L. *Cassia fistula* L. *Withania somnifera* Dunal *Azadirachta Indica* A. Juss *Aloe barbadensis* (L.) Burm.f *Azadirachta Indica* A. Juss *Withania somnifera* Dunal (WS)		Fe Co Cu Zn Se Cr Ni Cd As Pb	(Maharia *et al.*, 2010)
India	As		Rice	Mg Al Si K Ca Cr Mn Fe Co Ni Cu Zn As Ga Zr Sn Sb Pb	(Patel *et al.*, 2005)
Japan	Cd		Rice	Cd	(Arao *et al.*, 2010)
Japan	Hg	*Beryx splendens* (Lowe, 1834) *Thunnus thynnus* (Linnaeus, 1758) *Thunnus maccoyii* (Castelnau, 1872) *Thunnus obesus* (Lowe, 1839)		MeHg Hg	(Yamashita *et al.*, 2005)

		Makaira nigricans (Lacepède, 1802) *Tetrapturus audax* (Philippi, 1887) *Xiphias gladius* (Linnaeus, 1758) *Katsuwonus pelamis* (Linnaeus, 1758) *Platycephalus indicus* (Linnaeus, 1758) *Sillago japonica* (Linnaeus, 1758) *Trachurus japonicus* (Temminck & Schlegel, 1846) *Sardinops melanostictus* (Temminck & Schlegel, 1846) *Engraulis japonicus* (Linnaeus, 1758) *Engraulis japonicus* (Linnaeus, 1758) *Plecoglossus altivelis* (Temminck & Schlegel, 1846) *Oncorhynchus nerka* (Artedi, 1792) *Dissostichus eleginoides* (Temminck & Schlegel, 1846) *Thunnus maccoyii* (Castelnau, 1872) *Thunnus thynnus* (Linnaeus, 1758) *Thunnus albacares* (Bonnaterre, 1788) *Thunnus obesus* (Lowe, 1839) *Theragra chalcogramma* (Pallas, 1814) *Loligo bleekeri* (Keferstein, 1866) *Paralithodes camtschaticus* (Tilesius, 1815)			
Kenya	Various minerals	*Rastrineobola argentea* (Pellegrin, 1904)		As Hg Cd Pb Cr Cu	(Ngure *et al.*, 2017)
Kenya	Gold		Leaves Grass Corn Maize	Cr Cd Zn Pb	(Barmao *et al.*, 2019)
Kenya	Gold		Maize Cabbages Mangoes Potatoes	Cr Cd Zn Pb	(Ngure and Kinuthia, 2020)
Malaysia	Zn	*Abelmoschus esculentus* L. *Amaranthus tricolor* L. *Brassica rapa* L. *Capsicum annuum* L. *Cucurbita moschata* Duchesne ex Poir. *Ipomoea batatas* L.		Zn	(Wong *et al.*, 2021)

		Lagenaria siceraria (Molina) Standl. *Luffa acutangula* *Momordica charantia* L. *Solanum melongena* L. *Trichosanthes celebica* Cogn. *Vigna sinensis* (L.) Walp *Sauropus androgynus* (L.) Merr. *Luffa aegyptiaca* (L.) M. Roem. *Allium cepa* L. *Amaranthus viridis* L. *Lactuca sativa* L. *Ipomoea aquatica* Forssk.		
Malaysia	Various minerals	*Solanum melongena* L. *Allium cepa* L. *Ipomoea batatas* L.	Cr Cd Zn Pb	(Ismail *et al.*, 2005)
Malaysia	Gold	*Selaroides leptolepis* (Cuvier 1833) *Decapterus maruadsi* (Temminck & Schlegel, 1843) *Epinephelus lanceolatus* (Bloch, 1790) *Priacanthus tayenus* (Richardson, 1846) *Megalaspis cordyla* (Linnaeus, 1758) *Nibea soldado* (Lacepède, 1802) *Pristipomoides filamentosus* (Valenciennes 1830) *Siganus canaliculatus* (Park, 1797)	Cd Cu Fe Mn Pb Zn	(Rosli *et al.*, 2018)
Malaysia	Various minerals	*Anadara granosa* (Linnaeus, 1758)	Cd Cr Cu Pb Fe Zn	(Md Yunus *et al.*, 2014)
Malaysia	Various minerals	*Barbonymus gonionotus* (Bleeker, 1849) *Barbonymus schwanenfeldii* (Bleeker, 1854) *Cyclocheilichthys apogon* (Valenciennes 1842) *Hampala macrolepidota* (Kuhl & Van Hasselt, 1823) *Puntioplites bulu* (Bleeker 1851) *Thasselti achysurus* (Linnaeus, 1758) *Hemibagrus wyckii* (Bleeker, 1858) *Hemibagrus nemurus* (Valenciennes 1842) *Chitala chitala* (Hamilton, 1822) *Notopterus notopterus* (Pallas, 1769)	Cd Ni Pb	(Hashim *et al.*, 2014)

Morocco	Hg	*Pangasius micronemusda* (Valenciennes 1842) *Sardina pilchardus* (Walbaum, 1792) *Mugil cephalus* (Linnaeus, 1758) *Merluccius merlucci* (Linnaeus, 1758)	MeHg	(Elhamri *et al.*, 2007)
Niger	Various minerals	*Sarotherodon melanotheron* (Rüppell, 1852)	Cr Ni Cu Pb Ag Cd	(Moslen and Miebaka, 2017)
Niger	Various minerals	*Acalypha wilkesiana* L. *Aframomum melegueta* (L.) K. Schum. *Alchornea cordifolia* Müll.Arg. *Azadirachta indica* A. Juss. *Calotropis procera* (Aiton) W. T. Aiton *Cassia alata* (L.) Roxb. *Chromolaena odorata* (L.) R. M. King & H. Rob. *Citrus aurantifolia* (Christm.) Swingle *Eugenia uniflora* L. *Euphorbia hirta* L. *Cyclosorus afer* L. *Ficus exasperata* Vahl. *Garcinia kola* L. *Laportea aestuans* (L.) Chew. *Mangifera indica* L. *Momordica charantia* L. *Ocimum gratissimum* L. *Spondias mombin* L. *Zingiber officinale* Roscoe	K Ca Cr Mn Fe Ni Cu Zn Se Br Rb	(Obiajunwa *et al.*, 2002)
Pakistan	Cr	*Zanthoxylum armatum* DC. *Solanum xanthocarpum* L. *Plantago lanceolata* L.	Pb Cd	(Nawab *et al.*, 2015)
Peru	Gold	*Piaractus brachypomus* (Cuvier, 1818)	Hg	(Langeland *et al.*, 2017)
Peru	Gold	*Basilichthyes bonariensis* (Valenciennes, 1835) *Orestias* sp.	Hg	(Gammons *et al.*, 2006)
South Africa	Various minerals	*Adenia gummifera* (Harv.) Harms. *Alepidea amatymbica* Eckl. & Zeyh *Bulbine natalenses* (Harv.) Harms. *Drimia elata* Jacq. ex Willd. *Cassine transvaalensis* (Burtt Davy) Codd.	Cr Cu Fe Mn Ni Zn	(Okem, 2014)

		Hypoxis hemerocallidea Fisch.Mey. & Avé-Lall. *Lycopodium clavatum* L. *Momordica foetida* Schumach. *Ocotea bullata* (Burch.) E. Mey. *Rapanea melanophloeos* (L.) R.Br. *Schizocarphus nervosus* Burch.			
Tanzania	Gold	*Oreochromis niloticus* (Linnaeus 1758) *Tilapia zillii* (Gervais, 1878) *Protopterus aethiopicus* (Heckel, 1851) *Lates niloticus* (Linnaeus, 1758)		Hg	(Ikingura and Akagi, 1996)
Tanzania	Gold	*Manihot esculenta* Crantz.		As Hg Cd Pb Cr Cu	(Nyanza *et al.*, 2014)
Thailand	As	*Solen corneus* (Lamarck, 1818) *Meretrix meretrix* (Linnaeus, 1758)	Rice	As	(Nguyen *et al.*, 2018)
Thailand	Various minerals			Cd Cu Fe Mn Ni Pb Zn	(Khidkhan *et al.*, 2017)
Thailand	As	*Oryza sativa* L.		As	(Phimol *et al.*, 2017)
Thailand	Various minerals	*Anadara granosa* (Linnaeus, 1758)		Cd Cr Cu Hg Mn Ni Pb Zn	(Sudsandee *et al.*, 2017)
Thailand	Cd		Rice	Cd	(Suwatvitayakorn *et al.*, 2020)
Thailand	Zn		Rice	Cd	(Santasnachok *et al.*, 2015)
Uganda	Various minerals		Meet	Cu Co Fe Zn Pb Cr Ni	(Kasozi *et al.*, 2021)
United States	chumbo-zinco	*Campostoma oligolepis* (Hubbs & Greene, 1935) *Lepomis megalotis* (Rafinesque, 1820) *Hypentelium nigricans* (Lesueur, 1817)		Pb Zn	(Schmitt *et al.*, 2007)
United States	Copper and iron	*Sander vitreus* (Mitchill, 1818) *Micropterus dolomieu* (Lacepède 1802) *Ambloplites rupestris* (Rafinesque, 1817) *Esoxlucius* sp.		Hg	(Kerfoot *et al.*, 2018)

Vietnam	Various minerals		Rice	As	(Ngoc *et al.*, 2020)
Vietnam		*Saccostrea glomerata* (Gould, 1850)		As Cd Cr Cu Pb Zn	(Le *et al.*, 2015)
Vietnam	As	*Brassica juncea* (L.) Czern. *Brassica oleracea* L. *Benincasa hispida* (Thunb.) Cogn. *Centella asiatica* (L.) Urban. *Sauropus androgynus* (L.) Merr. *Ipomoea aquatica* L. *Brassica integrifolia* (H. West) O. E. Schulz *Phaseolus vulgaris* L. *Apium graveolens* L. *Basella alba* L. *Allium ascalonicum* L. *Brassica oleracea* L. *Lactuca sativa* L. *Ipomoea batatas* L. *Brassica oleracea* L. *Artemisia vulgaris* L. *Perilla frutescens* (L.) Britton. *Portulaca oleracea* (L.) DC. *Amaranthus tricolor* L. *Indian sorrel* L. *Oxalis corniculata* L.		Cd Pb As	(Bui *et al.*, 2016)
Vietnam	Various minerals		Rice	As Cd Cu Pb Ni Zn	(Tran *et al.*, 2020)
Zambia	Various minerals	*Amanita miomboensis* Pegler & Shah-Smith *Amanita loosei* (L.) Lam. *Corrugatus corrugatus* (Lamarck, 1819) *Lactarius edulis* *Lactarius kabansus* (Pegler & Piearce 1980) *Lactifluus rubiginosus* (Verbeken 2012) *Macrolepiota dolichaula* (Scop.) Singer (1948) *Riccia albofloccosa* L. *Riccia ciliata* Steph. *Riccia congoana* Steph. *Termitomyces clypeatus* Heim		Cu Zn Mn Ni Fe Co Pb	(Chungu *et al.*, 2019)

3 CHAPTER 2: INVISIBLE CONTAMINANTS AND FOOD SECURITY IN FORMER COAL MINING AREAS OF SANTA CATARINA, SOUTHERN BRAZIL[2]

Graziela Dias Blanco[1*], Rafael Barbizan Sühs[1], Escarlet Brizola[1], Patrícia Figueiredo Corrêa[2], Mari Lucia Campos[3]and Natalia Hanazaki[1]

[1] Department of Ecology and Zoology, Federal University of Santa Catarina (UFSC), 88040-900, Florianópolis, Santa Catarina, Brazil

[2] Herbário Padre Dr. RaulinoReitz (CRI), Universidade do Extremo Sul Catarinense, Criciúma, Santa Catarina, Brazil

[3]Department of Soils and Natural Resources, State University of Santa Catarina (UDESC), 88035-901, Lages, Santa Catarina, Brazil

ABSTRACT

Background: Mining activities have environmental impacts due to sediment movement and contamination of areas and may also pose risks to people's food security. In Brazil, the majority of coal mining activities are in the south, in the Santa Catarina carboniferous region. In this region, previously mined areas contaminated with heavy metals frequently occur nearby inhabited zones. Mining is part of the daily lives of local communities, and its environmental impacts are visible in the landscape; however, plants with medicinal and food use from these areas can be still consumed. Heavy metals are contaminants that do not have odor, color, or taste, and are therefore difficult to detect. We aimed to verify whether people use plants from contaminated mine areas, and understand which factors can influence the use of these resources, even from areas visibly impacted. Methods: We conducted 195 semi-structured interviews with residents from 14 areas nearby abandoned mines in the main municipalities of the Santa Catarina carboniferous region. We asked each interviewee about the length of time they lived in the region, their perception of the quality of the environment, and what plant species were used and for what purpose. We constructed generalized multivariate linear models to verify which variables can affect the group of species mentioned and generalized linear models to

---

[2]A formatação do texto e das referências do capítulo II seguem as normas da revista na qual foi publicada: Journal of Ethnobiology and Ethnomedicine.

verify which variables can affect the total number of citations. We estimated the frequency of citing species collected using the Smith index. Results: From all interviewees, 127 (65%) reported collecting plants for medicinal and food use, directly from contaminated mine 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 locally sourced plants, e.g., people know little about the danger of this contamination in their food and the risk of these contaminants to their health. These results also reveal a lack of information about contamination, as well as a lack of 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 mining areas.

Keywords: Ethnoecology, Food security, Coal mining, Local communities

3.1 BACKGROUND

Around the world, contaminated areas have endangered people's food security [1–3]. 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 [1, 2, 4]. Although the impact level of trace elements toxicity depends on the concentration at which it is ingested, chronic exposure to relatively low levels of heavy metals may also cause adverse effects [5]. 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 [5, 6]. The effects of these elements in human health can be very diverse, depending on the metal and the exposure. For example, the ingestion of cadmium above the WHO-recommended levels can cause severe damage in the renal system, and excess of chromium can cause uterine cancer [7, 8].

Local communities are human groups, located in the same region and time, that develop a cultural identity and a unique relationship with the environment [9–11]. The interaction of local communities with the environment is directly related to their culture and the experiences and perceptions of past and present generations [10], and is reflected in the use of local resources and dietary habits [12, 13]. 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 [1, 14], and northern Europe, related to increased mining activities and insecticide use in agriculture [15]. In Canada, there has been an increase in heavy metals in some foods used by indigenous communities [16]. In Latin America, studies with indigenous peoples and fishers have observed the presence of heavy metals in fish and plant resources consumed by local communities [17–20].

In Brazil, contamination of soil, plant, and fishery resources also poses a health risk to local communities [21, 22]. Coal mining in Brazil began in the late nineteenth century, and today, practically all coal produced in Brazil is mined in the southern area [23, 24]. Local communities began to settle in the neighborhoods of these mining areas since the decade of 1940, most of them comprised descendants of German, Italian, and Portuguese immigrants who work in mining [25, 26]. Before the arrival of European immigrants, the broad region was inhabited by Guarani and Xokleng.

As a new mineral extraction area was discovered, the forest cover vegetation was removed and a settlement was developed in the surroundings, to serve the mining workforce [27, 28]. Along the time, the major settlements gave rise to the urban areas of the region such as Criciúma and Lauro Muller [28]. Today, most inhabitants are descendants from those European immigrants and from the process of formation of a Brazilian identity which also mixed other cultures and ethnicities; groups of Amerindians remain in small groups, most of them restricted to very few indigenous territories [27]. The major period of coal mining was between 1975 and 1985, with an increase of these settlements; yet, coal mining is still one of the main economic activities together with agriculture [28, 29]. From the decade of 1980 onwards, the number of mining areas increased, but the number of local communities settled nearby these areas remain the same [30]. As a result of this historic process, some communities were settled very close to mines, or even partially on restored mined areas.

It is estimated that in the state of Santa Catarina alone, there are more than 6500 ha of abandoned areas contaminated by heavy metals from coal mining activities [31]. Due to diminishing profitability in the late twentieth century, some mined areas were abandoned while local communities developed in these locations. Even after decades of inactivity, abandoned mine areas are still contaminated by heavy metals [32] and may pose a risk to the food security of these communities. Some abandoned open-pit coal mines were restored according to each company's practices, reconstructing the landscape and soil to create minimal conditions for vegetation development [33]. The restoration process consists basically of filling the pit with pyrite and covering this layer with another layer of clay soil, covering this sterile layer with clayey regolith, and putting back soil, followed by planting species for soil fixation [34]. 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 soil with coal residues [31, 34]. Some plant species can survive and even thrive in these contaminated sites [35–38] and can be bioindicators of contamination and useful for bioremediation, if they have bioaccumulation potential [35, 37]. Some of these species, however, also have medicinal or food use, and therefore may pose a risk to human health [39]. Nevertheless, few studies are investigating whether plant resources occurring in areas contaminated by heavy metals are being used by the local population [40].

People perceive and categorize changes in the landscape over time [41, 42]. The perception of changes in the landscape by local inhabitants (e.g., changes in species diversity and richness, and air pollution) assists in understanding the environmental consequences of impacts such as urbanization, deforestation, and mineral extraction [43, 44]. Generally, individuals living for longer and closer to the resources are those who have greater knowledge and use of the plant resources [42]. Coupled with this, women tend to have greater knowledge and use of medicinal plants, as they are usually responsible for early health care in several local communities [45–48]. 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 [49]. 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 [49].

Considering the growing risk of contamination of plant resources [13, 18, 50, 51], we aimed to investigate whether local residents use plants obtained from contaminated mined areas and to understand which factors are related to plant use. We hypothesize that (1) the total number of species cited by interviewees will be affected by their residence time, sex, locality, perception of landscape change, and area type (*i.e.*, either abandoned or partially restored) and (2) the group of cited species will be related to 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.

3.2 METHODS

3.2.1 Study area

The study was conducted in the municipalities of Criciuma, Forquilhinha, Siderópolis, Treviso, Urussanga, and Lauro Müller, in the state of Santa Catarina (Fig. 1), in the main coal mining region in southern Brazil. We selected 14 former coal mine areas, according to the following criteria: areas of at least 1 ha, which were abandoned for at least 30 years, with a history of trace elements presence [32, 34, 52, 53], and with inhabited zones located at a maximum distance of 300 m from the deactivated mine areas. Some of these abandoned mine areas underwent an initial restoration process, which consisted of filling the pit with pyrite and covering this layer with another layer of clay soil (30– 50 cm) over the disturbed mine soil. The mining communities in Vila Funil, Rio Carvão, Barreiros, Guaitá, Cidade Alta, Vila Visconde, and São Sebastião Alto are settled near abandoned mine areas, and the mining communities of Vila Sao Jorge, Rio Fiorita, Volta Redonda, Campo Morozini, Santa Luzia, Santa Augusta, and São Sebastião are adjacent to partially restored mine areas.

Fig.1 Study area. Each number corresponds to a mining community: 1, Barreiros; 2, Guaitá; 3, Rio Cravão; 4, Volta Redonda; 5, Rio Morozini; 6, Vila Funil; 7, Vila Visconde; 8, Vila São Jorge; 9, Rio Fiorita; 10, Santa Luzia; 11, São Sebatião; 12, Santa Augusta; 13, São Sebastião: and, 14, Cidade Alta.

3.2.2 Data collection

We conducted semi-structured interviews with residents of the communities located in inhabited areas near the mined areas, individually, between February and March 2018 (Table 1). To interview the residents individually when there was more than one adult at the time of the interview, we asked only one person to respond, and when possible, we moved to a more reserved place to conduct the interview. We visited every house in each community once and interviewed those who were keen to participate in the research and who agreed with the free informed consent terms. One limitation of this method is that our sampling is possibly skewed for people who stay in their homes more often, but as we intended to cover all mining areas in the region, we had to choose between a broad sampling effort and an indepth sampling effort.

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 recorded: 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 they had observed any changes at the site since they began living there, and the responses were categorized a posteriori by the authors as (1) positive, e.g., positive changes have been observed over time in the landscape, such as an increase in the group of cited species; (2) neutral, e.g., no change was observed; and (3) negative, e.g., negative changes have been observed over time, such as in the group of cited species (Table 2). According to the interviewees, the positive aspects were mainly related to the mention of a good environment to live, with trees, birds, or a calm and safe place. Regarding the negative perception, the interviewees used the word "degradation" due to mining, referring to esthetically ugly places, air pollution, abandoned and careless areas, and areas without infrastructure for leisure, such as parks.

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 mining community	No. of interviews
Siderópolis	2944	Vila Funil	35	16
		Vila São Jorge	20	7
		Rio Fiorita	36	20
Lauro Muller	3261	Barreiros	27	16
		Guaitá	21	19
Criciúma	2678	Santa Luzia	37	8
		Vila Visconde	35	11
		São Sebastião Alto	25	8
		Santa Augusta	14	10
		São Sebastião	25	12
Treviso	1694	Volta Redonda	24	11
		Rio Morozini	26	16
Urussanga	8818	Rio Carvão	32	25
Forquilhinha	4122	Cidade Alta	23	16

Table 2 Summary of the variables raised during the interviews and used in the GLM analysis as tested variables.

Variable	**Explanation**
Perception	Observing environmental changes where you live. 1 Positive—has observed positive changes over time in the landscape, such as increased plants and animals. 2 Neutral—not observed any change. 3 Negative—has observed negative changes over time in the landscape, such as species loss.
Locality	Local community.
Gender	Men and woman.
These areas	In which mined context the interviewee lives. Mined and abandoned area: these areas are visibly degraded and with exposed tailings. Mined and abandoned area partially restored: these are greener areas with soil covered by a layer of clay and grass.
Residence time	How many years have residents lived in this community.

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 public or private institutions) about contamination of the mined areas (the full questionnaire is accessible in Supplementary material 1). Whenever possible, we conducted 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.

3.2.3 Data analysis

We built multivariate generalized linear models (GLMmv) to verify which variables could affect the group 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 the R environment with packages mvabund [54] for GLMmv, MASS [55] for GLM, and visreg [56] and vegan [57] for visualization of effects. The variables tested are listed in Table 2. For multivariate analysis, singletons (plants cited only once) and doubletons (plants cited twice) were removed.

To analyze the importance of the plants mentioned in the interviews, we used their frequency of citations and the Smith salience index given by $\Sigma(((Li - Rj)/Li)100)/N$, where Li is the size of the free listing, Rj is the position (order) of the item in a given free list (Li), and N is the total number of free listings (or the number of interviewees).

Table 3 Species cited exclusively as collected by 195 interviewees, number of citations per species, uses, and salience (Smith's index) [50]. We also considered that the first item of a given list has Rj = 0. 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 least salient. After assessing the Smith salience index, we calculated if the values differed by chance using a Monte Carlo analysis, following Chaves *et al.* [58].

3.3 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 the 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 before 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.

All of the 176 planted or collected species were cited (Supplementary material 2), of which 83 species (47%) were classified as collected from the mined areas. From these, 18 (10%) species were obtained exclusively through the collection in the mined areas (Table 3). The main species obtained exclusively by collecting from mined areas were *Psidium guajava*, *Pliniacauliflora,* 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 for species collected directly from mined areas varied between 0.12 and 0.01. Species with the highest salience and with significant results after Monte Carlo analysis were Psidium guajava, Pliniacauliflora, Psidium cattleianum, Morus sp., Foeniculum vulgare var. azoricum, Chelidonium majus, Bidens pilosa, Fragaria vesca, Justicia pectoralis, Aristolochiaesperanzae, Achillea millefolium, and Eriobotrya japonica (Table 3).

Table 3 Species cited exclusively as collected by 195 interviewees, number of citations per species, uses, and salience (Smith's index).

Species	Smith index	Salience p value	No. of citations	Use
Psidium guajava L.	0.12	0.00	30	F
Pliniacauliflora (DC.) Kausel	0.09	0.00	25	F
Psidium cattleianum Sabine	0.07	0.00	18	F
Morus sp.	0.06	0.00	14	F
Foeniculumvulgare var. azoricum (Mill.) Holub	0.05	0.01	12	M
Chelidonium majus L.	0.01	0.04	7	M
Bidens pilosa L.	0.01	0.01	6	M
Fragaria vesca L.	0.01	0.02	4	F
Justicia pectoralis Jacq.	0.00	0.00	3	M
*Aristolochiaesperanzae*Kuntze	0.00	0.00	3	M
Achillea millefolium L.	0.00	0.00	3	M
Eriobotrya japonica (Thunb.) Lindl.	0.00	0.00	21	F/ M
Equisetum giganteum L.	0.02	0.28	16	M
Passiflora edulis Sims	0.03	0.42	12	F
Inga edulis Mart.	0.04	0.16	11	M
Baccharis spp.	0.01	0.08	9	M
Campomanesiaxanthocarpa Mart. ex O. Berg	0.01	0.08	6	F
Butia capitata (Mart.) Becc.	0.01	0.06	4	F

When questioned whether they were aware of the presence of contamination in abandoned mine areas, 166 residents (85%) said they were. However, when asked about harm to the environment or their lives, only 19 residents (10%) reported some type of physical discomfort (*i.e.*, stomachache and low blood pressure), when ingesting the species *Baccharis* spp., Plectranthus barbatus, Solanum paniculatum, Arnica montana, and Achillea millefolium. Regarding harm to the environment, the interviewees cited atmospheric pollution, due to the excessive dust released in the region from coal extraction. All residents moved to the area after the mining activity ended and did not see what the landscape looked like before mining; however, 172 residents (88%) said they had observed changes; 113 residents (58%) reported negative changes, *i.e.*, forest loss, fewer animals, fewer plants (this type of response was classified as negative, a posteriori, by the authors); and 58 residents (30%) reported landscape improvements, *i.e.*, more trees, more plants, cleaner air (this type of response was classified as positive, a posteriori, by the authors). Another issue confirmed 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 the landscape (*i.e.*, positive, neutral, negative), location, and type of abandoned area (*i.e.*, either abandoned or partially restored) did not affect the group of species cited by respondents (Additional file 3).

The same variables were analyzed concerning the number of species cited. The locality, perception of changes in the landscape, and duration of residence time significantly affected the total number of cited species. The GLM explained 27% of the variation in the total number of species used (Table 4, Fig. 2), 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 relation to the model selected by AIC, Weight model weight more species collected than residents who had not observed landscape change over time. The locality also had a significant effect on the number of citations.

Table 4 Summary of models and variables tested with GLM. 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.

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

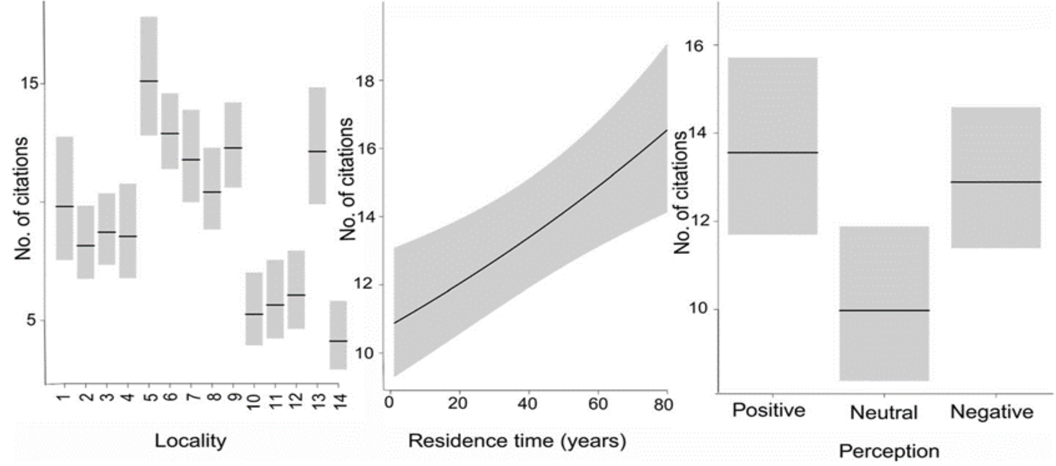
19	2.045	+			0.006546	3	780.473	1566.9	177.3	0
27	2.057	+		+	0.006744	4	779.747	1567.5	177.8	0
7	2.366	+	+			4	779.804	1567.6	177.9	0
15	2.382	+	+	+		5	779.256	1568.5	178.8	0
5	2.318		+			3	781.676	1569.4	179.7	0
13	2.335		+	+		4	781.111	1570.2	180.5	0
3	2.264	+				2	794.521	1593	203.4	0
1	2.23					1	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

3.4 DISCUSSION

Residents living in mining communities near abandoned or partially restored coal mine areas are consuming plant species from these areas for food and medicinal purposes, which puts their food security at risk: almost a half of the plants cited were collected from mined areas, and 18 species were collected exclusively in these areas. The consumption of species that occur in mined areas was also reported in other regions of South America, as well as in the USA, Europe, India, and China [1, 14, 15, 17, 20, 59]. Some of these species have been studied for their potential to bioaccumulate heavy metals, such as *Psidium guajava*, *Morus* sp., *Baccharis crispa*, *Baccharis* s*arothroides*, *Mentha arvensis*, and *Cymbopogon flexuosus* which bioaccumulate Al, Fe, Si, S, Ca, and Zn [36–38, 60–62]. 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.

Locality was the most important factor influencing the number of species cited (*i.e.*, 77% of the 27% that explained the use of plant species from mined areas). Localities studied here are local communities settled originally to supply the coal mining economy with laborers to work in coal mines [23]. Over time, these mining communities developed bonds with their environment, learning about the plant resources available in each place, a behavior co-evolving with the available plant resources and influenced by expertise, and direct and continuous observation of the environment [63, 64]. This behavior is also influenced by transformations in the social and cultural structures, policy systems, and spiritual beliefs [63, 64]. Even though these environments present a low plant diversity [65], the mining communities adapted to use the available resources for their medicine and food purposes.

Fig. 2 Graphical representation of the explanatory variables of the selected GLM model in relation to the number of species citations according



Besides, locality influenced species cited by the communities. This may be due to the high cultural diversity of people, including indigenous peoples such as Guarani and recent German and Italian immigrants [66, 67]. Santa Catarina, and other areas in the south and southeast of Brazil, is culturally heterogeneous, which may affect plant knowledge and use. The influence of different cultures and the mixture of knowledge are combined and integrated into the most recent generations [68]. This cultural influence may have a greater weight than, for example, the resource availability itself in the environment [68, 69]. 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 [42, 64].

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. However, we emphasize that since the categorization as “positive,” “neutral,” or “negative” was made a posteriori by the authors, these results reveal a broad and simplified view of what is considered as a perception of improvement (*i.e.*, positive) or loss (*i.e.*, negative) in the environment. Similar observations are reported by Silvano and Begossi [22], 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 apparent paradox may be due to contaminants such as heavy metals being invisible or due to psychological barriers [70, 71].

Invisible contaminants are those that cannot be detected by human sensory abilities, *i.e.*, cannot be seen and do not exude odor, taste, or sound [70]. 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 [39, 70, 72]. Psychological barriers, on the other hand, are when people are aware of the environmental impacts but do not act emphatically against them [71, 73]. People tend to think of environmental impacts as futuristic and distant from their reality, associated with governments failing to present more effective strategies involving local people, and within a framework of contemporary cultural and social issues [71, 74]. The social understanding of risk, such as food security risk, is built on views and beliefs associated with the social and cultural forces of each society or community [75]. The construction of this perception goes through a comparison stage. For a mining 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 [75, 76].

No significant differences were observed in the group of species cited, and this can be due to the low diversity of plants available in mined areas. Few species can survive and develop in environments impacted by heavy metals [77]. The mining activity tends to result in more homogeneous environments, affecting the microbial and fungal diversity in the soil thereby affecting plant diversity [77, 78], revealing the threat to the biodiversity of these environments.

We did not find a difference between species cited by women and men. This homogeneous distribution of knowledge across genders was also observed in other studies [45, 47]. 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 medicinal 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 of plant uses [47, 48].

The use of plant species from areas contaminated by coal mining 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 [79]. 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 [19]. 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 [80–83]. In Canada and the USA, rural and indigenous communities are twice as vulnerable to contamination of their food resources compared to the national average [84]. These communities have greater exposure to, and are in direct contact with, contaminating sources [13, 84], a situation similar to that faced by mining communities in southern Brazil.

The lack of food security due to the 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 [13, 22, 85]. In recent decades, the global return of incentives for coal extraction has raised concerns about the food security of local communities [32]. Coal is currently responsible for providing 29.6% of global energy needs and about 42% of all global electricity [32, 86]. The resurgence of coal mining may increase the contamination of areas previously mined for coal and add to the number of areas impacted by trace element contamination. In the far south of Brazil, children living in coal mined areas are at high risk of exposure leading to possible trace element poisoning [87]. For this reason, research that identifies whether there is use, and which species are being used for medicinal and food consumption in mined areas, is important to develop strategies aimed at guaranteeing the food security of mining communities.

3.5 CONCLUSION

Traditional and local knowledge are important tools for identifying and locating areas and resources that can pose a risk to the food security of mining communities. Consumption of plant species collected from abandoned mine sites in southern Brazil, coupled with a lack of information, is a reality and a concern. Plant species that can potentially bioaccumulate do occur in these areas and are being used locally as food or therapeutic resources. This situation is aggravated by the fact that several contaminants from mining are invisible and because of psychological barriers to recognizing the risks related to the contamination of the environment. Given this scenario, it is necessary and urgent to inform the population about the risk of invisible contaminants to reduce their vulnerability to food insecurity, combined with studies that quantify the extent of trace element contamination in plant resources resulting from mining activity.

3.6 REFERENCES

1. Guan Y, Chu C, Shao C, Ju M, Dai E. Study of integrated risk regionalisation method for soil contamination in industrial and mining area. Ecol Indic. 2017; 83:260–70.
2. Ranjan R. Assessing the impact of mining on deforestation in India. Resour Policy. 2019; 60:23–35.
3. Alves RRN, Rosa IML. Biodiversity, traditional medicine and public health: where do they meet? J EthnobiolEthnomed. 2007;3.
4. Tozsin G. Hazardous elements in soil and coal from the Oltu coal mine district. Turkey Int J Coal Geol. 2014; 131:1–6.
5. Brevik EC, Burgess LC. Soils and human health. Soils Hum Heal. 2012: 1–403.
6. Kim KH, Kabir E, Jahan SA. A review on the distribution of Hg in the environment and its human health impacts. J Hazard Mater. 2016;306: 376–85.
7. Staessen JA, Amery A, Lauwerys RR, Roels HA, Ide G, Vyncke G. Renal function and historical environmental cadmium pollution from zinc smelters. Lancet. 1994; 343:1523–7.
8. Achmad RT, Budiawan AEI. Effects of chromium on human body. Annu Res Rev Biol. 2017; 13:1–8.
9. Brandão CR, Borges MC. O lugar da vida - Comunidade e Comunidade Tradicional / El lugar de la vida - Comunidad y Comunidad Tradicional. Campo – TerritRevGeogr Agrária. 2014; 9:1–23.
10. Bordeleau S, Asselin H, Mazerolle MJ, Imbeau L. "Is it still safe to eat traditional food?" Addressing traditional food safety concerns in aboriginal communities. Sci Total Environ. 2016; 565:529–38.
11. Phungpracha E, Kansuntisukmongkon K, Panya O. Traditional ecological knowledge in Thailand: mechanisms and contributions to food security. Kasetsart J Soc Sci. 2016; 37:82–7.
12. Conti IL, Coelho-de-Souza G. Povos E Comunidades Tradicionais: a Produção De Políticas Públicas De Segurança Alimentar E Nutricional. Amaz - Rev Antropol. 2014; 5:780.
13. Briones Alonso E, Cockx L, Swinnen J. Culture and food security. Glob Food Sec. 2018;1 7:113–27.
14. Wu Q, Xing LT, Ye CH, Liu YZ. The influences of coal mining on the large karst springs in North China. Environ Earth Sci. 2011; 64:1513–23.
15. Tóth G, Hermann T, Da Silva MR, Montanarella L. Heavy metals in agricultural soils of the European Union with implications for food safety. Environ Int. 2016; 88:299–309.
16. Chan HM, Receveur O. Mercury in the traditional diet of indigenous peoples in Canada. Environ Pollut. 2000; 110:1–2.
17. Chávez A, Munoz M. Food security in Latin America. Food Nutr Bull. 2002; 23:349–50.
18. Xing Y, Peng H, Gao L, Luo A, Yang X. A Compound containing substituted indole ligand from a hyperaccumulator Sedum alfredii Hance under Zn exposure. Int J Phytoremediation. 2013.
19. Miller JR, Villarroel LF. Bolivia: Mining, river contamination, and human health. Encycl Environ Heal. 2011:421–41.
20. Parraguez-Vergara E, Contreras B, Clavijo N, Villegas V, Paucar N, Ther F. Does indigenous and campesino traditional agriculture have anything to contribute to food sovereignty in Latin America? Evidence from Chile, Peru, Ecuador, Colombia, Guatemala and Mexico. Int J Agric Sustain. 2018; 16:326–41.
21. Caldas ED, Machado LL. Cadmium, mercury and lead in medicinal herbs in Brazil. Food Chem Toxicol. 2004; 42:599–603.

22. Silvano RAM, Begossi A. From ethnobiology to ecotoxicology: fishers' knowledge on trophic levels as indicator of bioaccumulation in tropical marine and freshwater fishes. Ecosystems. 2016; 19:1310–24.
23. Belloli M, Quadros J, Guidi A. História do carvão de Santa Catarina. 1a. Belloli M, Quadros J, Guidi A, editors. Imprensa Oficial do Estado de Santa Catarina: Criciúma; 2002.
24. Paulo J, Silva S. Impactos ambientais causados por mineração. Rev Espaço da Sofhia. 2007; 8:1–13.
25. Klanovicz J. Minas de carvão: trabalho também de mulheres. Rev Estud Fem. 2004; 12:247–50.
26. Corrêa PF, De Sá G, Elias GA, Rocha-nicoleite E, Santos R. Mineração de carvão no Brasil: uma análise. V CongressoBrasileiro de Carvão Mineral 2016; 5:1–8.
27. Zanelatto J, Jung G, Ozório R. Índios e brancos no processo colonizador do Sul Catarinense na obra "Histórias do Grande Araranguá", de João Leonir dall'Alba. Rev História Comp. 2015; 9:174–202.
28. Sizenando JW. Mineração e espacialidade socioambiental: Exploração Carbonífera e ocupação territorial em Criciúma. Santa Catarina. 2011;73.
29. Pamplona M, Trindade LC. Espaços livres de Criciúma-sc como reflexos da mineração. X Colóquio QUAPÁ-SEL 2015.
30. Ruiz MS, Roic E. Conflitos Socioambientais Relacionados aos Impactos do Uso e Ocupação do Solo pela Mineração Subterrânea de Carvão em Criciúma - SC. Encontro da ANPAD – EnANPAD 2014;1–16.
31. Rocha-Nicoleite E, Overbeck GE, Müller SC. Degradation by coal mining should be priority in restoration planning. PerspectEcolConserv Associação Brasileira de Ciência Ecológica e Conservação; 2017; 15:202–5.
32. Schlickmann MB, Dreyer JBB, Spiazzi FR, Vieira FS, Nascimento B, Nicoleite ER, Kanieski MR, Duarte E, Schneider CR, Aguiar JT. Impact assessment from coal mining area in southern Brazil. J Agric Sci. 2018; 10:426.
33. Rocha-Nicoleite E, Campos ML, Colombo GT, Overbeck GE, Müller SC. Forest restoration after severe degradation by coal mining: lessons from the first years of monitoring. Rev Bras Bot. 2018; 41:653–64.
34. Campos ML, Almeida JA, Souza LS. Avaliação de três áreas de solo construído após mineração de carvão a céu aberto em Lauro Müller, Santa Catarina. Rev Bras Ciência do Solo. 2003; 27:1123–37.
35. Haque N, Peralta-Videa JR, Jones GL, Gill TE, Gardea-Torresdey JL. Screening the phytoremediation potential of desert broom (*Baccharis*sarothroides Gray) growing on mine tailings in Arizona, USA. Environ Pollut. 2008;153: 362–8.
36. Menezes APS, Da Silva J, Rossato RR, Santos MS, Decker N, Da Silva FR, *et al.* Genotoxic and biochemical changes in *Baccharis*trimera induced by coal contamination. Ecotoxicol Environ Saf. 2015; 114:9–16.
37. Manikandan R, Sahi SV, Venkatachalam P. Impact assessment of mercury accumulation and biochemical and molecular response of Mentha arvensis: a potential hyperaccumulator plant. Sci World J. 2015; 2015:1–10.
38. Gautam M, Pandey D, Agrawal M. Phytoremediation of metals using lemongrass (Cymbopogon citratus (D.C.) Stapf.) grown under different levels of red mud in soil amended with biowastes. Int J Phytoremediation. 2017; 19:555–62.
39. Arcuri ASA, Pontes JM. Ensaios Sobre Poluição E Doenças No Brasil. 1a. Hess S, editor. São Paulo: Outras Expressões; 2018.
40. Esquivel-Muelbert A, Baker TR, Dexter KG, Lewis SL, terSteege H, LopezGonzalez G, *et al.* Seasonal drought limits tree species across the neotropics. Ecography (Cop). 2017; 40:618–29.

41. Avellar C, Paulino U. Local perceptions towards biological conservation in the community of vilavelha, Pernambuco. Brazil Interciencia. 2005; 30:460–5.
42. Gaoue OG, Coe MA, Bond M, Hart G, Seyler BC, McMillen H. Theories and Major Hypotheses in Ethnobotany. Econ Bot. 2017; 71:269–87.
43. de Almeida GMA, Ramos MA, Araújo EL, Baldauf C, Albuquerque UP. Human perceptions of landscape change: the case of a monodominant forest of Attalea speciosa Mart ex. Spreng (Northeast Brazil). Ambio. 2016; 45:458–67.
44. Celentano D, Rousseau GX, Engel VL, Façanha CL, De Oliveira EM, De Moura EG. Perceptions of environmental change and use of traditional knowledge to plan riparian forest restoration with relocated communities in Alcântara, Eastern Amazon. J EthnobiolEthnomed. 2014; 10:11.
45. Figueiredo GM, Leitão-Filho HF, Begossi A. Ethnobotany of Atlantic Forest coastal communities: diversity of plant uses in Gamboa (Itacuruçá island, Brazil). Hum Ecol. 1993; 21:419–30.
46. Teklehaymanot T, Giday M, Medhin G, Mekonnen Y. Knowledge and use of medicinal plants by people around Debre Libanos monastery in Ethiopia. J Ethnopharmacol. 2007; 111:271–83.
47. Voeks RA. Are women reservoirs of traditional plant knowledge? Gender, ethnobotany and globalization in northeast Brazil. Singap J Trop Geogr. 2007; 28:7–20.
48. De Albuquerque UP, Soldati GT, Sieber SS, Ramos MA, De Sá JC, De Souza LC. The use of plants in the medical system of the Fulni-ô people (NE Brazil): a perspective on age and gender. J Ethnopharmacol. 2011; 133:866–73.
49. Vannella L, Lahner E, Osborn J, Bordi C, Miglione M, DelleFave G, *et al.* Risk factors for progression to gastric neoplastic lesions in patients with atrophic gastritis. 1a. Aliment. Pharmacol. Ther. 2010.
50. Ashraf S, Ali Q, Zahir ZA, Ashraf S, Asghar HN. Phytoremediation: environmentally sustainable way for reclamation of heavy metal polluted soils. Ecotoxicol Environ Saf. 2019; 174:714–27.
51. Rai PK, Lee SS, Zhang M, Tsang YF, Kim KH. Heavy metals in food crops: health risks, fate, mechanisms, and management. Environ Int. 2019; 125:365– 85.
52. Barnes TJ. Geographical intelligence: American geographers and research and analysis in the Office of Strategic Services 1941-1945. J Hist Geogr. 2006; 32:149–68.
53. Hugen C, Miquelluti DJ, Campos ML, de Almeida JA, Ferreira ÉRNC, Pozzan M. Cu and Zn contents in soil profiles of different lithologies in Santa Catarina. Rev Bras Eng Agric e Ambient 2013; 622–628.
54. Wang Y, Naumann U, Wright ST, Warton DI. Mvabund- an R package for model-based analysis of multivariate abundance data. Methods EcolEvol. 2012; 3:471–4.
55. Brian A, Venables B, Bates DM, Firth D, Ripley MB Package ‘MASS’ 1a. 2019.
56. Breheny AP, Burchett W, Breheny MP Package ‘visreg’ 2a. 2018.
57. Taylor RAJ, Digby PGN, Kempton RA. Multivariate analysis of ecological communities. J Anim Ecol. 1987; 56:1083.
58. Chaves L da S, do Nascimento ALB, Albuquerque UP. What matters in free listing? A probabilistic interpretation of the salience index. Acta Bot Brasilica. 2019; 33:360–9.
59. Kaushik A, Kansal A, Santosh M, Kumari S, Kaushik CP. Heavy metal contamination of river Yamuna, Haryana, India: assessment by metal enrichment factor of the sediments. J Hazard Mater. 2009; 164:265–70.
60. Oti WO. Bioaccumulation factors and pollution indices of heavy metals in selected fruits and vegetables from a derelict mine and their associated health implications. Int J Environ Sustain. 2015; 4.

61. Kanwal F, Rehman R, Warraich HA. Synthesis of novel polyaniline composites with Eriobotrya japonica leaves for removal of methyl red dye from wastewater. Bulg Chem Commun. 2019; 51:586–91.
62. Randjelovic S, Kostic D, Arsic B, Stojanovic G. Bioaccumulation of metals in different species of mulberry. SavremTehnol. 2014; 3:105–10.
63. Mazzocchi F. Western science and traditional knowledge: Despite their variations, different forms of knowledge can learn from each other. EMBO Rep European Molecular Biology Organization. 2006; 7:463–6.
64. Kohsaka R, Rogel M. Traditional and local knowledge for sustainable development: empowering the indigenous and local communities of the world 2019; 1–13.
65. Klein AS, Citadini-Zanette V, Lopes RP, Santos R. Regeneração natural em área degradada pela mineração de carvão em Santa Catarina, Brasil. Rev Esc Minas. 2009; 62:297–304.
66. Seyferth G. The diverse understandings of foreign migration to the south of Brazil (1818-1950). Vibrant Virtual Brazilian Anthropol. 2013; 10:118–62.
67. Corrêa J. Atividade Minerária no Sul de Santa Catarina: Impactos Ambientais Decorrentes da Exploração do Carvão. 1934.
68. Abreu DBDO, Santoro FR, De AUP, Ladio AH, De MPM. Medicinal plant knowledge in a context of cultural pluralism: a case study in northeastern Brazil. J Ethnopharmacol. 2015; 175:124–30.
69. Menendez-Baceta G, Aceituno-Mata L, Reyes-García V, Tardío J, Salpeteur M, Pardo-De-Santayana M. The importance of cultural factors in the distribution of medicinal plant knowledge: a case study in four Basque regions. J Ethnopharmacol. 2015; 161:116–27.
70. Vyner HM. The psychological dimensions of health care for patients exposed to radiation and the other invisible environmental contaminants. Soc Sci Med. 1988; 27:1097–103.
71. Tam KP, Chan HW. Environmental concern has a weaker association with pro-environmental behavior in some societies than others: a cross-cultural psychology perspective. J Environ Psychol. 2017; 53:213–23.
72. Donaldson SG, Van Oostdam J, Tikhonov C, Feeley M, Armstrong B, Ayotte P, *et al.* Environmental contaminants and human health in the Canadian Arctic. Sci Total Environ. 2010; 408:5165–234.
73. Franzen A, Vogl D. Two decades of measuring environmental attitudes: a comparative analysis of 33 countries. Glob Environ Chang. 2013; 23:1001–8.
74. Gifford R. The dragons of inaction: psychological barriers that limit climate change mitigation and adaptation. Am Psychol. 2011; 66:290–302.
75. Carvalho SW, Block LG, Sivaramakrishnan S, Manchanda RV, Mitakakis C. Risk perception and risk avoidance: the role of cultural identity and personal relevance. Int J Res Mark. 2008; 25:319–26.
76. Janmaimool P, Watanabe T. Evaluating determinants of environmental risk perception for risk management in contaminated sites. Int J Environ Res Public Health. 2014; 11:6291–313.
77. Payette S, Delwaide A. Shift of conifer boreal forest to Lichen-Heath Parkland caused by successive stand disturbances. Ecosystems. 2003; 6:540–50.
78. de QPD, Zhalnina K, Davis-Richardson AG, Drew JC, Menezes FB, Camargo FA, Triplett EW. Coal mining practices reduce the microbial biomass, richness and diversity of soil. Appl Soil Ecol. 2016; 98:195–203.
79. Borch A, Kjærnes U. Food security and food insecurity in Europe: an analysis of the academic discourse (1975-2013). Appetite. 2016; 103:137–47.
80. Huang SH, Li Q, Yang Y, Yuan CY, Ouyang K, Wang B, *et al.* Accumulation characteristics and chemical speciation of Cd, Zn and Pb in soils impacted by a Pb-Zn mining area. Kem u Ind Chem Chem Eng. 2017; 66:53–8.

81. Mahar A, Wang P, Ali A, Awasthi MK, Lahori AH, Wang Q, *et al.* Challenges and opportunities in the phytoremediation of heavy metals contaminated soils: a review. Ecotoxicol Environ Saf. 2016; 126:111–21.
82. Huang Y, Chen Q, Deng M, Japenga J, Li T, Yang X, He Z. Heavy metal pollution and health risk assessment of agricultural soils in a typical periurban area in southeast China. J Environ Manag. 2018; 207:159–68.
83. Dong J, Yu M, Bian Z, Zhao Y, Cheng W. The safety study of heavy metal pollution in wheat planted in reclaimed soil of mining areas in Xuzhou, China. Environ Earth Sci. 2012; 66:673–82.
84. Loring PA, Whitely C. Food security and food system sustainability in North America. Encycl. Food Secur. Sustain. 2018.
85. Kuhnlein HV, Chan HM. Environment and contaminants in traditional food systems of northern indigenous peoples. Annu Rev Nutr. 2000; 20:595–626.
86. Silva LFO, Querol X, da Boit KM, de VSFO, Madariaga JM. Brazilian coal mining residues and sulphide oxidation by Fenton's reaction: an accelerated weathering procedure to evaluate possible environmental impact. J Hazard Mater. 2011; 186:516–25.
87. Santos M, Soares MCF, Baisch PRM, Baisch PRM. Baisch ALM Silva Júnior FMR. Biomonitoring of trace elements in urine samples of children from a coal-mining region. Chemosphere. 2018; 197:622–6.

3.7 SUPLEMENTARY MATERIAL

Supplementary material 1: Interview - Ethnobotanical Project in the Coal Region

Interviewer name:
Date:
Interview number:
Interviewee name: [confidential information] Age:
Gender: F ( ) M ( )
Location (Municipality, Street and House #):

1.how long have you lived in this place?
What is your place of origin?
Do you work or worked in coal mining?
2 Since you live here, what landscape changes have you observed?
2.1do you know or remember what the landscape looked like before mining?
2.2 do you know or has anyone ever talked to the community about the possible contamination of coal mined areas?

3 Do you collect medicinal plants that occur near your home? Yes ( ) no ( )
4 Do you collect food plants that occur near your home, such as fruits, vegetables or roots?
Yes ( ) no ( )

5 Do you plant any medicinal plants in your home? Yes ( ) no ( )
6 Do you plant any food plants in your home such as vegetables or fruits? Yes ( ) no ( ) [if answer is no for questions 3,4,5 and 6, skip to question 8]
7 What medicinal and food plants do you collect or plant, and for what? [m: mined area, mr: restored mined area. Fill one line to each plant]
8 Plant/purpose/which part do you use?/harvesting or planting location/m or mr
9 Do you buy any medicinal plants? Yes ( ) no ( ) [if answer is no skip to question 11]
10 Where do you buy medicinal plants?
11 What medicinal plants do you buy?
12 Have you ever felt uneasy or uncomfortable after having had tea made of collected

or planted herbs/plants? Y ( ) n ( ) [if the answer is yes, write down which plant(s)]

13 What discomfort? [this question can be induced suggesting examples such as bellyache, headache]

14 Are you aware of mining areas near where you live? Do you know which mined areas exist near where you live? [show the map with the mined areas and locate the interviewee where she/he lives. Write down the corresponding area numbers]

15 Do you know anyone who lives nearby this area who uses and collects medicinal plants? [write down the name and where the person lives]

Supplementary material 2: List of species cited as used by residents. C: Collected, P: Planted.

Family	**Species**	**Way of obtaining**	**Smith Index**
Acanthaceae	*Justicia pectoralis* Jacq.	C	0.42054
	Echinodorus grandiflorus (Cham. &Schltdl.) Micheli	C/P	0.37361
Amaryllidaceae	*Allium porrum* L.	P	0.89167
	Allium cepa L.	P	0.86637
	Allium sativum L.	P	0.77783
	*Allium schoenoprasum*L.	P	0.8022
Amaranthaceae	*Alternanthera brasiliana* (L.) Kuntze	C/P	0.44592
	Beta vulgaris L.	P	0.23748
	Chenopodium ambrosioides L.	P	0.20714
	Spinacia oleracea L.	P	0.64242
Anacardiaceae	*Mangifera indica* L.	C/P	0.56865
Annonaceae	*Annona squamosa* L.	C/P	0.68818
	Annona montana Macfad.	C/P	0.87879
Apiaceae	*Daucus carota* L.	P	0.68438
	Foeniculum vulgare Mill.	C	0.47881
	Petroselinum crispum (Mill.) Fuss	P	0.39644
Apocynaceae	*Hancornia speciosa* Gomes	P	0.54545
Araceae	*Dieffenbachia amoena*Bull.	C/P	0.65385
Arecaceae	*Butia capitata* (Mart.) Becc.	C	0.82235
	Cocos nucifera L.	C/P	0.11111
	Euterpe oleracea Mart.	C/P	0.37002
Aristolochiaceae	*Aristolochiaes peranzae* Kuntze	C	0.50556
Asparagaceae	*Sansevieria sp.*	C/P	0.33333
Asphodelaceae	*Aloe vera* (L.) Burm. f.	C/P	0.46882
Asteraceae	*Achillea millefolium* L.	C	0.23748
	Achyrocline satureioides (Lam.) DC.	C/P	0.4227
	Anthemis nobilis L.	P	0.23748
	*Arnica montana*L.	C/P	0.45556
	Artemisia vulgaris L.	P	0.44444
	Artemisia absinthia St.-Lag.	P	0.29157
	Baccharis articulata (Lam.) Pers.	C	0.3141
	*Baccharis milleflora*DC.	C	0.3141
	Bidens pilosa L.	C	0.3373
	Cichorium intybus L.	C/P	0.53593

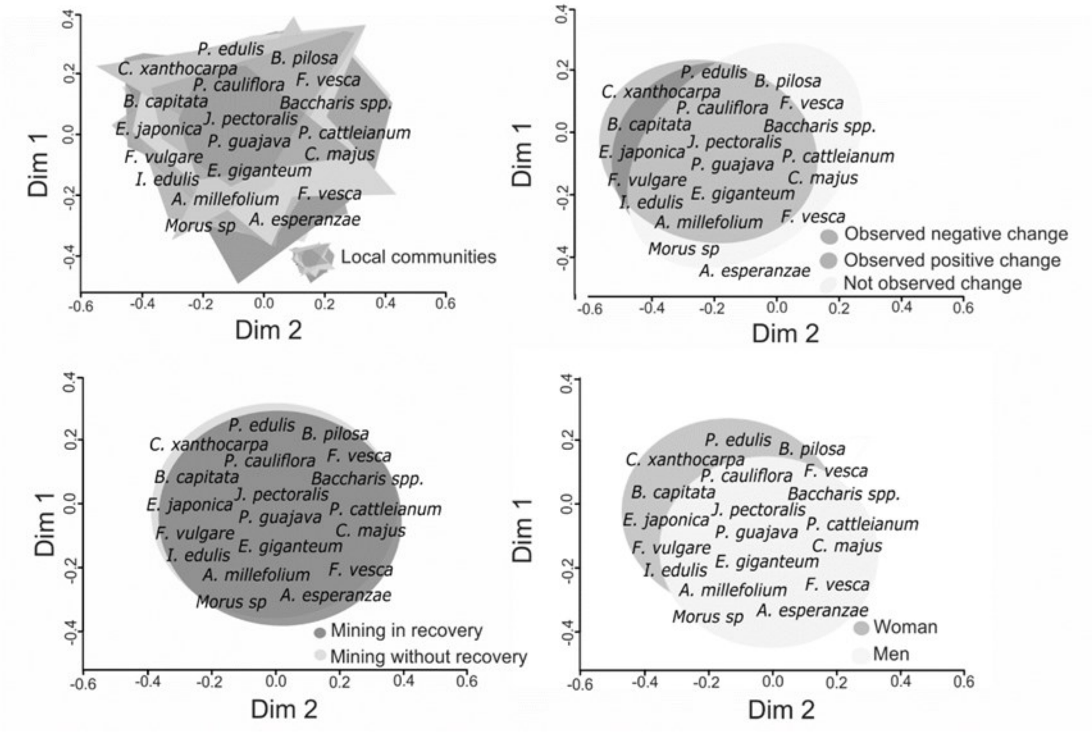
	Cynara scolymus L.	P	0.25659
	Echinodorus grandiflorus (Cham. &Schltdl.) Micheli	C/P	0.37361
	Eclipta alba (L.) Hassk.	C/P	0.24688
	Lactuca sativa L.	C/P	0.95035
	Matricaria chamomilla L.	P	0.3992
	Mikania glomerata Spreng.	P	0.29056
	Smallanthus sonchifolius (Poepp.) H. Rob.	C/P	0.33333
	Taraxacum officinale F.H. Wigg.	P	0.44444
	Tithonia diversifolia (Hemsl.) A. Gray	P	0.26923
	Vernonia polyantha s(Spreng.) Less.	P	0.12987
	Vernonia scorpioides (Lam.) Pers.	P	0.44811
Bixaceae	*Bixa orellana*L.	P	0.36825
Boraginaceae	*Borago officinalis* L.	P	0.33333
	Symphytum officinale L.	P	0.6553
Brassicaceae	*Brassica oleracea* L.	P	0.74967
	Eruca vesicaria (L.) Cav.	C/P	0.46348
	Nasturtium officinale W.T. Aiton	P	1
	*Raphanus raphanistrum*L.	C/P	0.56
Bromeliaceae	*Ananas comosus* (L.) Merr.	C/P	0.98134
Cactaceae	*Hylocereu sundatus* (Haw.) Britton & Rose	C/P	0.3165
Caricaceae	*Carica papaya* L.	C/P	0.56453
Celastraceae	*Maytenusilicifolia*Mart. exReissek	P	0.33743
Chloranthaceae	*Hedyosmumbrasiliense*Miq.	C/P	0.76923
Clusiaceae	*Garcinia brasiliensis*Mart.	P	1
	Garcinia gardneriana (Planch. &Triana) Zappi	P	0.90598
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	P	0.795
Costaceae	*Costusspicatus* (Jacq.) Sw.	C/P	0.26851
Crassulaceae	*Bryophyllum pinnatum* (Lam.) Oken	C/P	0.16111
Cucurbitaceae	*Cucumis anguria*L.	C/P	0.58333
	Cucumis melo L.	P	0.50227
	Cucumis sativus L.	P	0.55752
	*Cucurbita moschata*Duchesne	P	0.86346
	Cucurbita pepo L.	C/P	1
	Cucurbita sp.	C/P	0.86346
	Sechium edule (Jacq.) Sw.	C/P	0.70907
Dioscoreaceae	*Dioscoreabulbifera*L.	P	0.96296
Ebenaceae	*Diospyros kaki* Thunb.	P	0.78211
Equisetaceae	*Equisetum giganteum*L.	C	0.26825

Euphorbiaceae	*Euphorbia tirucalli*L.	P	0.23636
	Manihot esculenta Crantz	P	0.91226
Fabaceae	*Arachis hypogaea*L.	C/P	0.85714
	Bauhinia cheilantha (Bong.) Steud.	P	0.16822
	*Erythrina crista-galli*L.	P	0.78788
	Inga edulis Mart.	C	0.68532
	*Mimosa pudica*L.	C/P	0.55556
	Paubrasilia echinata (Lam.) Gagnon, H.C. Lima & G.P. Lewis	C/P	0.36364
	Phaseolus vulgaris L.	P	0.5079
	Phseolus spp.	P	0.68563
Gentianaceae	*Centaurium erythraea* Rafn	P	0.37166
Juglandaceae	*Juglans regia* L.	P	0.66667
Lamiaceae	*Lavandula angustifolia* Mill.	C/P	0.5
	*Leonurus sibiricus*L.	C	0.66667
	Melissa officinalis L.	C	0.44964
	Mentha arvensis L.	C	0.30595
	*Mentha pulegium*L.	C/P	0.32498
	*Ocimumbasilicum*L.	C/P	0.74916
	*Ocimumtenuiflorum*L.	C/P	0.35714
	*Origanum majorana*L.	C/P	0.5
	Origanum vulgare L.	C/P	0.60802
	Plectranthus barbatus Andrews	P	0.36156
	*Salvia hispanica*L.	C/P	0.09091
	Salvia officinalis L.	P	0.3646
Lauraceae	*Cinnamomum camphora* (L.) J. Presl	C/P	0.3
	Cinnamomum zeylanicum Blume	P	0.67308
	Laurus nobilis L.	C/P	0.39204
	*Ocotea odorifera (*Vell.) Rohwer	C/P	0.30769
	Persea americana Mill.	C/P	0.90326
Lythraceae	*Punica granatum* L.	P	0.43643
	Cuphea carthagenensis (Jacq.) J.F. Macbr.	C/P	0.33036
Malpighiaceae	*Malpighia emarginata*DC.	P	0.92431
Malvaceae	*Abelmoschus esculentus* L.	P	0.5
	Malva sylvestris L.	C/P	0.26336
Melastomataceae	*Miconia albicans*	C/P	0.48148
Moraceae	*Artocarpus heterophyllus* Lam.	C/P	0.59066
	*Ficus carica*L.	P	0.7631

	Morus alba L.	P	0.20202
	Morus sp.	C	0.87878
Musaceae	*Musa spp.*	C/P	0.84691
Myristicaceae	*Myristica fragrans* Houtt.	P	0.68182
Myrtaceae	*Campomanesiaxanthocarpa*Mart. ex O. Berg	C	0.54395
	Eucalyptus globulus Labil.	P	1
	*Eugenia uniflora*L.	P	0.47296
	Pliniacauliflora (DC.) Kausel	C	0.71321
	*Psidium cattleianum*Sabine	C	0.87714
	Psidium guajava L.	C	0.6758
	Syzygium aromaticum (L.) Merr. & L.L. Perry		0.33333
	Syzygium jambolanum (Lam.) DC.	P	1
Oxalidaceae	*Averrhoa carambola* L.	C/P	0.58888
Papaveraceae	*Chelidonium majus* L.	C	0.39924
Passifloraceae	*Passiflora edulis* Sims	C	0.53228
Phytolaccaceae	*Petiveriaalliacea*L.	C/P	0.45048
Piperaceae	*Piper spp.*	C/P	0.53778
Plantaginaceae	*Plantago major* L.	C/P	0.26193
Poaceae	*Cymbopogon citratus* (DC.) Stapf	P	0.38997
	*Cymbopogon winterianus*Jowitt ex Bor	C/P	0.28651
	Rottboellia exaltata (Lour.) Clayton.	P	0.03333
	Saccharum officinarum L.	P	0.79037
	Zea mays L.	C/P	0.50322
Portulacaceae	*Portulaca oleracea* L.	P	0.44709
Pteridaceae	*Adiantum capillus-veneris* L.	C/P	0.41529
Rosaceae	*Filipendulaulmaria* (L.) Maxim	P	0.375
	*Fragaria vesca*L.	C	0.61067
	Malus domestica (Suckow) Borkh.	C/P	0.64795
	Eriobotrya japonica (Thunb.) Lindl.	C/P	0.36364
	Prunus persica (L.) Batsch	P	0.55677
	Pyrus sp.	P	0.41793
	Rosmarinus officinalis L.	C/P	0.46376
	*Rubus fruticosus*L.	P	0.39655
Rubiaceae	*Coffea sp.*	C/P	0.90234
Rutaceae	*Citrus limon* (L.) Burm f.	P	0.59058
	Citrus reticulata Blanco	P	0.5491
	Citrus sinensis (L.) Osbeck	P	0.60734
	Citrus x aurantium L.	P	0.8198

	Ruta graveolens L.	P	0.26241
Sapindaceae	*Litchi chinensis* Sonn.	P	0.31579
Sapotaceae	*Synsepalum dulcificum* (Schumach. &Thonn.) Daniell	P	0.36319
Smilacaceae	*Smilax japicanga*Griseb.	P	0.36364
Solanaceae	*Brunfelsi auniflora* (Pohl) D. Don	C/P	0.34783
	Capsicum sp.	P	0.41358
	Nicotiana tabacum L.	C/P	0.77778
	*Solanum lycopersicum*L.	P	0.50081
	*Solanum paniculatum*L.	P	0.20882
	Solanum tuberosum L.	P	0.61877
Urticaceae	*Cecropia pachystachya*Trécul	P	0.11765
Verbenaceae	*Aloysia triphylla* Royle	C/P	0.3874
Virbunaceeae	*Sambucus australis* Cham. &Schltd.	C/P	0.16414
Vitaceae	*Cissus sicyoides*L.	P	0.39172
	Vitis vinifera L.	C/P	0.4348
Zingiberaceae	*Curcuma longa* L.	C/P	0.24604
	Zingiber officinale Roscoe	C/P	0.32437

Supplementary material 3: PCoA showing that there was no difference in the set of species collected from mined areas between mining 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).



4 CHAPTER 3: DESCRIÇÃO DAS CARACTERÍSTICAS MORFOFISIOLÓGICAS, DE POLINIZAÇÃO, DISPERSÃO, BIOACUMULAÇÃO E USO DE ESPÉCIES VEGETAIS EM ÁREAS MINERADAS[1]

Blanco, G. D.[a*]; Marciniak, B.[a]; Tagliari, M.[b]; Campos, M. L.[c]; Hanazaki, N.[a]

[a] Laboratório de Ecologia Humana e Etnobotânica, Departamento de Ecologia e Zoologia, Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brasil.
[b] Municipal Faculty of Education and Environment, Clevelândia, St. Coronel Ferreira Belo, 85530-000, Paraná, Brazil
[c] Laboratório de Análises Químicas do Solo e Calcário, Departamento de Solos e Recursos Naturais, Universidade do Estado de Santa Catarina, Lages, Santa Catarina, Brasil

RESUMO

Áreas de extração de carvão mineral abandonadas representam um desafio socio-ambiental e de soberania alimentar, pois geralmente apresentam características de intensas alterações físicas e químicas e presença de elementos-traço, como Cd, Cr, Pb, Cu, Zn, entre outros. Por esta razão, não são todas as espécies vegetais que conseguem povoar estes ambientes. As espécies que conseguem povoar estes ambientes podem estar sendo selecionadas devido a presença de características que facilitam sua sobrevivência, tais como tipo de raiz, forma de vida e/ou capacidade bioacumuladora. Além disso, esses ambientes minerados também têm proximidade com áreas habitadas por pessoas e o consumo de espécies contaminadas pode trazer riscos à saúde humana. O objetivo deste estudo foi descrever as características morfofisiológicas, de polinização, dispersão de sementes e o potencial bioacumulador das espécies vegetais que ocorrem em áreas de extração de carvão mineral abandonadas. Investigamos também o potencial uso medicinal e/ou alimentício associado a estas espécies. Compilamos uma lista de 451 espécies a partir de 8 estudos que analisaram a composição florística destas áreas na região sul do Brasil, com diferentes períodos temporais de abandono da mineração de carvão (de 3 a 40 anos). Ao longo do tempo estes ambientes passaram por alterações em relação à composição das espécies e de suas características, tais como, forma de polinização, dispersão de sementes, tipo de raiz e via fotossintética. A maior ocorrência foi polinização por entomofilia, dispersão de sementes por zoocoria e anemocoria, tipo de raiz fasciculada nos primeiros anos e via fotossintética C4 nos primeiros anos e C3 nos anos seguintes. A riqueza diminui e a presença de espécies com capacidade bioacumuladora aumentou nas áreas com maior tempo de abandono. Mais da metade das espécies (61,7 %) apresenta uso associado; 23,2 % das espécies foram estudadas quanto à bioacumulação e entre essas 93,3 % bioacumulam. Estes resultados apontam a possíveis alterações nas estruturas ecológicas locais de áreas de mineração, aumento da disponibilidade de elementos-traço no ambiente e riscos à saúde humana.

Palavras-chaves: Riqueza, Mineração, Origem, Bioacumulação, Etnoecologia.

4.1 INTRODUÇÃO

A despeito dos recentes avanços nos acordos internacionais sobre mudanças climáticas, que impõem limites sobre a extração de combustíveis fósseis (Arayara, 2021), as atividades de extração de minérios nos países em desenvolvimento e subdesenvolvidos tem crescido nas últimas décadas (Candeias *et al.* 2019). Entre esses minérios, o carvão é considerado um dos mais extraídos no mundo para fins energéticos (Finkelman *et al.* 2021). Dados recentes indicam que países como China e Estados Unidos apresentam aumento na emissão de gases de efeito estufa, perda de paisagem, contaminação de córregos e do solo, além de chuva ácida, em decorrência da extração de carvão mineral (Finkelman *et al.* 2021). A mineração de carvão pode ocorrer de duas formas: a céu aberto ou subterrânea. A mineração a céu aberto envolve a geração de grandes volumes de estéril e rejeitos carbonosos constituídos por rochas fragmentadas, compostos de enxofre como a pirita (FeS_2) e carvão de baixa qualidade (Gaivizzo *et al.*, 2002). Quando expostos às condições oxidantes do meio, a pirita e outros minerais sulfetados geram, entre outros produtos, o ácido sulfúrico, uma grande quantidade de metais que são lixiviados das rochas e minerais presentes nas camadas onde encontra-se a jazida de carvão mineral (Campos *et al.*, 2010), num processo conhecido como DAM (Drenagem ácida de mina). A DAM é caracterizada por baixo valor de pH ($\leq 3,0$), presença de Al, Fe, Mn e elementos-traço como As, Cd, Cu, Ni, Pb, Zn, Cr, Hg em composições e concentrações que dependem da cinética dos processos geoquímicos (Robertson,1994; Alexandre,1999, Campos *et al.*, 2010; Haldar, 2018), mineralogia, tipo e quantidade de sulfeto oxidado, temperatura, ação bacteriana (*Thiobacillus ferrooxidans*), entre outros fatores específicos de cada ambiente (Muniz, 2009). A acidez do solo pós-mineração aumenta a disponibilidade de Al e Mn na solução do solo e por consequência torna esses elementos mais disponíveis para absorção pelas plantas. O Mn é um micronutriente, que assim como os outros micronutrientes (como Cu e Zn), tem a faixa entre essenciabilidade e toxidez muito estreita

(Campos *et al.*, 2010). Já elementos como, por exemplo, o Al não apresenta função biológica e são tóxicos, interferindo diretamente no crescimento radicular (Campos *et al.*, 2010).

Atividades de mineração a céu aberto tem levado também ao aumento no número de áreas abandonadas, outrora utilizadas para extração mineral de carvão (Finkelman *et al.* 2021; Worlanyo & Jiangfeng 2021). O uso e abandono de áreas utilizadas para extração mineral no mundo é tão grande que se faz difícil estimar o seu tamanho total. Somente nos Estados Unidos, das áreas conhecidas, existem aproximadamente 390.000 áreas que foram mineradas e foram abandonadas (United States Government Accountability Office, 2020). Essas áreas abandonadas contribuem com severos impactos negativos (e.g., contaminação no solo, nos vegetais e recursos hídricos) (Adewumi & Laniyan 2020), além de impactos na saúde humana (e.g., doenças crônicas e cânceres) (Adewumi & Laniyan 2020; Adewumi *et al.* 2020). No processo de sucessão ecológica, essas áreas têm apresentado menor riqueza de espécies, favorecimento de espécies com características específicos (e.g., forma de vida herbácea, polinização por anemofilia) (Kirmer *et al.* 2008), aumento de espécies exóticas (Lemke *et al.* 2013), contaminação da cadeia alimentar (Blanco *et al.* 2020) e diminuição dos serviços ecossistêmicos (Wu *et al.* 2020).

Compreender quais espécies vegetais estão se estabelecendo nestes ambientes e quais suas características pode ajudar a compreender melhor quais espécies conseguem se desenvolver nestes ambientes, quais características podem ser favoráveis e quais os possíveis impactos destas áreas nas interações ecológicas (Freitas *et al.* 2012; Cianciaruso *et al.* 2009). Principalmente em regiões com pouca informação, como áreas de exploração mineral de carvão do sul do Brasil, que pouco se sabe da situação ecológica das áreas antes da mineração, o número e localização de algumas das áreas abandonadas e o tempo exploração mineral. Algumas destas características como, por exemplo, o tipo de raiz (Fan *et al.* 2021), forma de vida (Guo *et al.* 2020) e ciclo de vida (Quintela-Sabarís *et al.* 2020; Day *et al.* 2010), via fotossintética (Srivastava *et al.* 2012), síndromes de dispersão (Kirmer *et al.* 2008) e de polinização (Phillips *et al.* 2021), têm sido investigadas, para compreender melhor as respostas das espécies vegetais que ocorrem em áreas impactadas pelas atividades de mineração (Kirmer *et al.* 2008).

Estas características têm sido investigadas pois, a comunidade vegetal que se estabelece em áreas que foram mineradas deve estar adaptada a uma baixa diversidade e à redundância funcional comprometida das comunidades microbianas (e.g., falta de bactérias fixadoras de N_2), solos pobres em macro e micronutrientes e presença de elementos-traço (Fan *et al.* 2021). Por estas razões, por exemplo, é possível encontrar um maior número de espécies que apresentem as raízes pouco desenvolvidas e com menor volume, diâmetro e comprimento radicular, dominando principalmente as camadas superiores do solo (Fan *et al.* 2021; Day *et al.* 2010). Espécies com ciclo de vida perene e com crescimento de raiz lateral tendem a ter mais sucesso e conseguir sobreviver em áreas mineradas porque passam por um período maior de adaptação e podem aguardar melhores condições do ambiente para florescerem e dispersarem as suas sementes (Day *et al.* 2010; Quintela-Sabarís *et al.* 2020). Assim, essas espécies podem criar um habitat favorável para a colonização de outras espécies devido ao crescimento de suas raízes, ajudando no controle da erosão do solo e retenção de água e minerais (Quintela-Sabarís *et al.* 2020).

Além disso, dado o déficit de bons competidores e possíveis predadores em áreas mineradas abandonadas, as espécies exóticas podem ser favorecidas, como foi observado em áreas mineradas para extração de carvão na China (Lemke *et al.* 2013). Nestes ambientes também encontramos espécies dominantes com forma de vida herbácea e adaptabilidade a ambientes contaminados, resistência a temperaturas elevadas e rápida resposta a mudanças no ambiente (Sarma & Barik 2011a; Guo *et al.* 2020). A diversidade de espécies herbáceas é um dos fatores que influenciam na estrutura e função do ecossistema, na composição da comunidade de plantas e no *pool* de nutrientes do solo (Guo *et al.* 2020). Além disso, na fisiologia das espécies vegetais que ocorrem nestes ambientes predomina a via fotossintética C4, associada a uma melhor capacidade de sobrevivência em ambientes contaminados por elementos-traço (Srivastava *et al.* 2012). Espécies C4 conseguem utilizar elementos como Manganês (Mn) e Cádmio (Cd) (abundantes em áreas de mineração de carvão) para o processo de fotossíntese (Srivastava *et al.* 2012; Sivaram *et al.* 2018).

A abundância de metais como Mn, Alumínio (Al), Cd e Chumbo (Pb) nessas áreas pode afetar também a polinização das espécies. Alguns destes elementos são tóxicos para os insetos e podem diminuir e afetar a atratividade dos recursos florais para os polinizadores (Phillips *et al.* 2021). A taxa de visitação de animais polinizadores que ocorrem em áreas mineradas pode ser reduzida em até 41% para o caso de abelhas (Sivakoff & Gardiner 2017; Phillips *et al.* 2021). Assim, as espécies vegetais que se estabelecem em áreas abandonadas pela mineração podem apresentar uma menor visitação de polinizadores, e quando isso ocorre, a polinização tende a ser feita por entomofilia. As áreas de mineração também podem funcionar como grandes receptores de sementes, pois são áreas abertas e sem competidores nos primeiros anos (Lemke *et al.* 2013; Kirmer *et al.* 2008), ainda que grande parte destas espécies não venham a germinar (Lemke *et al.* 2013; Kirmer *et al.* 2008). Entretanto, ainda se sabe pouco sobre os mecanismos de dispersão de espécies que povoam áreas de mineração abandonadas

(Lemke *et al.* 2013; Kirmer *et al.* 2008). Espécies que se estabelecem em áreas abandonadas pela mineração também podem bioacumular elementos-traço (e.g., Mg e Al) presentes nas camadas inferiores do solo (Campos *et al.* 2003; Blanco *et al.* 2020, Ali *et al.* 2019; Ashraf *et al.* 2019), sendo potenciais fontes de bioacumulação e transmissão de elementos tóxicos para a fauna (Ali *et al.* 2019) e para os seres humanos (Caldas & Machado 2004).

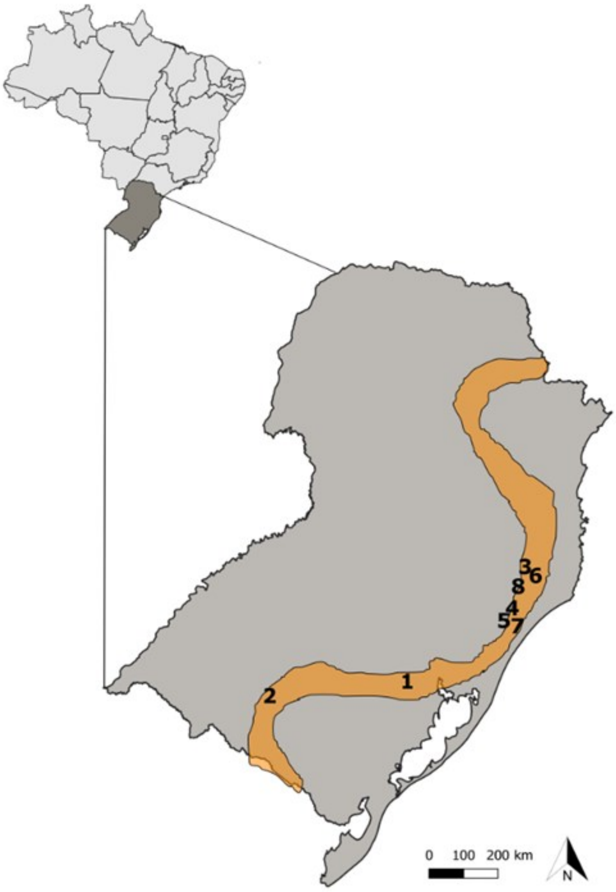
Diante desta situação e para investigar as características ecológicas da comunidade vegetal em áreas abandonadas pela mineração de carvão e seus potenciais impactos ecológicos e para soberania e segurança alimentar e saúde humana, os objetivos deste estudo são: I) descrever e compreender a riqueza, as características (*i.e.*, tipo de raiz, formas de dispersão de sementes e polinização, forma e ciclo de vida e via fotossintética), distribuição (*i.e.*, nativa do Brasil ou exótica) e o potencial bioacumulador das espécies que ocorrem ao longo do tempo em áreas que foram mineradas para extração de carvão; II) compreender se as espécies que apresentam uso associado (*i.e.*, medicinal ou alimentício) apresentam potencial bioacumulador em áreas que foram mineradas para extração de carvão.

4.2 MÉTODOS

4.2.1 Área de estudo

O estudo foi realizado na região carbonífera do sul do Brasil. Esta região se estende por três estados do país (Rio Grande do Sul, Santa Catarina e Paraná) (Belloli *et al.* 2002; Elias & Santos 2016). Esta região se localiza principalmente sob o domínio do Bioma de Mata Atlântica, caracterizado por ser uma região heterogênea, com diferentes fitofisionomias e elevada riqueza de espécies (Maçaneiro *et al.* 2016). As principais fitofisionomias da região são a Floresta Ombrófila Densa e Mista (Medeiros *et al.* 2005; Rezende *et al.* 2018). A região apresenta clima temperado mesotérmico, com temperaturas anuais 16-17 °C, umidade média anual entre 78-80% e precipitação total anual de 1.527 mm (Maçaneiro *et al.* 2016). Devido ao crescimento urbano, atividades industriais, extração mineral e exploração madeireira na região, hoje resta em torno 28% de cobertura vegetal original na região (Rezende *et al.* 2018). Entre as atividades que impactaram negativamente estes ambientes, a mineração de extração de carvão é uma das mais preocupantes (Blanco *et al.* 2020) (Figura 1).

Fig 1: Região carbonífera do sul do Brasil. Em laranja a região com maior concentração da atividade de extração mineral de carvão. Os números correspondem às áreas de estudo cujos levantamentos foram incluídos: 1- Butia, RS (Zocche e Porto, 1992); 2- Lavras do Sul, RS (Frizzo e Porto, 2004); 3- Urussanga, SC (Klein, 2006); 4- Siderópolis, SC (Santos *et al.*, 2007); 5- Siderópolis, SC (Costa, 2007); 6- Urussanga, SC (Klein *et al.* (2009); 7- Siderópolis, SC (Lorenzi *et al.*, 2013); 8- Treviso, SC (Machado, 2018).



A extração mineral de carvão na região começou no final do século XIX, sendo que o auge da extração foi entre as décadas de 1960 e 1980. Os estados do Rio Grande do Sul e Santa Catarina são responsáveis por 99% de toda a extração mineral de carvão do país (Belloli *et al.* 2002). Até 2017, a extração de carvão no Brasil estava em declínio, devido a mudanças na matriz energética do país, e pelo carvão da região ser considerado de baixa qualidade, sendo necessário elevados volumes de material extraído para atender principalmente o mercado interno do país (Elias & Santos 2016). Entretanto, no ano de 2020 e 2021 a política interna do país voltou a injetar investimentos econômicos na exploração de novas áreas para extração mineral de carvão, e aumentou o tempo de uso deste recurso até 2050 como fonte energética (Arayara, 2021). Muitas áreas que foram abandonadas não apresentam nenhum tipo de plano de restauração (Rocha-Nicoleite *et al.*, 2018). Esta região também apresenta um mosaico de áreas atualmente mineradas e a presença de diversos grupos humanos e centros urbanos (Blanco, Sühs, *et al.* 2020a; Blanco, Hanazaki, *et al.* 2020b).

4.2.2 Revisão bibliográfica e o banco de dados

Realizamos um levantamento bibliográfico em quatro plataformas de busca (Scopus, Science Direct, Google Acadêmico e Scielo) de artigos indexados que tivessem estudado a composição florística de áreas que foram mineradas para a extração do carvão mineral no sul do Brasil. Adicionalmente, consultamos especialistas e pesquisadores que atuam com o levantamento de espécies em áreas de mineração do sul do Brasil e que pertencem à Universidade do Estado de Santa Catarina da região de Criciúma. Estes pesquisadores nos encaminharam artigos, dos quais 3 foram incluídos na presente pesquisa. Foram encontrados ao todo 8 estudos realizados entre 1992 e 2018. Estes trabalhos foram realizados na região carbonífera do Rio Grande do Sul e de Santa Catarina (Fig 1). As áreas mineradas onde foram feitos esses levantamentos da vegetação variaram entre 3 e 40 anos de abandono (*i.e.* áreas que foram mineradas para extração mineral, mas não são mais exploradas) ou abandonadas com processo de restauração do solo (*i.e.*, recomposição topográfica e paisagística da áreas, e inclusão de camada de solo com nutriente e calcário). Em todos os estudos, consideramos apenas as espécies que se estabeleceram nas áreas no processo de sucessão secundária e não foram plantadas (Tabela 1).

Tabela 1: Estudos que registraram e analisaram a composição florística de áreas mineradas para a extração do carvão mineral no sul do Brasil.

Referência	Características/foco do estudo	Município	Tempo de abandono na data do estudo
Zocche e Porto (1992)	Levantamento de espécies herbáceas até arbustivas	Butiá, RS	7 anos de abandono
Frizzo e Porto (2004)	Levantamento de espécies herbáceas, herbaceo-arbustiva, arbórea e arbustivo-arbórea	Lavra do Sul, RS	20 anos de abandono
Klein (2006)	Levantamento de espécies Arbustos, árvores, trepadeira herbáceas, epífitas e ervas terrícolas	Urussanga, SC	28 anos de abandono
Santos *et al.* (2007)	Levantamento de espécies Árvores, arbustos, herbáceas terrícolas e videiras	Siderópolis, SC	40 anos de abandono
Costa (2007)	Levantamento de espécies herbáceo-arbustiva	Siderópolis, SC	3 anos de restauração
Klein *et al.* (2009)	Levantamento de espécies herbáceas até arbóreas	Urussanga, SC	28 anos de abandono
Lorenzi *et al.* (2013)	Avaliação da composição florística e estrutura fitossociológica das comunidades vegetais	Siderópolis, SC	37 anos de abandono
Machado (2018)	Levantamento de espécies herbáceo-subarbustiva	Treviso, SC	9 anos de restauração

Compilamos uma lista de espécies citadas nos artigos, posteriormente verificada quanto à possibilidade de sinonímias usando Flora do Brasil 2020 (Flora do Brasil, 2020). Com base nesta lista de espécies, acessamos os bancos de dados da Plant Trait Database (Kattge *et al.* 2020) para identificar as características morfofisiológicas das espécies: tipo de raiz (pivotante ou fasciculada); formas de vida (herbácea, trepadeira, liana, arbusto, árvore, epífita);

via fotossintética (C3, C4, CAM); ciclo de vida (perene, anual). Verificamos as síndromes de dispersão de sementes (anemocoria, autocoria, zoocoria) e de polinização (anemofilia, entomofilia—incluindocantarofilia, psicofilia, fanelofilia, zoofilia—incluindoornitofilia, quiropterofilia). Para identificar se as espécies são nativas ou exóticas do Brasil utilizamos a Flora do Brasil 2020 (Flora do Brasil, 2020), a Base de Dados Nacional de Espécies Exóticas para Santa Catarina (Base de Dados Nacional de Espécies Exóticas Invasoras, 2021) e a Global Biodiversity Information Facility (Rivas *et al.*, 2017). Para complementar as informações de polinização e dispersão de sementes para aquelas espécies que não foram encontradas no Plant Trait Database acessamos também a Encyclopediaof Life (Chaves *et al.*, 2009) e Interaction Web Database (Bezerra *et al.*, 2009; Santos *et al.* 2010; Genrich *et al.*, 2016); e Guislon (2015); Gressler *et al.* (2006); Costa (2017); José & Timóteo (2014) e Dalló (2018).

Ao todo foram 15 áreas estudadas nos 8 artigos levantados. A média do tempo de abandono das áreas foi de 20 anos e as áreas foram agrupadas em três períodos: a) 3 anos até 10 anos após a mineração; b) 11 anos até 25 anos após a mineração e; c) 26 anos até 40 anos após a mineração. Este agrupamento foi realizado levando em conta o número total 15 áreas estudadas nos 8 artigos, ou seja, para cada período, foram selecionadas 5 áreas, para que se pudesse analisar temporalmente as características das espécies.

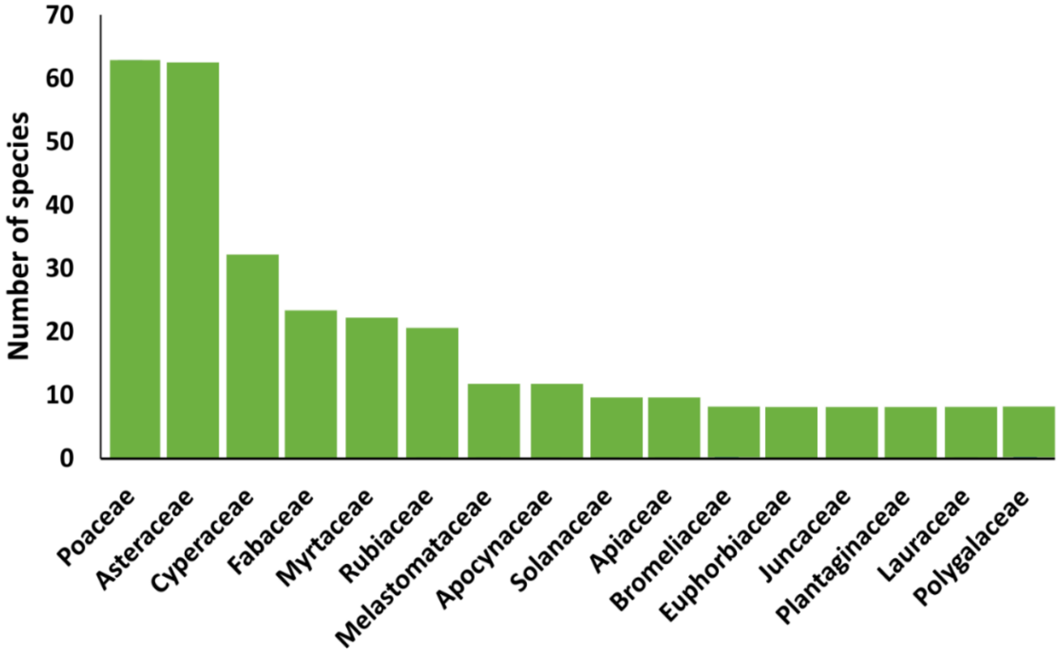
Para o levantamento do potencial bioacumulador realizamos um levantamento bibliográfico na plataforma Scopus utilizando a palavra “bioaccumulation” mais o nome da espécie. A plataforma Scopus foi a que retornou o maior número de resultados após a busca. Cada artigo retornado nessa busca foi avaliado para identificar se a espécie bioacumulava, não bioacumulava ou se os resultados eram inconclusivos; e verificamos também quais partes da planta foram estudadas em cada artigo.

Por fim, verificamos o uso alimentício e/ou medicinal das espécies nos bancos de dados do World Checklist KEW (Govaerts *et al.* 2021) e Useflora (Useflora 2021); bem como as partes usadas. A lista com todas as espécies e informações compiladas podem ser acessadas no Supplementary material 1.

4.3 RESULTADOS

Ao todo foram encontradas 451 espécies distribuídas em 88 famílias botânicas, sendo as famílias mais representativas Poaceae (63 espécies), Asteraceae (62 espécies) e Cyperaceae (32 espécies) que juntas englobaram 34,5 % das espécies (Fig. 2). As espécies mais frequentes nos estudos foram: *Alchornea triplinervia* (11 áreas), *Baccharis dracunculifolia* (10 áreas), *Myrsine coriacea* (9 áreas) e *Cabralea canjerana* (8 áreas).

Fig2: Principais famílias botânicas e o seu número respectivo de espécies identificadas nas áreas de mineração no sul do Brasil.



Um total de 266 espécies ocorreram em áreas abandonadas, 151 espécies em áreas recuperadas e 34 espécies em ambas as áreas. Em relação à distribuição, 85,4 % (388 espécies) são nativas, 13,2% (60 espécies) exóticas, sendo que destas 35,0 % (21 espécies) são invasoras, e 1,0 % (6 espécies) não puderam ter sua distribuição determinada.

4.3.1 Características morfofisiológicas, de polinização e dispersão de sementes

A principal via fotossintética das espécies vegetais que ocorrem nas áreas mineradas para extração de carvão foi C3 (70,7 % das ocorrências, ou 321 espécies). Quanto ao tipo de raiz, 63,2 % (287 espécies) tinham raiz pivotante e 30,4 % (152 espécies) fasciculada. Predomina a forma de vida herbácea (50,6 % ou 230 espécies), seguida por arbustiva (20,2 %, ou 92 espécies). Em relação ao ciclo de vida, 69,1 % (314 espécies) são perenes e 18,9 % (86 espécies) são anuais; o restante das espécies não foi possível identificar o seu tipo de ciclo de vida. As formas de polinização foram: 49,4 % (223 espécies) entomofilia, 21,3 % (97 espécies) anemofilia, 11,3 % (51 espécies) zoofilia e 1,1 % (5 espécies) autofilia. Já em relação às principais formas de dispersão das sementes, 29,2 % (132 espécies) foi por zoocoria, 26,8 %

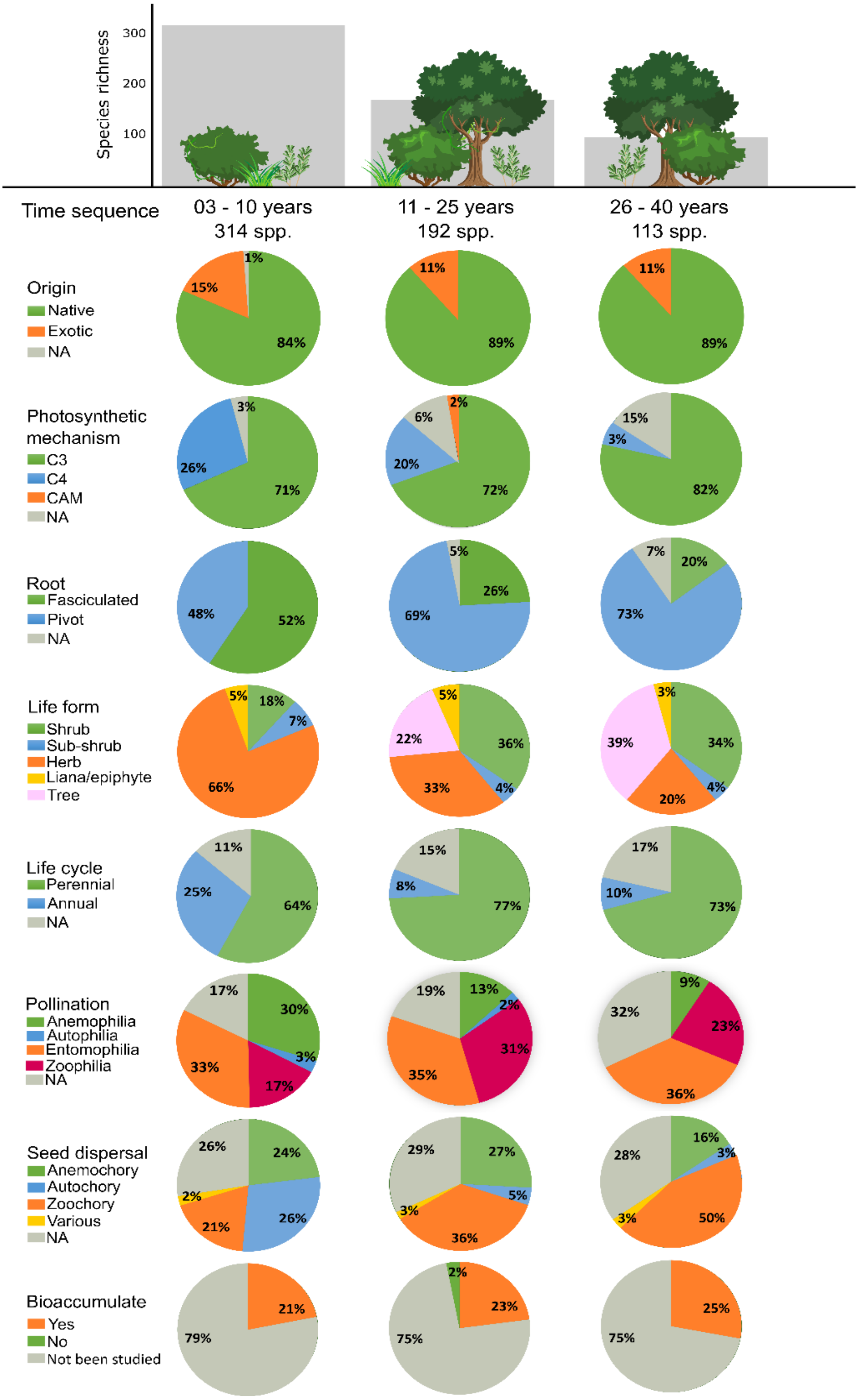
(121 espécies) por anemocoria e 19,2 % (85 espécies) por autocoria.

4.3.2 Descrição das características morfofisiológicas das espécies ao longo do tempo

Em áreas com diferentes períodos de tempo de sucessão as características morfofisiológicas, de polinização, dispersão de sementes e bioacumulação da comunidade vegetal varia (Fig.3). As espécies nativas predominam em todos os períodos, mas no período de 26 anos até 40 anos 50% das espécies que são exóticas, também são consideradas invasoras. Apesar do predomínio das espécies com metabolismo C3, a proporção de espécies C4 é maior nas áreas com menos tempo de abandono (de 3 até 10 anos) quando comparada aos outros períodos. Espécies com raiz fasciculada predominam no período de 3 anos até 10 anos, mas sua proporção é menor do que as espécies pivotantes nos períodos de 11 anos até 25 anos e de 26 anos até 40 anos (69,2 % e 73,4 %, respectivamente). As espécies herbáceas, mais frequentes no período de 3 anos até 10 anos, são substituídas por arbustos (34,8 % das espécies) no período de 11 anos até 25 anos e árvores (38,0 % das espécies) no período de 26 anos até 40 anos.

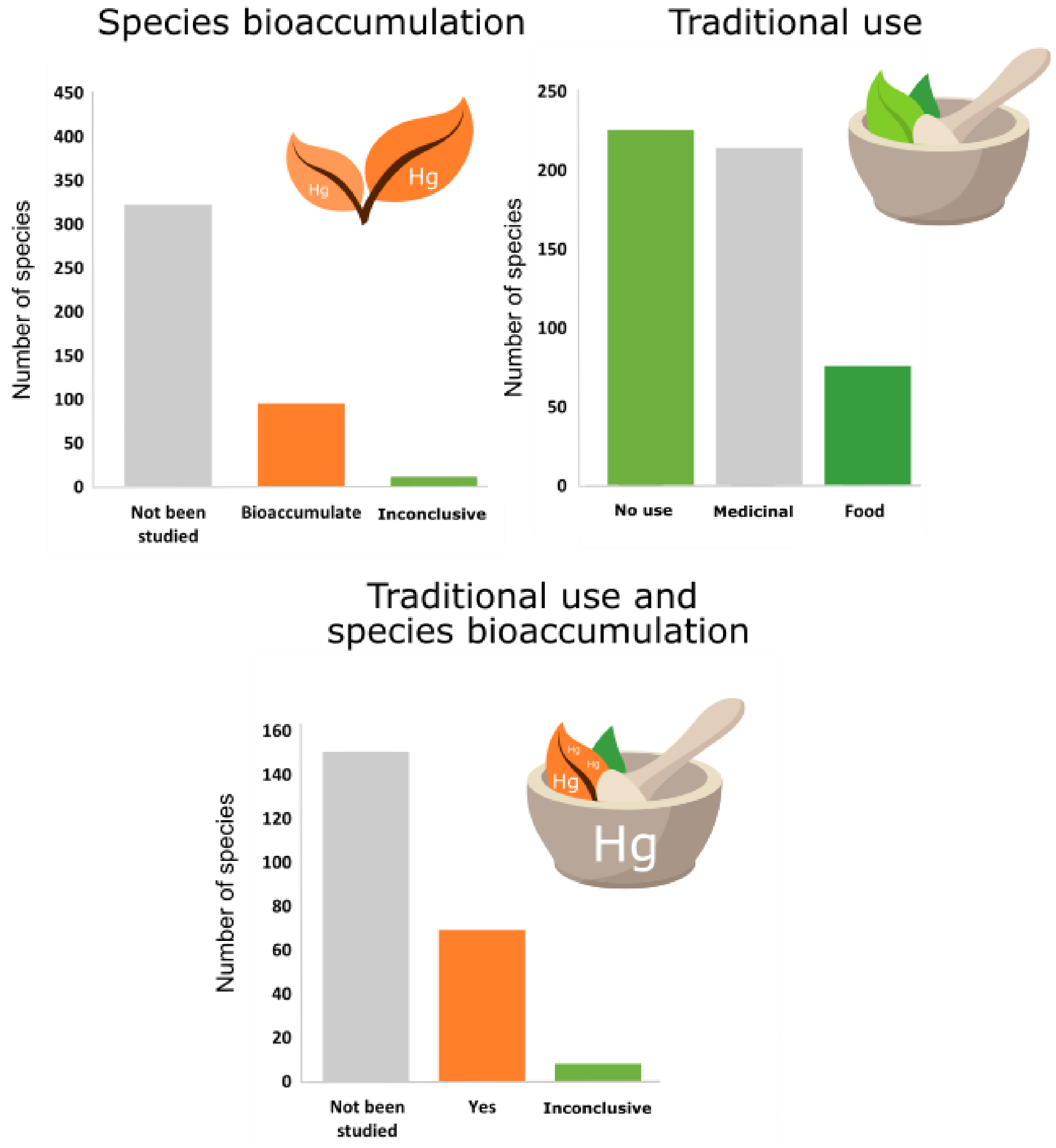
O ciclo de vida anual, presente em 23,8 % das espécies no período de 3 anos até 10 anos, diminui para menos de 10,0 % ao longo do tempo. As principais formas de polinização foram a entomofilia (mais de 30,0 % em todos os períodos) e a anemofilia principalmente no período de 3 até 10 anos, e a zoofilia aparece nas áreas com período de 11 anos até 25 anos e no período de 26 anos até 40 anos. A dispersão de sementes no período de abandono mais recente é principalmente por autocoria e anemocoria, mas nos períodos seguintes a zoocoria se torna a principal forma de dispersão (Fig. 3).

Fig. 3: Resumo das características morfofisiológicas, polinização, dispersão de sementes, e bioacumulação das espécies ao longo do tempo em áreas que foram mineradas para extração de carvão.NA= informação não encontrada



Em relação à bioacumulação, das 451 espécies, encontramos estudos para 105 delas e, destas, 93,3 % (98 espécies) são bioacumuladoras (Fig. 4). As partes analisadas nos estudos de bioacumulação foram, principalmente, 31,4% folhas, 23,6% planta inteira, 11,8% raiz e 11,0 % fruto. Há registro de uso alimentício para 15,2 % das espécies (69 espécies) e de uso medicinal para 46,5 % (210 espécies) (Fig. 4). Para aquelas espécies com evidências de bioacumulação, 76 delas apresentam uso associado. Para a maior parte dessas 76 espécies (92,0 %), a parte da planta consumida é também aquela na qual foi identificada a acumulação de elementos-traço.

Fig. 4: Bioacumulação e do uso tradicional associado das espécies vegetais que ocorrem em áreas que foram mineradas para extração de carvão e foram abandonadas no sul do Brasil.



4.4 DISCUSSÃO

O perfil das espécies que povoam as áreas de mineração abandonadas sofre transformações ao longo do tempo. A maior presença de espécies bioacumuladoras e espécies invasoras nestes ambientes são alertas preocupantes das transformações ecológicas favorecidas pela atividade de mineração. A presença de espécies anuais, de metabolismo C4 e raiz fasciculada nos anos iniciais de povoamento indica uma comunidade vegetal que se adapta a esses ambientes alterados, mesmo em áreas nas quais houve a colocação de uma camada de solo após o abandono da mineração (Figueiredo *et al.* 2012; Guo *et al.* 2020). Ao longo do tempo, esses ambientes favorecem espécies de ciclo de vida perene, de raiz pivotante e metabolismo C3. A presença de elementos-traço nestes ambientes pode estar favorecendo algumas dessas características, e pode também resultar em outros impactos da entomofilia e zoocoria, além de ameaçar a segurança alimentar quando são bioacumulados em plantas usadas na alimentação ou medicina.

No período de 3 anos até 10 anos, que corresponde ao período inicial de povoamento e mais desafiador para o estabelecimento das espécies num ambiente que teve seu solo alterado e a vegetação removida, observamos a predominância de espécies herbáceas e com raiz fasciculada. Em áreas mineradas e com potencial presença de elementos-traço, as espécies herbáceas tendem a povoar melhor estes ambientes do que espécies com outras formas de vida (Guo *et al.* 2020; Sarma & Barik 2011b). Isso ocorre, pois, as herbáceas apresentam melhor adaptabilidade a ambientes alterados e resistência a mudanças no meio ambiente (Guo *et al.* 2020; Sarma & Barik 2011b). Na Índia, a riqueza de herbáceas nos primeiros anos de povoamento é significativamente maior em áreas mineradas do que em áreas não mineradas (Sarma & Barik 2011b). Entretanto, mesmo entre as áreas mineradas pelo carvão, nos primeiros anos de povoamento, a riqueza de espécies de herbáceas varia significativamente, como foi observado na China (Guo *et al.* 2020). Esta variação tem sido atribuída a variação na densidade e disponibilidade de micro e macronutrientes no solo, a variação na temperatura média, principalmente no inverno, e a variação na precipitação média (Guo *et al.* 2020). Os resultados descritos no presente estudo parecem indicar que, assim como nas áreas de mineração de carvão abandonadas na Índia e na China, as espécies herbáceas e com raiz fasciculada predominam na colonização inicial destes ambientes.

Mesmo que as espécies com metabolismo C3 tenham sido mais numerosas, no período de 3 anos até 10 anos as espécies C4 representaram 26 % das espécies neste período. As espécies C4 destas áreas pertencem em sua maioria às famílias Poaceae (72 %) e Cyperaceae (20 %), sendo em sua maioria gramíneas e com raízes fasciculadas, como *Andropogon bicornis*, que foi a espécie C4 mais frequente nos estudos. Em áreas de mineração de carvão na Índia, espécies C4 e fasciculadas tem se mostrado importantes na restauração de solos contaminados por elementos-traço (e.g., Cd), melhorando a qualidade do solo (*i.e.*, auxiliam na reciclagem de macro e micronutrientes) e conseguindo diminuir a erosão do solo (as raízes fasciculadas contribuem para reter o solo, protegendo contra a lixiviação) (Rusinowski *et al.* 2019; Sivaram *et al.* 2018). Para a região estudada, espécies como *A. bicornis* podem estar favorecendo a restauração desses ambientes; além disso, *A. bicornis* é uma espécie nativa da região sul do Brasil, que apresenta uma alta taxa de germinação em ambientes contaminados por elementos-traço (Figueiredo *et al.* 2012).

A polinização por entomofilia foi a principal síndrome das espécies no período de 3 anos até 10 anos. O mesmo foi observado em áreas de mineração de carvão abandonadas e contaminadas por elemento-traço na China (Xun *et al.* 2018), mas com uma redução no tempo de forrageamento e quantidade de néctar coletado pelos polinizadores, quando comparado com áreas vizinhas sem contaminação por elemento-traço (Xun *et al.* 2018). Na Índia também foi observado uma diminuição de forrageamento das abelhas de 40% nesse tipo de ambiente (Sivakoff & Gardiner 2017). Os elementos-traço oriundos das atividades de mineração e disponíveis em níveis elevados no solo também se acumulam no néctar das flores e influenciam negativamente a dinâmica de polinização (Xun *et al.* 2018; Sivakoff & Gardiner 2017). Elementos como Cd e selênio (Se) em níveis acima do recomendado pelas organizações nacionais de saúde tem sido observado no mel das abelhas que polinizam espécies contaminadas por elementos-traço (Burden *et al.* 2019). Além da diminuição da frequência de forrageamento dos polinizadores, na Índia o grupo de abelhas que visita estas espécies teve uma diminuição na riqueza e abundância (Dawid Moroń *et al.* 2012). Nos períodos seguintes, de 11 anos até 25 anos, e de 26 anos até 40 anos, a zoofilia passou a ser uma das três principais síndromes de polinização. Esta maior visitação de diferentes espécies para polinização pode representar uma fonte potencial de distribuição de elementos-traço para outras áreas e outros grupos de espécies, como já observado na Índia (Hladun *et al.* 2015).

Anemocoria e autocoria foram as principais síndromes de dispersão de sementes no período de 3 anos até 10 anos, provavelmente devido à baixa atratividade do ambiente para animais dispersores (Alday *et al.* 2011). Com o passar do tempo, o aumento de atrativos florísticos e a mudança na composição da comunidade vegetal, a zoocoria passa a ser a síndrome dominante de dispersão no período de 11 anos até 25 anos e de 26 até 40 anos. Entre os grupos dispersos por zoocoria Myrtaceae foi a família com o maior número de espécies (26,4

%) e o gênero *Eugenia* e *Syzygium* foram os mais representativos. Algumas espécies destes gêneros, como a *Eugenia uniflora* L. e *Syzygium cumini* (L.) Skeels têm revelado potencial em bloquear ou reverter o efeito tóxico de elementos-traço (e.g. Hg) no ambiente, impedindo que estes elementos atinjam outras espécies ou se concentrem em níveis elevados nos seus tecidos e se acumulem nas suas sementes (Cunha *et al.* 2019; Sobral-Souza *et al.* 2014). Essas adaptações minimizam os efeitos deletérios de uma alta concentração de elementos-traço, já que espécies sem estes mecanismos podem ter comprometido o seu potencial de dispersão de sementes e sua germinação, com uma baixa produção de sementes, formação de anomalias na semente, não formação da raiz ou diminuição no crescimento da raiz, e bloqueio nos processos bioquímicos que sinalizam para início da germinação (Sethy & Ghosh 2013).

Espécies perenes representam mais de 50 % das espécies em todos os períodos, concordando com estudos que mostram que as espécies perenes são mais comuns em áreas mineradas (Quintela-Sabarís *et al.* 2020). Já a presença de espécies anuais no início da colonização de ambientes minerados (25 % no período de 3 até 10 anos) pode estar relacionada às suas características de início de processo sucessional, mas também à presença de elementos-traço que estão mais disponíveis nos anos iniciais após o abandono da mineração, além das concentrações elevadas de fósforo, que auxilia no crescimento rápido dessas espécies (Alday *et al.* 2011).

No período de 11 anos até 25 anos e de 26 anos até 40 anos, observamos tanto a diminuição na riqueza de espécies como o aumento de espécies invasoras. Em áreas mineradas pelo carvão na Espanha foi observado um padrão semelhante: a riqueza das espécies aumentou nos 13 primeiros anos após o abandono e dos 14 anos até os 32 anos houve uma queda na riqueza (Hernández & Pastor 2008). A diminuição da riqueza de espécies em áreas mineradas para extração de carvão e abandonadas também foi observada em Gana e esta diminuição pode estar associada à presença de elementos-traço (Nero 2021). Na Espanha, as espécies lenhosas aumentaram exponencialmente 32 anos após o abandono (Alday *et al.* 2011; Hernández & Pastor 2008). Este aumento é relacionado à melhoria no processo de restauração da vegetação ao fixar o nitrogênio atmosférico, produzindo uma grande quantidade de matéria orgânica do solo e aumentando a mineralização de nitrogênio, facilitando assim a invasão e o desenvolvimento de espécies de sucessão tardia (Alday *et al.* 2011).

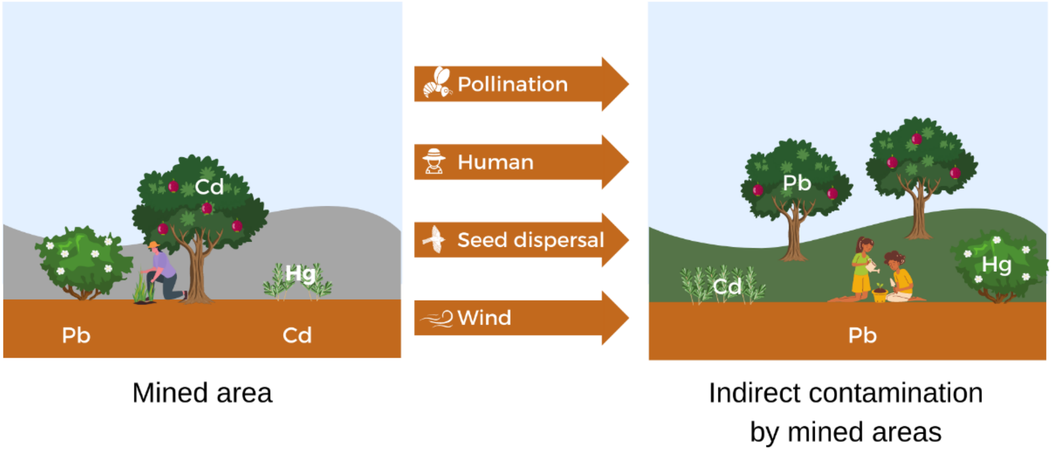
No período mais tardio houve um aumento de espécies exóticas: entre as arbóreas, 50 % eram invasoras como, por exemplo, *Acacia mearnsii* Wild, *Morus alba* L. e *Psidium guajava* L. As espécies exóticas, ainda que em menor número do que as espécies nativas, são preocupantes devido ao seu poder de distribuição em áreas alteradas (Lemke *et al.* 2013). *P.*

guajava bioacumula elementos-traço (e.g. Pb) em suas folhas e frutos e, dependendo da intensidade do consumo, pode representar um risco à segurança alimentar das pessoas (Gutiérrez 2015).

Ao longo do tempo, observamos o aumento de espécies com potencial bioacumulador. Os elementos-traço que são bioacumulados impactam desde a fisiologia individual das espécies até a dinâmica e funcionamento das comunidades (Adams *et al.* 2015). Elementos-traço como os metais pesados impactam severamente a dinâmica do solo (Adams *et al.* 2015), os níveis de C:N (Meifang Yan *et al.* 2020; Ata-Ul-Karim *et al.* 2020), desequilibram as concentrações dos nutrientes de minerais (Ata-Ul-Karim *et al.* 2020) e afetam o funcionamento da microbiota do solo (Chen *et al.* 2013). O funcionamento dos órgãos vegetais e processos fotossintéticos ficam mais lentos (Rusinowski *et al.* 2019), a absorção de CO_2 é prejudicada (Meifang Yan *et al.* 2020) e a biomassa das plantas diminui mesmo em espécies bioacumuladoras (Rusinowski *et al.* 2019). Estes elementos-traço podem ser distribuídos ao longo da cadeia alimentar, através do néctar, pólen, folhas, frutos e casca das plantas (Phillips *et al.* 2021; Moreira 1996) (Fig. 5). Estes elementos-traço oriundos da mineração também ameaçam a segurança alimentar de comunidades locais e tradicionais. Na Amazônia, o mercúrio contamina o leite materno dosYanomami (Ramos *et al.* 2020); na Espanha, espécies frutíferas apresentam concentrações de Pb e Cd em seus frutos consumidos localmente (Grau-Perez *et al.* 2018; Fernández *et al.* 2016); em Gana, elementos-traço foram encontrados na urina de crianças de comunidades locais (Bortey-Sam *et al.* 2015).

Apesar das limitações do presente estudo, tais como, ausência de estudos em áreas não mineradas para comparação dos resultados aqui encontrados, ausência de dados sobre a abundância das espécies, uso de diferentes esforços amostrais dos estudos, duração da atividade mineradora e forma da extração mineral em cada área, nossos resultados trazem um alerta sobre aspectos importantes da bioacumulação e das características morfofisiológicas, de polinização e dispersão de sementes de espécies que podem influenciar na estruturação de comunidades ecológicas e na contaminação para as pessoas (Fig.5). Identificamos aspectos que devem ser foco de estudos futuros, como a análise da capacidade bioacumulativa das espécies que ocorrem nestas áreas, estudos sobre as guildas de polinizadores e dispersores de sementes e possíveis mudanças nos seus comportamentos de forrageamento, e avaliação do risco ecotoxicológico das espécies consumidas por moradores no entorno destes ambientes.

Fig. 5. Áreas mineradas para extração de carvão e abandonadas funcionando como possíveis centros de dispersão de elementos-traço. Dispersão de elementos-traço de áreas mineradas para áreas que não foram mineradas, por meio da polinização, coleta e dispersão humana, dispersão de sementes e dispersão de propágulos, sementes, pólen e elementos-traço pelo vento.



4.5 CONCLUSÃO

A capacidade bioacumuladora de elementos-traço em áreas de mineração pode representar um dos grandes desafios socioambientais do século, tanto por seus impactos nas comunidades ecológicas como por ser um risco à soberania alimentar e à saúde das pessoas. O povoamento de espécies vegetais em áreas de mineração para extração do carvão que foram abandonadas pode ser fortemente afetado pela presença de elementos-traço. Ao longo do tempo as características dessas áreas intensamente alteradas tendem a selecionar espécies com conjuntos de características que potencializam a dispersão de elementos-traços para áreas vizinhas não mineradas. O estudo do potencial de bioacumulação dessas espécies que ocorrem em áreas alteradas pela mineração necessita maiores esforços, principalmente para espécies que apresentam uso alimentício ou medicinal associados e para aquelas espécies-chave que são importantes para outros grupos ecológicos, que podem dispersar elementos-traço através da polinização e dispersão de sementes.

4.6 REFERÊNCIAS

ABAD, M. J.; BERMEJO, P. *Baccharis* (compositae): A review update. *Arkivoc*, n. 7, p. 76–96, 2007.

ADAMS, J.; GOODEY, N. M.; GALLAGHER, F. Soil Biology & Biochemistry Plant e soil interactions in metal contaminated soils. *Soil Biology and Biochemistry*, v. 80, p. 224–231, 2015.

ADEWUMI, A. J.; LANIYAN, T. A. Contamination, sources and risk assessments of metals in media from Anka artisanal gold mining area, Northwest Nigeria. *Science of the Total Environment*, v. 718, p. 137235, 2020.

ADEWUMI, A. J. P. *et al.* Exposure of children to heavy metals from artisanal gold mining in Nigeria: evidences from bio-monitoring of hairs and nails. *Acta Geochimica*, v. 39, n. 4, p. 451–470, 2020.

ALDAY, J. G. *et al.* Functional groups and dispersal strategies as guides for predicting vegetation dynamics on reclaimed mines. *Plant Ecology*, v. 212, n. 11, p. 1759–1775, 2011.

ALI, H.; KHAN, E.; ILAHI, I. Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. *JournalofChemistry*, v. 19, 2019.

ARAUJO, ELIANA ROCHA. Fechamento de minas no Brasil não tem legislação federal específica e coloca em risco o ambiente e populações locais. *Centro de Tecnologia Mineral*, p. 1–26, 2015.

ARAUJO, ELIANE R; CHAVES FERNANDES, F. R. Mineração no Brasil: crescimento econômico e conflitos ambientais. *Mineração no Brasil*, p. 65–68, 2016, 2009.

ASGARI LAJAYER, B.; GHORBANPOUR, M.; NIKABADI, S. Heavy metals in contaminated environment: Destiny of secondary metabolite biosynthesis, oxidative status and phytoextraction in medicinal plants. *Ecotoxicology and Environmental Safety*. v. 7, 2007.

ASHRAF, S. *et al.* Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. *Ecotoxicology and Environmental Safety*, v. 174, p. 714–727, 2019.

ATA-UL-KARIM, S. T. *et al.* Effects of soil properties, nitrogen application, plant phenology, and their interactions on plant uptake of cadmium in wheat. *JournalofHazardousMaterials*, v. 384, p. 121452, 2020.

BASE DE DADOS NACIONAL DE ESPÉCIES EXÓTICAS INVASORAS.Instituto Hórus de Desenvolvimento e Conservação Ambiental, Florianópolis – SC. 2021. Disponível em: <http://bd.institutohorus.org.br.>

BELLOLI, M.; QUADROS, J.; GUIDI, A. *História do carvão de Santa Catarina*. 1ª ed. Criciúma: Imprensa Oficial do Estado de Santa Catarina, 2002.

BERTHIER-FOGLAR, S.; GAUDICHAUD, F.; TOLAZZI, S. Recursos minerais nas Américas: Mutações de um continente. *IdeAs*, v. 8, p. 1–6, 2016.

BEZERRA, E. L. S, I. C. MACHADO & M. A. R. MELLO. Pollination networks of oil-flowers: a tiny world within the smallest of all worlds. Journal of Animal Ecology 78: 1096-1101, 2009.

BLANCO, G. D.; HANAZAKI, N.; *et al.*a. Exploring the interfaces between ethnobiology and ecotoxicology: A novel approach. *Ethnobiology letters*, v. 11, p. 29–37, 2020.

BLANCO, G. D.; SÜHS, R. B.; *et al.*b. Invisible contaminants and food security in former coal mined areas of Santa Catarina, southern Brazil. *Journal of Ethnobiology and Ethnomedicine*, v. 16, p. 1–11, 2020.

BORTEY-SAM, N. *et al.* Human health risks from metals and metalloid via consumption of food animals near gold mines in Tarkwa, Ghana: Estimation of the daily intakes and target hazard quotients (THQs). *Ecotoxicology and Environmental Safety*, v. 111, p. 160–167, 2015.

BRIONES ALONSO, E.; COCKX, L.; SWINNEN, J. Culture and food security. *Global Food Security*, v. 17, p. 113–127, 2018.

BURDEN, C. M. *et al.* Acute sublethal exposure to toxic heavy metals alters honey bee (*Apis mellifera*) feeding behavior. *Scientific Reports 2019 9:1*, v. 9, n. 1, p. 1–10, 2019. 2021.

CALDAS, E. D.; MACHADO, L. L. Cadmium, mercury and lead in medicinal herbs in Brazil. *Food and Chemical Toxicology*, v. 42, n. 4, p. 599–603, 2004.

CAMPOS, M. L.; ALMEIDA, J. A.; SOUZA, L. S. Avaliação de três áreas de solo construído após mineração de carvão a céu aberto em Lauro Müller, Santa Catarina. *Revista Brasileira de Ciência do Solo*, v. 27, n. 6, p. 1123–1137, 2003.

CANDEIAS, C. *et al.* Mining activities: Health impacts. *Encyclopedia of Environmental Health*, p. 415–435, 2019.

CHAVE J, COOMES D, JANSEN S, LEWIS SL, SWENSON NG, ZANNE AE. Towards a worldwide wood economics spectrum. *Ecology Letters,* v. 12, p. 351-366, 2009.

CHEN, L. XING *et al.* Shifts in microbial community composition and function in the acidification of a lead/zinc mine tailings. *Environmental Microbiology*, v. 15, n. 9, p. 2431–2444, 2013.

CIANCIARUSO, M. V.; SILVA, I. A.; ANTÔNIO BATALHA, M. Diversidades filogenética e funcional: novas abordagens para a Ecologia de comunidades. *Biota Neotrop*, v. 9, n. 3, 2017.

CONDE, M. Resistanceto mining: A review. *EcologicalEconomics*, v. 132, p. 80–90, 2017.

CONTI, I. L.; COELHO-DE-SOUZA, G. Povos E Comunidades Tradicionais: a Produção De Políticas Públicas De Segurança Alimentar E Nutricional. *Amazônica - Revista de Antropologia*, v. 5, n. 3, p. 780, 2014.

CUI, C. Q. *et al.* Waste mine to emerging wealth: Innovative solutions for abandoned underground coal mine reutilization on a waste management level. *Journal of Cleaner Production*, v. 19, p. 119748, 2020.

CUNHA, F. A. B. *et al.* Cytoprotective effect of Eugenia uniflora L. against the waste contaminant mercury chloride. *Arabian Journal of Chemistry*, v. 12, n. 8, p. 4197–4203, 2019.

DAWID MOROŃ *et al.* Abundance and diversity of wild bees along gradients of heavy metal pollution. *Journal of Applied Ecology*, v. 49, p. 118–125, 2012.

DE MEDEIROS, C. A.; CINTRA, M. R. V. P. Impacto da ascensão chinesa sobre os países latino-americanos. *Revista de Economia Politica*, v. 35, n. 1, p. 28–42, 2015.

EBRAHIMI, M.; TAHERIANFARD, M. *The effects of heavy metals exposure on reproductive systems of cyprinid fish from Kor River Item Type Journal Contribution*. Disponível em: <http://hdl.handle.net/1834/11305>.

EDRAKI, M. *et al.* Designing mine tailings for better environmental, social and economic outcomes: A review of alternative approaches. *Journal of Cleaner Production*, v. 84, n. 1, p. 411–420, 2014.

EJATLAS. *Mapeando Justiça Ambiental*. Disponível em: <https://ejatlas.org/>. Acesso em: 5 jul. 2021.

ERICSSON, M.; LÖF, O. Mining's contribution to national economies between 1996 and 2016. *Mineral Economics*, v. 32, p. 223–250, 2019.

FAN, G. *et al.* Impacts of Underground Coal Mining on the Roots of Xeromorphic Plant: A Case Study. *Environmental Engineering Science*, v. 38, n. 6, p. 500–512, 2021.

FENG, X. *et al.* Human exposure to methylmercury through rice intake in mercury mining areas, Guizhou province, China. *Environmental Science and Technology*, v. 42, n. 1, p. 326–332, 2008.

FERNÁNDEZ-LLAMAZARES, Á. *et al.* A State-of-the-Art Review of Indigenous Peoples and Environmental Pollution. *Integrated Environmental Assessment and Management*, v. 16, n. 3, p. 324–341, 2020.

FERRARI, P. A. Banco de dados etnobotânicos: construção de uma ferramenta de armazenamento e proteção de informações sobre a sociobiodiversidade. TCC (graduação) - Universidade Federal de Santa Catarina. Centro de Ciências Biológicas.112 f, 2012.

FICKEN, K. L. G.; BYRNE, P. G. Heavy metal pollution negatively correlates with anuran species richness and distribution in south-eastern Australia. *Austral Ecology*, v. 38, n. 5, p. 523–533,2013.

FIGUEIREDO, M. A. *et al.* Germination of native grasses with potential application in the recovery of degraded areas in QuadriláteroFerrífero, Brazil. *Biota Neotropical,* p. 123-135, 2012.

FINKELMAN, R. B.; WOLFE, A.; HENDRYX, M. S. The future environmental and health impacts of coal. *Energy Geoscience*, v. 2, n. 2, p. 99–112, 2021.

FLORA DO BRASIL 2020. Jardim Botânico do Rio de Janeiro. Disponível em: < http://floradobrasil.jbrj.gov.br/ >. Acesso em: 06 out. 2021

FREIRE, S. E.; URTUBEY, E.; GIULIANO, D. A. Caracteres epidérmicos de lasespeciesdel género *Baccharis* (Asteraceae) usadas enla medicina popular. *Caldasia*, v. 7, n. 1, p. 23–38, 2007.

FREITAS, J. R.; CIANCIARUSO, M. V; BATALHA, M. A. Functional diversity, soil features and community functioning: a test in a cerrado site. *Brazilian Journal Biology*, v. 72, n. 3, p. 464, 2012.

FRENCH, M. *et al.* Community exposure and vulnerability to water quality and availability: a case study in the mining-affectedPazña Municipality, Lake Poopó Basin, Bolivian *Altiplano*. *Environmental Management*. p. 30-45, 2017

GARDNER, T. A. *et al.* Understanding the biodiversity consequences of habitat change: The value of secondary and plantation forests for neotropical dung beetles. *Journal of Applied Ecology*, v. 45, n. 3, p. 883–893, 2008.

GASPER, A. L. DE *et al.* Inventário florístico florestal de Santa Catarina: espécies da Floresta Ombrófila Mista. *Rodriguésia*, v. 64, n. 2, p. 201–210, 2013.

GEORGE-LAURENTIU, M.; FLORENTINA-CRISTINA, M.; ANDREEA-LORETA, C. The Assessment of Social and Economic Impacts Associated to an Abandoned Mining Site Case study: Ciudanovita (Romania). *Procedia Environmental Sciences*, v. 32, p. 420–430, 2016.

GRAU-PEREZ, M. *et al.* Arsenic exposure, diabetes-related genes and diabetes prevalence in a general population from Spain. *Environmental Pollution*, v. 235, p. 948–955, 2018.

GRESSLER, E.; PIZO, M. A.; MORELLATO, L. P. C. Pollination and seed dispersal of Brazilian Myrtaceae. *Brazilian Journal of Botany*, v. 29, n. 4, p. 509–530, 2006.

GENRICH, C., M. A. R. MELLO, F. A. O. SILVEIRA, J. L. BRONSTEIN & A. P. PAGLIA. Duality of interaction outcomes in a plant-frugivore multilayer network.2016 Disponível em: <http://www.scielo.br/j/rbb/a/dhSyP7Q6jRXyZL6Ny6Q7bHc/abstract/?lang=en>. Acesso em: 14 set. 2021.

GOVAERTS, R., DRANSFIELD, J., ZONA, S., HODEL, D.R. & HENDERSON, A. World Checklist of Arecaceae. 2021. Disponível em: < http://wcsp.science.kew.org/>Acesso em: 14 set. 2021.

GUISLON, A. V. Composição florística e estrutural da comunidade arbórea da floresta ombrófila densa montana no Parque Estadual da Serra Furada, Santa Catarina. 2015. Disponível em: <http://repositorio.unesc.net/handle/1/2936>. Acesso em: 14 set. 2021.

GUO, C. *et al.* Effects of meteorology and soil on the herb species diversity in plantations in a reclamation area of coal mine after 6 years. *Environmental Science andPollutionResearch*, v. 27, n. 19, p. 24231–24241, 2020.

GUTIÉRREZ, P. *Biomonitoreo de metales pesados enhojas y frutos de guayabo (Psidium guajava L.) y de guamúchil (Pithecellobium dulce (Roxb.) Benth.) e nel Área Metropolitana de Guadalajara*. 111 f. 2015.

HADDAWAY, N. R. *et al.* Evidence of the impacts of metal mining and the effectiveness of mining mitigation measures on social–ecological systems in Arctic and boreal regions: a systematic map protocol. *Environmental Evidence,* v. 8, n. 1, p. 1–11, 2019.

HERNÁNDEZ, A. J.; PASTOR, J. Relationship between plant biodiversity and heavy metal bioavailability in grasslands overlying an abandoned mine. *Environ Geochem Health*, v. 30, p. 127–133, 2008.

HLADUN, K. R.; PARKER, D. R.; TRUMBLE, J. T. Cadmium, Copper, and Lead Accumulation and Bioconcentration in the Vegetative and Reproductive Organs of Raphanus sativus: Implications for Plant Performance and Pollination. *Journal of Chemical Ecology 2015 41:4*, v. 41, n. 4, p. 386–395, 7 abr. 2015. Disponível em: <https://link.springer.com/article/10.1007/s10886-015-0569-7>. Acesso em: 23 set. 2021.

HOGAN, C. M.; TREMBLAY, G. A. Abandoned mines in Canada. *Annual Meetings of the American Society of Mining and Reclamation*, v. 1, p. 774–784, 2006.

MEDEIROS, J. D.; MAURÍCIO SAVI; BERNARDO FERREIRA ALVES DE BRITO. DNA extraction from basidiomata Seleção de áreas para criação de Unidades de Conservação na Floresta Ombrófila Mista. *Biotemas*, v. 18, p. 33–50, 2005.

MAÇANEIRO, J P. *et al.* Regeneração de uma Floresta Ombrófila Mista no Planalto Catarinense. *Biotemas*, v. 29, p. 31–42, 2016.

JOSÉ, S.; TIMÓTEO, A. The impact of habitat degradation on seed dispersal networks: implications for habitat management in montado forests. f. 171. 2014. Disponível em: <http://hdl.handle.net/10316/47413>.Acesso em: 14 set. 2021.

KATTGE, J, BÖNISCH, G, DÍAZ, S, *et al.* TRY plant trait database – enhanced coverage and open access. Global Change Biologic, 26: 119– 188, 2020.

KEW NAMES MATCHING SERVICE. Disponível em: <http://namematch.science.kew.org/>. Acesso em: 14 set. 2021.

KIRMER, A. *et al.* Importance of regional species pools and functional traits in colonization processes: Predicting re-colonization after large-scale destruction of ecosystems. *Journalof Applied Ecology*, v. 45, n. 5, p. 1523–1530, out. 2008.

KLANOVICZ, J. Minas de carvão: trabalho também de mulheres. *Revista Estudos Feministas*, v. 12, n. 2, p. 247–250, 2004.

KLEIN, A. S. *Áreas degradadas pela mineração de carvão no sul de Santa Catarina: vegetação versus substrato*. 2006. 93 f. 2006. Disponível em: <http://comiteitajai.org.br:8080/handle/123456789/247>.

KLEIN, A. S. *et al.* Natural regeneration in an area degraded by coal mining in Santa Catarina State, Brazil. *Revista Escola de Minas*. 2009.

LASCHEFSKI, K. Rompimento de barragens em Mariana e Brumadinho -MG: Desastres como meio de apropriação de territórios por mineradoras. *Enanpege*, p. 1–14, 2019.

LEMKE, D. *et al.* Invasion of a mined landscape: what habitat characteristics are influencing the occurrence of invasive plants? *International Journal of Mining, Reclamation and Environment*, v. 27, n. 4, p. 275–293, 2013.

MARMITT, J. *et al.* Plantas Medicinais da RENISUS Com Potencial Anti-inflamatório: Revisão Sistemática Em Três Bases de Dados Científicas. Medicinal Plants RENISUS With Potential Anti-inflammatory: Systematic Review In Three Scientific Databases. v. 9, n. 2, p. 129–144, 2007.

MAUS, V. *et al.* a global-scale data set of mining areas. *Scientific Data,* v. 7, p. 289, 2020.

MAZZELLA, D. C. *Baccharis trimera* (Less.) DC. y *Baccharis* crispa Spreng. especies de carquejas utilizadas con fines medicinales, caracterización y análisis genéticos de poblaciones en Lavalleja, Uruguay. Cecilia Díaz Cúneo. 2012.

MENEZES, A. P. S. *et al. Baccharis trimera* (less.) DC as genotoxicity indicator of exposure to coal and emissions from a thermal power plant. *Archives of Environmental Contamination and Toxicology*, v. 65, n. 3, p. 434–441, 2013.

MENTON, M. *et al.* The COVID-19 pandemic intensified resource conflicts and indigenous resistance in Brazil. *World Development*, v. 138, p. 105222, 2021.

MILLER, J. R.; VILLARROEL, L. F. Bolivia: Mining, River Contamination, and Human Health. *Encyclopedia of Environmental Health*, p. 421–441, 2011.

MITTAL, A. K. Abandoned mines: Information on the Number of Hardrock Mines, Cost of Cleanup, and Value of Financial Assurances. *Natural ResourcesCommitteeOpinion*, p. 1–13, 2011.

MORAES, V. Avaliação do potencial mutagênico e bioacumulador de metais pesados de *Baccharis trimera* Less. e *Equisetum hyemale* L. *Aleph*, 2014.

MOREIRA, J. C. Threats by heavy metals: Human and environmental contamination in Brazil. *Science of the Total Environment*, v. 188, n. 1, 1996.

NERO, B. F. Structure, composition and diversity of restored forest ecosystems on mine-spoils in South-Western Ghana. *PLOS ONE*, v. 16, n. 6, 2021.

NGUYEN, N.; BORUFF, B.; TONTS, M. Fool's gold: Understanding social, economic and environmental impacts from gold mining in Quang Nam province, Vietnam. *Sustainability (Switzerland)*, v. 10, n. 5, 2018.

ONU. *Panorama Social da América Latina.* 2020. Disponível em: <www.cepal.org/apps>.

OTERO, X. L. *et al.* Arsenic in rice agrosystems (water, soil and rice plants) in Guayas and Los Ríos provinces, Ecuador. *Science of the Total Environment*, v. 573, p. 778–787, 2016.

PAMPLONA, M.; TRINDADE, L. C. Espaços Livres De Criciúma-Sc Como Reflexos Da Mineração. *X Colóquio QUAPÁ-SEL*, 2015.

PAULA, A. *et al.* Chemosphere Chemical and toxicological effects of medicinal *Baccharistrimera* extract from coal burning area. v. 146, p. 396–404, 2016.

PERON, A. P. *et al.* Avaliação mutagênica das plantas medicinais *Baccharis trimera* Less. e *Solanum melongena* L. em células de medula óssea de ratos Wistar. *Revista Brasileira de Biociências*, p. 127–130, 2008.

PHILLIPS, B. B. *et al.* Impacts of multiple pollutants on pollinator activity in road verges. *Journal of Applied Ecology*, v. 58, n. 5, p. 1017–1029, 2021.

QUINTELA-SABARÍS, C. *et al.* Plant functional traits on tropical ultramafic habitats affected by fire and mining: Insights for reclamation. *Diversity*, v. 12, n. 6, 2020.

RAMOS, A. R. A.; OLIVEIRA, K. A. DE; RODRIGUES, F. DOS S. Mercury-Based Mining in Yanomami Indigenous Lands and Accountabilities. *Ambiente e Sociedade*, v. 23, p. 1–22, 2020.

REICH, P. B. *et al.* The evolution of plant functional variation: traits, spectra, and strategies. *International Journal of Plant Sciences*, v. 164, n. 3, p. 143–164, 2003.

REZENDE, C. L., SCARANO, F.R. ASSAD, E.D., JOLY, C.A., METZGER, J.P., B.B.N. STRASSBURG, M. TABARELLI, G.A. FONSECA, R.A. Mittermeier, From hotspot to hopespot: An opportunity for the Brazilian Atlantic Forest, Perspectives in Ecology and Conservation, v. 16, p. 208-214, 2018.

RIVAS, P. M D. P.; MUÑOZ LARA, D. G.; RUIZ CAMAYO, M. A.; FERNÁNDEZ, T. L. F.; MUÑOZ, F. A.; PÉREZ MUÑOZ, N. Colección Mastozoológica del Museo de Historia Natural de la Universidad del Cauca. Universidad del Cauca. Occurrence Dataset. Disponível em: https://doi.org/10.15472/ciasei accessed via GBIF.org on 2017-09-13 Acesso em: 7 set. 2021.

ROCHA, C.; LIBERATO, R. S. Food sovereignty for cultural food security: The case of an indigenous community in Brazil. *Food, Culture and Society*, v. 16, n. 4, p. 589–602, 2013a.

ROCHA-NICOLEITE, E.; OVERBECK, G. E.; MÜLLER, S. C. Degradation by coal mining should be priority in restoration planning. *Perspectives in EcologyandConservation*, v. 15, n. 3, p. 202–205, 2017.

RUIZ, M. S.; ROIC, E. Conflitos Socioambientais Relacionados aos Impactos do Uso e Ocupação do Solo pela Mineração Subterrânea de Carvão em Criciúma - SC. *Encontro da ANPAD - EnANPAD,* v. 38, p. 1–16, 2014.

RUSINOWSKI, S. *et al.* Cultivation of C4 perennial energy grasses on heavy metal contaminated arable land: Impact on soil, biomass, and photosynthetic traits. *Environmental Pollution*, v. 250, p. 300–311, 2019.

SANTOS, G. M M, C. M. L. AGUIAR & M. A. R. MELLO. Flower-visiting guild associated with the Caatinga flora: trophic interaction networks formed by social bees and social wasps with plants. Apidologie 41: 466-475, 2010.

SANTOS, R. *et al.* Spontaneous vegetation on overburden piles in the coal basin of Santa Catarina, Brazil. *Restoration Ecology*, v. 16, n. 3, p. 444–452, 2008.

SAHA, D. *et al.* Investigation of Environmental-Concern Trace Elements in Coal and Their Combustion Residues from Thermal Power Plants in Eastern India. *Natural Resources Research*, v. 28, n. 4, p. 1505–1520, 2019.

SARMA, K.; BARIK, S. K. Coal mining impact on vegetation of the Nokrek Biosphere Reserve, Meghalaya, India. *Biodiversity*, v. 12, n. 3, p. 154–164, 2011.

SETHY, S. K.; GHOSH, S. Effect of heavy metals on germination of seeds. *Journal of Natural Science, Biology, and Medicine*, v. 4, n. 2, p. 272, 2013.

SILVA, R. M. G. *et al.* Genotoxic activity and toxicity of *Baccharis trimera* Less. regarding the bioaccumulation of heavy metals. v. 6, n. 26, p. 4321–4327, 2012.

SIVAKOFF, F. S.; GARDINER, M. M. Soil lead contamination decreases bee visit duration at sunflowers. *Urban Ecosystems*, v. 20, n. 6, p. 1221–1228, 2017.

SIVARAM, A. K. *et al.* Comparison of plants with C3 and C4 carbon fixation pathways for remediation of polycyclic aromatic hydrocarbon contaminated soils. *ScientificReports*, v. 8, n. 1, 2018.

SIZENANDO, J. W. Mineração e espacialidade socioambiental: Exploração Carbonífera e ocupação territorial em Criciúma, Santa Catarina. p. 73, 2011.

SOBRAL-SOUZA, C. E. *et al.* Cytoprotective effect against mercury chloride and bioinsecticidal activity of *Eugenia jambolana* Lam. *ArabianJournalofChemistry*, v. 7, n. 1, p. 165–170, 2014.

SONEGO, R. C.; BACKES, A.; SOUZA, A. F. Descrição da estrutura de uma Floresta Ombrófila Mista, RS, Brasil, utilizando estimadores não-paramétricos de riqueza e rarefação de amostras 1. *Acta Botanica Brasilica*,2007.

SOUZA, L. C. DE *et al.* Teores de Arsênio em solos de três regiões do estado de Santa Catarina. *Revista Ambiente e Água*, v. 9, n. 3, p. 445–458, 2016.

SRIVASTAVA, J. *et al.* Response of C3 and C4 Plant Systems Exposed to Heavy Metals for Phytoextraction at Elevated Atmospheric CO_2 and at Elevated Temperature. *Environmental Contamination*. v. 5, p. 167-178, 2012.

SUPPI, I. M. *et al.* Cobalt and manganese content in soils of Santa Catarina. *Revista de CienciasAgroveterinarias*, v. 17, n. 4, p. 579–588, 2018.

UNITED STATES GOVERNMENT ACCOUNTABILITY OFFICE. *MINES Information on Number of Mines, Expenditures, and Factors That Limit Efforts to Address Hazards Accessible Version United States Government Accountability Office*. 2020.

VAN OOSTDAM, J. *et al.* Human health implications of environmental contaminants in Arctic Canada: A review. *Science of the Total Environment*, v. 351–352, p. 165–246, 2005.

CITADINI-ZANETTE, V.; BOFF, V. P. *Levantamento florístico em áreas mineradas a céu aberto na região carbonífera de Santa Catarina, Brasil.* v. 1, 1992.

<https://koha.inpa.gov.br/cgi-bin/koha/opac-detail.pl?biblionumber=7651>.

WEILER, A. M. *et al.* Food sovereignty, food security and health equity: A meta-narrative mapping exercise. *Health Policy and Planning*, v. 30, p. 1078–1092, 2015.

WORLANYO, A. S.; JIANGFENG, L. Evaluating the environmental and economic impact of mining for post-mined land restoration and land-use: A review. *Journal of Environmental Management*, v. 279, p. 111623, 2021.

WU, Z. *et al.* Spatial distribution of the impact of surface mining on the landscape ecological health of semi-arid grasslands. *Ecological Indicators*, v. 111, p. 105996, 2020.

XUN, E. *et al.* Heavy metals in nectar modify behaviors of pollinators and nectar robbers: Consequences for plant fitness. 2018. <https://doi.org/10.1016/j.envpol.2018.07.128>.

YADAV, A. K.; BHAGAT, R. B.; YADAV, V. Does coal mining affect household food security? An empirical study of Dhanbad, India. *Agriculture and Food Security*, v. 8, n. 1, 2019.

YAN, B. *et al.* Leachability characteristic of heavy metals and associated health risk study in typical copper mining-impacted sediments. *Chemosphere*, v. 239, 2020.

YAN, M. *et al.* Vegetation type and plant diversity affected soil carbon accumulation in a postmining area in Shanxi Province, China. *Land Degradation & Development*, v. 31, n. 2, p. 181–189, 30 jan. 2020. Disponível em: <https://onlinelibrary.wiley.com/doi/full/10.1002/ldr.3438>. Acesso em: 29 ago. 2021.

ZANELATTO, J.; JUNG, G.; OZÓRIO, R. Índios e brancos no processo colonizador do Sul Catarinense na obra "Histórias do Grande Araranguá", de João Leonir dall'Alba. *Revista de História Comparada*, v. 9, n. 1, p. 174–202, 2015.

ZANK, S.; HANAZAKI, N. The coexistence of traditional medicine and biomedicine: A study with local health experts in two Brazilian regions. *PLOS ONE*, v. 12, n. 4, p. e0174731, 1 abr. 2017. Disponível em: <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0174731>. Acesso em: 25 set. 2021.

ZHAO, F. J. *et al.* Soil contamination in China: Current status and mitigation strategies. *Environmental Science and Technology*, v. 49, n. 2, p. 750–759, 2015.

ZOCCHE, J. J. *et al.* Elemental composition of vegetables cultivated over coal-mining waste. *Anais da Academia Brasileira de Ciencias*, v. 89, n. 3, p. 2383–2398, 2017.

4.7 SUPPLEMENTARY MATERIAL

Supplementary material 1: Lista geral das espécies analisadas, origem, características morfofisiológicas, de polinização, dispersão de sementes e bioacumulação. N: Native; E: Exotic; F: Food; M: Medicinal; NA: Informação não encontrada; Tempo 1: de 3 anos até 10 anos; Tempo 2: de 11 anos até 25 anos; Tempo 3: de 26 anos até 40 anos; Tempo 4: em todas.

Species	**Autor**	**Time**	**Origin**	**Use**	**Bioaccumulator**	**Root**	**Seed dispersal**	**Pollination**	**Life forms**	**C3/C4**	**Ciclo de vida**
Acacia mearnsii De Wild.	Lorenzi (2013)	3	I	F/A	Yes	Pivot	Autochory	Entomophilia	Tree	C3	Perennial
Acanthospermum australe (Loefl.) Kuntze	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Zoochory	Entomophilia	Herb	C3	Perennial
Acanthosyris spinescens (Mart. & Eichler) Griseb.	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	NA	NA	Shrub	C3	NA
Achillea millefolium L.	Santos *et al.* (2007)	1_2	E	M	Yes	Pivot	NA	Psychophilia	Herb	C3	Perennial
Achyrocline satureioides (Lam.) DC.	Santos *et al.* (2007); Machado (2018); Costa (2007); Klein (2006); Klein *et al.* (2009)	4	N	No	Not studied	Pivot	NA	NA	Herb	C4	Perennial
Actinostemon concolor (Spreng.) Müll.Arg.	Machado (2018)	1_2	N	M	Not studied	Pivot	Autochory	Anemophilia	Shrub	C3	Perennial
Aegiphila integrifolia (Jacq.) Moldenke	Zocche e Porto (1992); Lorenzi (2013)	4	N	M	Not studied	Pivot	Anemochory	Anemophilia	Shrub	C3	Perennial
Aeschynomene sensitiva Sw.	Costa (2007)	1	N	M	Not studied	Pivot	NA	NA	Sub-shrub	C3	Perennial
Agalinis communis (Cham. & Schltdl.) D'Arcy	Zocche e Porto (1992)	1	N	F/A	Not studied	Pivot	NA	Entomophilia	Herb	C3	Perennial
Ageratum conyzoides L.	Costa (2007); Machado (2018)	1	N	No	Not studied	Pivot	NA	Entomophilia	Herb	C3	Annual

Alchornea triplinervia (Spreng.) Mull.Arg.	Zocche e Porto (1992); Klein (2006); Lorenzi (2013); Klein *et al.* (2009)	4	N	F/A	Not studied	Pivot	Zoochory	Zoophilia	Shrub	C4	Perennial
Allophylus edulis (A.St.-Hil. *et al.*) Hieron. ex Niederl.	Frizzo e Porto (2004)	1_2	N	No	Not studied	Pivot	NA	Entomophilia	Shrub	C4	Perennial
Alternanthera philoxeroides (Mart.) Griseb.	Machado (2018)	1	N	No	Not studied	Pivot	NA	Entomophilia	Sub-shrub	C4	Annual
Amaioua guianensis Aubl.	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	Zoochory	NA	Shrub	C4	Perennial
Amaioua intermedia Mart. ex Schult. & Schult.f.	Santos *et al.* (2007)	1_2	N	F/A	Yes	Pivot	Zoochory	Zoophilia	Shrub	C3	Perennial
Andropogon bicornis L.	Costa (2007); Klein (2006); Machado (2018); Santos *et al.* (2007)	4	N	F	Not studied	Fasciculated	Autochory/ Anemochory	Anemophilia	Herb	C4	Perennial
Andropogon lateralis Nees	Zocche e Porto (1992)	1	N	F	Not studied	Fasciculated	Autochory/ Anemochory	Anemophilia	Herb	C3	Perennial
Anemia phyllitidis (Sav.) Sw.	Santos *et al.* (2007)	3	N	F	Not studied	NA	NA	NA	Herb	C3	Perennial
Annona dolabripetala Warm.	Santos *et al.* (2007)	2	N	F	Not studied	Fasciculated	Zoochory	NA	Tree	C3	Perennial
Annona emarginata Raddi	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Zoochory	NA	Shrub	C3	Perennial
Arachis burkartii Handro	Zocche e Porto (1992)	1	N	No	Yes	Pivot	NA	NA	Herb	C3	Perennial
Arachis pintoi Krapov. & W.C. Greg.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	NA	Herb	C3	Perennial
Aspidosperma camporum Müll.Arg.	Frizzo e Porto (2004)	3	N	M	Not studied	Pivot	NA	Entomophilia	Tree	C3	Perennial

Aspidosperma tomentosum Mart. & Zucc.	Frizzo e Porto (2004)	2	N	No	Yes	Pivot	Anemochory	Fanelophilia	Tree	C3	Perennial
Aspilia montevidensis (Spreng.) Kuntze	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia	Herb	NA	Perennial
Avena sativa L.	Machado (2018)	1	E	No	Inconclusive	Fasciculated	Autochory/ Anemochory	Anemophilia	Herb	C3	Perennial
Axonopus compressus (Kunth) R.M. King & H. Rob.	Frizzo e Porto (2004)	1_2	N	M	Inconclusive	Fasciculated	Autochory/ Anemochory	Anemophilia	Herb	C4	Perennial
Axonopus fissifolius (Raddi) Kuhlm.	Costa (2007)	1	N	No	Not studied	Fasciculated	Autochory/ Anemochory	Anemophilia	Herb	C4	Perennial
Axonopus obtusifolius (Raddi) Chase	Costa (2007); Machado (2018)	1_2	N	No	Not studied	Fasciculated	Autochory/ Anemochory	Anemophilia	Herb	C4	Perennial
Axonopus polystachyus G.A. Black	Costa (2007)	1	N	No	Not studied	Fasciculated	Autochory/ Anemochory	Anemophilia	Herb	C4	Perennial
Axonopus siccus (Nees) Kuhlm.	Frizzo e Porto (2004)	2	N	M	Not studied	Fasciculated	Autochory/ Anemochory	Anemophilia	Herb	C4	Perennial
Baccharis aliena (Spreng.) Joch.Müll.	Frizzo e Porto (2004)	2	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Shrub	C3	Perennial
Baccharis articulata (Lam.) Pers.	Frizzo e Porto (2004); Zocche e Porto (1992)	1_2	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Shrub	C3	Perennial
Baccharis conyzoides (Less.) DC.	Machado (2018); Costa (2007)	1	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Liana/	C3	Perennial
Baccharis crispa Spreng.	Frizzo e Porto (2004)	4	N	M	Yes	Pivot	Anemochory	Cantarofilia/ Psychophilia	Sub-shrub	C3	Perennial
Baccharis dracunculifolia DC.	Frizzo e Porto (2004); Zocche e Porto (1992); Klein *et al.* (2009); Costa (2007);	4	N	M	Not studied	Pivot	Anemochory	Entomophilia	Shrub	C3	Perennial

	Klein (2006); Lorenzi (2013); Santos *et al.* (2007)										
Baccharis leucopappa DC.	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Sub-shrub	C3	Perennial
Baccharis oblongifolia (Ruiz & Pav.) Pers.	Klein *et al.* (2009); Klein (2006)	2	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Shrub	C3	Perennial
Baccharis punctulata DC.	Klein (2006); Santos *et al.* (2007)	1_2	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Shrub	C3	Perennial
Baccharis sagittalis (Less.) DC.	Zocche e Porto (1992)	4	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Shrub	C3	Perennial
Baccharis semiserrata DC.	Zocche e Porto (1992); Santos *et al.* (2007)	1_2	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Shrub	C3	Perennial
Baccharis spicata (Lam.) Baill.	Zocche e Porto (1992); Costa (2007); Santos *et al.* (2007)	1_2	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Shrub	C3	Perennial
Baccharis uncinella DC.	Santos *et al.* (2007); Costa (2007)	1_2	N	M	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Shrub	C3	Perennial
Baccharis vulneraria Baker	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Anemochory	Cantarofilia/ Psychophilia	Sub-shrub	C3	Perennial
Begonia cucullata Willd.	Machado (2018); Santos *et al.* (2007)	1_2	N	M	Not studied	Pivot	NA	Entomophilia/ Ornithophilia	Herb	C3	Perennial
Begonia fischeri Schrank	Machado (2018)	1	N	F/A	Yes	Pivot	NA	Entomophilia/ Psychophilia	Sub-shrub	C3	Perennial
Bidens pilosa L.	Costa (2007); Machado (2018)	1	E	No	Not studied	Pivot	NA	Entomophilia/ Psychophilia	Herb	C3	Annual
Blutaparon portulacoides (A.St.-Hill.) Mears	Machado (2018)	1	N	M	Not studied	Pivot	NA	Entomophilia/ Psychophilia	Herb	NA	Perennial
Boehmeria caudata Willd.	Zocche e Porto (1992)	4	N	No	Not studied	Pivot	NA	Entomophilia/ Psychophilia	Shrub	C3	Perennial

Borreria brachystemonoides Cham. & Schltdl.	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	NA	Entomophilia/ Ornithophilia	Herb	C3	Perennial
Borreria capitata (Ruiz & Pav.) DC.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	Entomophilia/ Ornithophilia	Herb	C3	Perennial
Borreria verticillata (L.) G. Mey.	Zocche e Porto (1992)	2	N	M	Not studied	Pivot	NA	Entomophilia/ Ornithophilia	Sub-shrub	C3	Perennial
Bothriochloa exaristata (Nash) Henrard	Costa (2007)	1	N	No	Yes	Fasciculated	NA	Entomophilia/ Ornithophilia	Herb	C4	Annual
Bowlesia incana Ruiz & Pav.	Machado (2018)	1	N	M	Not studied	Pivot	NA	Entomophilia/ Ornithophilia/ Anemophilia	Herb	NA	Annual
Briza minor L.	Zocche e Porto (1992)	1	E	F/A	Yes	Fasciculated	Anemochory/ Zoochory	Entomophilia/ Ornithophilia/ Anemophilia	Herb	C3	Annual
Buchnera integrifolia Larrañaga	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	NA	Entomophilia/ Ornithophilia/ Anemophilia	Herb	C3	Perennial
Buddleja stachyoides Cham. & Schltdl.	Machado (2018)	1	N	F	Not studied	Pivot	Zoochory	Entomophilia/ Ornithophilia/ Anemophilia	Shrub	C3	NA
Butia capitata (Mart.) Becc.	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Zoochory	Entomophilia/ Psychophilia	Tree	C3	Annual
Cabralea canjerana (Vell.) Mart.	Klein *et al.* (2009); Klein (2006)	1_2	N	F/A	Yes	Pivot	Zoochory	Psychophilia/ Entomophilia	Shrub	C3	NA
Cantinoa mutabilis (Rich.) Harley & J.F.B. Pastore	Zocche e Porto (1992); Machado (2018)	1_2	N	No	Not studied	Pivot	Autochory	Entomophilia/ Ornithophilia	Shrub	NA	Annual
Carex phalaroides Kunth	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Autochory	Entomophilia/ Ornithophilia	Herb	C3	Perennial
Carex sororia Kunth	Zocche e Porto (1992)	1	N	M	Not studied	Fasciculated	Autochory	Entomophilia/ Ornithophilia	Herb	C3	Perennial
Casearia sylvestris Sw.	Zocche e Porto (1992); Klein *et al.* (2009); Klein	4	N	No	Not studied	Pivot	Zoochory	Entomophilia/ Ornithophilia	Shrub	C3	Perennial

	(2006); Lorenzi (2013)										
Cecropia glaziovii Snethl.	Zocche e Porto (1992); Lorenzi (2013)	4	N	M	Yes	Pivot	Zoochory	Entomophilia/ Ornithophilia	Tree	C3	Perennial
Cedrela fissilis Vell.	Frizzo e Porto (2004)	4	N	No	Not studied	Pivot	Zoochory	Entomophilia/ Ornithophilia	Tree	C3	Perennial
Celtis spinosa Spreng.	Frizzo e Porto (2004)	2	N	M	Yes	Fasciculated	NA	Entomophilia/ Psychophilia	Shrub	C3	NA
Celtis tala Gillies ex Planch.	Frizzo e Porto (2004)	2	N	M	Yes	Fasciculated	NA	Entomophilia/ Psychophilia/ Ornithophilia	Shrub	C3	NA
Cenchrus clandestinus (Hochst. ex Chiov.) Morrone	Frizzo e Porto (2004)	2	I	F/A	Yes	Fasciculated	NA	Chantophilia/ Entomophilia	Herb	C4	Annual
Centella asiatica (L.) Urban	Zocche e Porto (1992); Machado (2018); Santos *et al.* (2007)	4	N	M	Not studied	Pivot	NA	Chantophilia/ Entomophilia	Herb	NA	Perennial
Centrosema virginianum (L.) Benth.	Frizzo e Porto (2004)	2	N	M	Yes	Pivot	Zoochory	Chantophilia/ Entomophilia	Liana/	C3	Perennial
Chaetogastra clinopodifolia DC.	Machado (2018)	1	N	No	Not studied	Pivot	Anemochory	Ornitophilia	Sub-shrub	NA	Perennial
Chaetogastra gracilis (Bonpl.) DC.	Costa (2007)	2	N	No	Not studied	Pivot	Anemochory	Ornitophilia	Sub-shrub	NA	Perennial
Chaetogastra herbacea (DC.) P.J.F. Guim. & Michelang.	Klein *et al.* (2009)	1	N	No	Not studied	Pivot	Anemochory	Ornitophilia	Sub-shrub	NA	Perennial
Chaetogastra versicolor (Lindl.) P.J.F. Guim. & Michelang.	Costa (2007)	1_2	N	M	Not studied	Pivot	Anemochory	Ornitophilia	Sub-shrub	NA	Perennial
Chamaecrista flexuosa (L.) Greene	Machado (2018)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Shrub	C3	Perennial

Chaptalia excapa (Pers.) Baker	Klein *et al.* (2009)	1	N	M	Not studied	Pivot	Zoochory	Entomophilia	Herb	C3	NA
Christella dentata (Forssk.) Brownsey & Jermy	Machado (2018)	1_2	I	M	Not studied	NA	NA	NA	Herb	NA	NA
Chromolaena laevigata (Lam.) R.M. King & H. Rob.	Klein (2006)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Shrub	NA	Perennial
Citharexylum montevidense (Spreng.) Moldenke	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	NA	NA	Tree	C3	Perennial
Citharexylum myrianthum Cham.	Frizzo e Porto (2004)	3	N	No	Not studied	Pivot	NA	NA	Tree	C3	Perennial
Citronella paniculata (Mart.) R.A.H oward	Zocche e Porto (1992)	2	N	F/A	Yes	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Citrus x aurantium	Zocche e Porto (1992)	2_3	E	No	Not studied	Pivot	Zoochory	Ornitophilia	Tree	C3	NA
Clethra scabra Pers.	Zocche e Porto (1992); Santos *et al.* (2007); Klein *et al.* (2009); Klein (2006); Lorenzi (2013)	4	N	No	Not studied	Pivot	Anemochory	Zoophilia	Shrub	C3	Perennial
Clusia criuva Cambess.	Klein *et al.* (2009)	2	E	No	Not studied	Pivot	NA	NA	Shrub	C3	Perennial
Coccocypselum condalia Pers.	Santos *et al.* (2007)	2_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Herb	NA	NA
Coccocypselum lanceolatum Pers.	Klein (2006)	2	N	F/A	Yes	Pivot	Zoochory	Entomophilia	Herb	NA	NA
Coffea arabica L.	Zocche e Porto (1992)	2	I	F/A	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Commelina benghalensis L.	Machado (2018)	1	E	F/A	Yes	Fasciculated	Autochory	Entomophilia	Herb	C3	Perennial/Annual
Commelina diffusa Burm.f.	Costa (2007); Machado (2018)	1	E	F/A	Yes	Fasciculated	Autochory	Entomophilia	Herb	C3	Perennial/Annual

Commelina erecta L.	Costa (2007); Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Entomophilia	Herb	C3	Perennial/Annual
Conyza blakei (Cabrera) Cabrera	Frizzo e Porto (2004)	2	N	No	Yes	Pivot	Anemochory	Entomophilia	Sub-shrub	C3	NA
Conyza bonariensis (L.) Cronquist	Costa (2007); Machado (2018)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Sub-shrub	C3	NA
Cortaderia selloana (Schult.) Archers. & Graebn.	Machado (2018); Costa (2007);	4	I	M	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C3	Annual
Croton celtidifolius Baill.	Costa (2007); Santos *et al.* (2007)	2_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Croton gnaphalii Baill.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	NA
Cupania vernalis Cambess.	Frizzo e Porto (2004)	2_3	N	M	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Cuphea carthagenensis (Jacq.) J. Macbr.	Zocche e Porto (1992); Machado (2018); Costa (2007)	1	N	No	Not studied	Pivot	NA	NA	Herb	C3	Annual
Cyathea atrovirens (Langsd. & Fisch.) Domin.	Klein (2006)	2_3	N	No	Not studied	NA	NA	NA	Shrub	C3	NA
Cyathea delgadii Sternb.	Zocche e Porto (1992); Klein (2006); Lorenzi (2013)	4	N	M	Not studied	NA	NA	NA	Shrub	C3	NA
Cyclospermum leptophyllum (Pers.) Sprague	Machado (2018)	1	N	F/A	Yes	Pivot	NA	NA	Herb	NA	Annual
Cynodon dactylon (L.) Pers.	Zocche e Porto (1992); Machado (2018)	1	I	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual
Cyperus aggregatus (Willd.) Endl.	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial

Cyperus barrosianus Herter	Machado (2018)	1	N	M	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Cyperus brevifolius (Rottb.) Endl. ex Hassk.	Machado (2018)	1	N	M	Yes	Fasciculated	Autochory	Anemophilia	Herb	C4	Perennial
Cyperus difformis L.	Machado (2018)	1	E	M	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Cyperus hermaphroditus Standl.	Costa (2007)	1	N	M	Yes	Fasciculated	Autochory	Anemophilia	Herb	C4	Perennial
Cyperus iria L.	Costa (2007)	1	N	M	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C4	Perennial
Cyperus laxus Lam.	Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C4	Perennial
Cyperus meyenianus Kunth.	Machado (2018); Costa (2007)	1	N	M	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C4	Perennial
Cyperus odoratus L.	Costa (2007); Machado (2018)	1	N	M	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Cyperus prolixus Kunth.	Machado (2018); Costa (2007)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Cyperus rigens Michx.	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C4	Perennial
Cyperus virens Michx.	Costa (2007); Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Cyrtocymura scorPioneiraides (Lam.) H. Rob.	Machado (2018)	1	N	No	Not studied	Pivot	NA	NA	Sub-shrub	NA	NA
Declieuxia dusenii Standl.	Santos *et al.* (2007)	2	N	M	Not studied	Pivot	NA	Entomophilia	Herb	C3	NA
Desmanthus virgatus (L.) Willd.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	NA	Sub-shrub	C3	Perennial
Desmodium adscendens (Sw.) DC.	Santos *et al.* (2007); Costa (2007); Machado (2018); Klein (2006)	4	E	No	Not studied	Pivot	Zoochory	Entomophilia	Sub-shrub	C3	Perennial
Dichanthelium sabulorum (Lam.)	Costa (2007); Machado (2018)	2_3	N	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Annual

Gould & C. A. Clark											
Dichondra sericea Sw.	Zocche e Porto (1992)	1	N	M	Yes	Pivot	NA	NA	Herb	C3	NA
Dicranopteris flexuosa (Schrader) Underwood	Klein (2006)	2_3	N	No	Not studied	NA	NA	NA	Herb	C3	Perennial
Didymopanax morototoni (Aubl.) Decne. & Planch.	Zocche e Porto (1992); Machado (2018)	3	N	F/A	Yes	Pivot	NA	NA	Tree	C3	Annual
Digitaria ciliaris (Retz.) Koeler	Zocche e Porto (1992); Machado (2018)	1	E	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual
Digitaria violascens Link.	Costa (2007)	1	E	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual
Distimake dissectus (Jacq.) A.R. Simões & Staples	Machado (2018)	1	N	No	Not studied	Pivot	NA	NA	Liana/ Epiphyte	NA	Perennial
Ditassa succedanea Rapini	Klein (2006)	2	N	M	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	NA	Perennial
Drymaria cordata (L.) Willd. Ex Roem. & Schult.	Costa (2007); Machado (2018)	1	E	F	Not studied	Pivot	Zoochory	Entomophilia	Herb	C3	Annual
Duguetia lanceolata A.St.-Hil.	Santos *et al.* (2007)	2	N	F/A	Yes	Fasciculated	Zoochory	Zoophilia	Tree	C3	Perennial
Echinochloa crus-galli (L.) P. Beauv.	Costa (2007)	1	I	F/A	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual
Eclipta prostrata L.	Machado (2018)	1	N	No	Not studied	Pivot	Autochory	Entomophilia	Herb	NA	Perennial/Annual
Eleocharis filiculmis Kunth	Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Eleocharis minima Kunth	Zocche e Porto (1992)	1	N	No	Yes	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Eleocharis montana (Kunth) Roem. & Schult.	Costa (2007)	1	N	M	Yes	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual

Elephantopus mollis Kunth	Zocche e Porto (1992)	2_3	N	F/A	Yes	Pivot	NA	Entomophilia	Herb	C3	Perennial
Eleusine indica (L.) Gaertn.	Costa (2007)	1	E	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual
Eleusine tristachya (Lam.) Lam.	Zocche e Porto (1992)	1	N	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual
Emilia fosbergii Nicolson	Costa (2007)	1	E	M	Not studied	Pivot	NA	Psychophilia	Herb	C3	Annual
Emmeorhiza umbellata (Spreng.) K. Schum.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	Entomophilia	Liana/Epiphyte	NA	NA
Epidendrum fulgens A. Brongn.	Costa (2007); Klein (2006)	4	N	M	Yes	Fasciculated	Anemochory	Entomophilia	Herb	C3	Perennial
Equisetum giganteum	Zocche e Porto (1992)	1	NA	No	Not studied	Pivot	NA	NA	NA	C3	Perennial
Eragrostis airoides Nees	Zocche e Porto (1992); Machado (2018)	1	N	No	Not studied	Fasciculated	Zoochory	Anemophilia	Herb	C4	Annual
Eragrostis lugens Nees	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Zoochory	Anemophilia	Herb	C4	Perennial
Eragrostis neesii Trin.	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Zoochory	Anemophilia	Herb	C4	Perennial
Eragrostis polytricha Nees	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Zoochory	Anemophilia	Herb	C4	Perennial
Erechtites hieracifolius (L.) Raf. ex DC.	Machado (2018); Costa (2007)	1	N	F/A	Not studied	Pivot	NA	Entomophilia	Herb	C3	NA
Erechtites valerianifolius (Wolf) DC.	Costa (2007); Klein (2006); Machado (2018)	4	N	F/A	Yes	Pivot	NA	Entomophilia	Herb	C3	Annual
Eriobotrya japonica (Thunb.) Lind. Sinon.	Zocche e Porto (1992)	1	E	M	Not studied	Pivot	Zoochory	Entomophilia/ Psychophilia/ Ornitophilia	NA	C3	Perennial
Eryngium elegans Cham. & Schltdl.	Zocche e Porto (1992)	1	N	M	Yes	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Eryngium horridum Malme	Frizzo e Porto (2004)	2	N	M	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial

Eryngium pandanifolium Cham. & Schltdl.	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Eryngium pristis Cham. & Schltdl.	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Erythroxylum deciduum A.St. Hill	Klein (2006)	2_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Esenbeckia grandiflora Mart.	Zocche e Porto (1992); Santos *et al.* (2007); Klein *et al.* (2009); Klein (2006); Lorenzi (2013)	2_3	N	M	Yes	Pivot	Autochory	Zoophilia	Shrub	C3	NA
Eucalyptus globulus Sm.	Klein (2006)	2	E	M	Yes	Pivot	Zoochory	Entomophilia	NA	C3	Perennial
Eucalyptus saligna Sm.	Zocche e Porto (1992); Santos *et al.* (2007); Klein *et al.* (2009); Klein (2006); Lorenzi (2013)	4	E	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Eugenia bacopari D. Legrand	Klein (2006)	2_3	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Eugenia beaurepairiana (Kiaersk.) D.Legrand	Klein (2006)	2_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Eugenia melanogyna (D. Legrand) Sobral	Frizzo e Porto (2004)	2_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Eugenia multicostata D. Legrand	Frizzo e Porto (2004)	2_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Eugenia stigmatosa DC.	Frizzo e Porto (2004)	2	N	F/A	Yes	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Eugenia uniflora L.	Frizzo e Porto (2004)	2	N	No	Inconclusive	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial

Eugenia uruguayensis Cambess.	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Eugenia verticillata (Vell.) Angely	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Eumachia astrellantha (Wernham) Delprete & J.H. Kirkbr.	Frizzo e Porto (2004)	2	N	F/A	Yes	Pivot	NA	Entomophilia	Shrub	NA	NA
Euphorbia hirta L.	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Autochory	Entomophilia/ Psychophilia	Herb	C4	NA
Euphorbia papillosa A.St.-Hil.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Autochory	Entomophilia/ Psychophilia	Herb	C4	NA
Euploca lagoensis (Warm.) Diane & Hilger	Zocche e Porto (1992)	1	N	F/A	Not studied	Pivot	Zoochory	Entomophilia	Herb	NA	Perennial
Euterpe oleracea Mart.	Klein *et al.* (2009); Klein (2006)	2	N	No	Not studied	Fasciculated	NA	Entomophilia	NA	NA	Perennial
Ficus cestrifolia Schott ex Spreng.	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Ficus insipida Willd.	Frizzo e Porto (2004)	3	N	M	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Fimbristylis autumnalis (L.) Roem. & Schult.	Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C4	Annual
Fimbristylis complanata (Retz.) Link	Costa (2007)	1	N	M	Yes	Fasciculated	Autochory	Anemophilia	Herb	C4	Annual
Fimbristylis dichotoma (L.) Vahl	Machado (2018); Costa (2007)	1	N	F/A	Yes	Fasciculated	Autochory	Anemophilia	Herb	C4	Annual
Foeniculum vulgar e	Frizzo e Porto (2004)	1	NA	No	Not studied	Pivot	NA	NA	NA	C3	Perennial
Fuirena robusta Kunth	Machado (2018)	1	N	F/A	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual

Fuirena umbellata Rottb.	Zocche e Porto (1992); Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Galianthe equisetoides (Cham. & Schltdl.) E.L. Cabral	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia	Herb	NA	NA
Galianthe laxa (Cham. & Schltdl.) E.L. Cabral	Santos *et al.* (2007)	2	N	M	Not studied	Pivot	Zoochory	Entomophilia	Herb	NA	Perennial
Galium hirtum Lam.	Klein (2006)	2_3	N	M	Not studied	Pivot	NA	Entomophilia	Herb	C3	Annual
Galium hypocarpium (L.) Endl. ex Griseb.	Santos *et al.* (2007)	2	N	M	Not studied	Pivot	NA	Entomophilia	NA	C3	Annual
Gamochaeta americana (Mill.) Wedd.	Costa (2007); Machado (2018)	1	N	F/A	Not studied	Pivot	NA	NA	Herb	C3	Perennial
Gomesa varicosa (Lindl.) M.W. Chase & N.H.Williams	Klein (2006)	2	N	M	Not studied	Fasciculated	Anemochory	Entomophilia	Herb	NA	Perennial
Gomphocarpus physocarpus E. Mey.	Costa (2007)	1	E	No	Not studied	Pivot	NA	NA	Shrub	C3	Perennial
Guapira opposita (Vell.) Reitz	Klein (2006)	2_3	N	M	Yes	Pivot	Zoochory	Zoophilia	Shrub	C3	Perennial
Guatteria australis A.St.-Hil.	Santos *et al.* (2007)	2_3	N	No	Not studied	Fasciculated	Zoochory	Zoophilia	Shrub	NA	Perennial
Gymnanthes klotzschiana Müll.Arg.	Frizzo e Porto (2004)	2_3	N	No	Not studied	Pivot	NA	NA	Shrub	NA	NA
Habenaria parviflora Lindl.	Machado (2018); Santos *et al.* (2007)	1	N	No	Not studied	Fasciculated	Anemochory	Entomophilia	Herb	NA	Perennial
Hedychium coronarium J. Koenig	Machado (2018); Klein (2006)	2_3	I	No	Not studied	Fasciculated	Zoochory	Entomophilia	Herb	C3	Perennial

Hedyosmum brasiliens Sweet	Machado (2018)	2_3	N	No	Not studied	Fasciculated	NA	NA	NA	C3	Perennial
Heisteria silvianii Schwacke	Machado (2018)	2_3	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	NA	NA
Herbertia pulchella	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	NA	Entomophilia	Herb	C3	Perennial
Heterocondylus alatus	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Shrub	C3	Perennial
Heterocondylus decipiens	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Sub-shrub	C3	Perennial
Hexasepalum apiculatum	Frizzo e Porto (2004)	2_3	N	No	Not studied	Pivot	NA	Entomophilia/Ornitophilia	Sub-shrub	C3	Perennial
Hydrocotyle bonariensis Lam.	Machado (2018)	1	N	M	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Annual
Hydrocotyle ranunculoides L.f.	Machado (2018)	1	N	No	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Annual
Hymenachne amplexicaulis (Rudge) Nees	Machado (2018)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Annual
Hypericum brasiliense Choisy	Zocche e Porto (1992); Costa (2007)	1	N	F/A	Not studied	Pivot	Zoochory	Entomophilia	Herb	C3	Perennial
Hypoxis decumbens L.	Zocche e Porto (1992); Machado (2018); Santos *et al.* (2007)	2_3	N	M	Not studied	Fasciculated	Zoochory	Entomophilia	Herb	C3	Perennial
Imperata brasiliensis Trin.	Machado (2018)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	NA	Annual
Indigofera campestris Bonq.	Costa (2007)	1	N	F/A	Not studied	Pivot	Autochory	Entomophilia	Herb	NA	Perennial
Inga edulis Willd.	Machado (2018)	2_3	N	F/A	Yes	Pivot	Zoochory	Entomophilia	NA	C3	Perennial
Ipomoea cairica (L.) Sweet	Machado (2018)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia	Liana/Epiphyte	C3	Perennial
Ischaemum minus J. Presl	Costa (2007); Machado (2018)	1	N	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	NA	Annual
Jacaranda puberula Cham.	Zocche e Porto (1992); Klein *et al.* (2009); Klein	4	N	No	Not studied	Pivot	Anemochory	Entomophilia/Ornitophilia	Tree	C3	Perennial

	(2006); Lorenzi (2013)									
Jarava filifolia (Nees) Ciald.	Zocche e Porto (1992)	1	N	M	Yes	Fasciculated	Anemochory	Anemophilia	Herb	NA	Annual
Juncus bufonius L.	Zocche e Porto (1992)	1	N	M	Not studied	Fasciculated	Zoochory	Entomophilia/ Ornitophilia/ Anemophilia	Herb	C3	Perennial
Juncus capillaceus Lam.	Frizzo e Porto (2004); Zocche e Porto (1992); Machado (2018)	2_3	N	F/A	Yes	Fasciculated	Zoochory	Entomophilia/ Ornitophilia/ Anemophilia	Herb	C3	Perennial
Juncus effusus L.	Machado (2018)	1	N	No	Yes	Fasciculated	Zoochory	Entomophilia/ Ornitophilia/ Anemophilia	Herb	C3	Perennial
Juncus imbricatus Laharpe	Costa (2007)	1	N	No	Not studied	Fasciculated	Zoochory	Entomophilia/ Ornitophilia/ Anemophilia	Herb	C3	Perennial
Juncus marginatus Rostk.	Costa (2007)	1	N	F	Not studied	Fasciculated	Zoochory	Entomophilia/ Ornitophilia/ Anemophilia	Herb	C3	Perennial
Juncus microcephalus Bonpand & Kunth	Costa (2007)	1	N	No	Not studied	Fasciculated	Zoochory	Entomophilia/ Ornitophilia/ Anemophilia	Herb	C3	Perennial
Juncus scirpoides Lam.	Costa (2007)	1	N	M	Yes	Fasciculated	Zoochory	Entomophilia/ Ornitophilia/ Anemophilia	Herb	C3	Perennial
Juncus tenuis Willd.	Machado (2018)	1	N	No	Not studied	Fasciculated	Zoochory	Entomophilia/ Ornitophilia/ Anemophilia	Herb	C3	Perennial
Kaunia rufescens (Lund ex DC.)	Zocche e Porto (1992); Lorenzi (2013)	2_3	N	No	Not studied	Pivot	NA	NA	Shrub	NA	NA
Krapovickasia macrodon	Costa (2007)	2	N	No	Not studied	Pivot	NA	NA	Herb	NA	NA
Lamanonia ternata Vell.	Zocche e Porto (1992); Klein (2006); Lorenzi (2013); Santos *et al.* (2007)	4	N	F/A	Not studied	Pivot	Anemochory	Zoophilia	Shrub	NA	Perennial

Lantana camara L.	Santos *et al.* (2007)	2	E	No	Yes	Pivot	Zoochory	Psychophilia	Shrub	C3	Perennial
Laplacea fruticosa (Schrad.) Kobuski	Klein (2006)	2	N	No	Inconclusive	Pivot	NA	NA	Shrub	NA	Perennial
Lavandula angustifolia L.	Santos *et al.* (2007)	1_3	E	M	Not studied	Pivot	Zoochory	Entomophilia/ Psychophilia	NA	C3	Perennial
Leandra australis (Cham.) Cogn.	Klein (2006); Machado (2018); Santos *et al.* (2007)	4	E	No	Yes	Pivot	Zoochory	Zoophilia	Shrub	C3	NA
Lessingianthus sellowii (Less.) H. Rob.	Costa (2007)	1	N	F/A	Yes	Pivot	NA	NA	Herb	NA	Perennial
Lindernia dubia (L.) Pennell	Machado (2018)	1	N	M	Yes	Pivot	NA	NA	Herb	C3	NA
Liparis nervosa Lindl.	Klein (2006); Santos *et al.* (2007)	1_3	N	M	Yes	Fasciculated	Anemochory	Entomophilia	Herb	NA	Perennial
Lithraea brasiliensis Marchand	Frizzo e Porto (2004)	2	N	No	Inconclusive	Pivot	NA	Entomophilia	Shrub	C3	Perennial
Lobelia hederacea Cham.	Zocche e Porto (1992); Machado (2018)	1	N	No	Not studied	Fasciculated	NA	NA	Herb	C3	Perennial
Lolium multiflorum L.	Machado (2018)	1	E	No	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C3	Annual
Ludwigia decurrens Walter	Costa (2007)	1	N	M	Not studied	Pivot	NA	Entomophilia	Herb	C3	Annual
Ludwigia leptocarpa (Nutt.) H. Hara	Costa (2007); Machado (2018)	1	N	F/A	Not studied	Pivot	NA	Entomophilia	Shrub	C3	Annual
Ludwigia longifolia (DC.) Hara	Costa (2007)	1	N	No	Not studied	Pivot	NA	Entomophilia	Shrub	C3	Annual
Ludwigia multinervia (Hook. & Arn.) Ramamoorthy	Costa (2007)	1	N	No	Not studied	Pivot	NA	Entomophilia	Shrub	C3	Annual

Ludwigia octovalvis (Jacq.) P. H. Raven	Costa (2007)	1	N	M	Yes	Pivot	NA	Entomophilia	Shrub	C3	Annual
Luehea divaricata Mart.	Frizzo e Porto (2004)	1_3	N	M	Not studied	Pivot	NA	Entomophilia	Tree	C3	Perennial
Lysimachia minima (L.) U. Manns & Anderb.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	NA	Herb	NA	Annual
Magnolia ovata (A.St.-Hil.) Spreng.	Klein (2006)	1_3	N	F	Not studied	Fasciculated	Zoochory	Zoophilia	Tree	C3	Perennial
Malus domestica L.	Santos *et al.* (2007)	2	E	F/A	Not studied	Pivot	Zoochory	Entomophilia/ Psychophilia/ Ornitophilia	NA	C3	Perennial
Mandevilla atroviolacea (Stadelm.) R. E. Woodson	Klein (2006)	2	N	No	Not studied	Pivot	Anemochory	Psychophilia/ Entomofilia	Liana/	C3	Perennial
Mandevilla urophylla (Hook. F.) Woodson	Klein (2006)	2	N	No	Not studied	Pivot	Anemochory	Psychophilia/ Entomofilia	Liana/	C3	Perennial
Matayba elaeagnoides Radlk.	Frizzo e Porto (2004); Klein (2006)	2	N	No	Inconclusive	Pivot	NA	NA	Shrub	C3	Perennial
Matayba guianensis Aubl.	Klein *et al.* (2009); Klein (2006)	4	N	M	Not studied	Pivot	Zoochory	Zoophilia	Shrub	C3	Perennial
Matayba intermedia Radlk.	Zocche e Porto (1992)	2	N	No	Not studied	Pivot	NA	NA	Shrub	NA	Perennial
Mecardonia procumbens var. tenella (Cham. & Schltdl.) V.C. Souza	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	NA	NA	Herb	NA	Perennial
Megathyrsus maximus (Jacq.) B.K. Simon & S.W.L. Jacobs	Machado (2018)	1	I	No	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual

Melinis minutiflora P. Beauv.	Costa (2007)	1	I	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual
Melinis repens (Willd.) Zizka	Costa (2007)	1	I	M	Yes	Fasciculated	Anemochory	Anemophilia	Herb	NA	Annual
Mentha arvensis L.	Santos *et al.* (2007)	1	E	F/A	Not studied	Pivot	Zoochory	Entomophilia	NA	C3	Perennial
Miconia formosa Cogn.	Klein *et al.* (2009); Klein (2006)	1_3	N	No	Inconclusive	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Miconia ligustroides (DC.) Naudin	Zocche e Porto (1992); Lorenzi (2013); Santos *et al.* (2007)	1_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Miconia pusilliflora (DC.) Naudin	Santos *et al.* (2007)	2	N	No	Not studied	Pivot	Zoochory	Zoophilia	Shrub	C3	Perennial
Miconia sellowiana Naudin	Santos *et al.* (2007)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Microgramma squamulosa (Kaulf.) de la Sota	Klein (2006)	2	N	M	Not studied	Pivot	Anemochory	NA	Herb	NA	Perennial
Micropsis spathulata (Pers.) Cabrera	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	NA	Herb	C3	Annual
Mikania campanulata Gardner	Machado (2018)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Mikania cordifolia (L.F.) Willd.	Costa (2007); Machado (2018)	1	N	M	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Mikania cynanchifolia Hook. & Arn. ex B.L. Rob.	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Mikania glomerata Spreng.	Santos *et al.* (2007)	1_3	N	M	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Mikania laevigata Ach. Bip. Ex Baker	Klein (2006)	2	N	M	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial

*Mikania lanuginos*a DC.	Machado (2018)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Mikania micrantha H.B. & K.	Costa (2007)	1	N	M	Yes	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Mikania paranensis Dusén	Klein (2006)	1_3	N	No	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Mimosa bimucronata (DC.) O. Kuntze	Zocche e Porto (1992); Machado (2018); Klein (2006); Santos *et al.* (2007)	4	N	No	Not studied	Pivot	Autochory	Entomophilia	Shrub	C3	Perennial
Mimosa pudica L.	Machado (2018)	1	N	F/A	Yes	Pivot	Autochory	Entomophilia	Sub-shrub	C3	Perennial
Mimosa ramulosa Benth.	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	Autochory	Entomophilia	Shrub	C3	Perennial
Mitracarpus megapotamicus (Spreng.) Kuntze	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	NA	Entomophilia/ Ornitophilia	Herb	C3	NA
Mollinedia schottiana (Spreng.) Perkins	Santos *et al.* (2007)	1_3	N	No	Not studied	Fasciculated	Zoochory	Zoophilia	Shrub	C3	Perennial
Morus alba L.	Santos *et al.* (2007)	1_3	I	F/A	Not studied	Pivot	Zoochory	Ornitophilia/ Psychophilia	Tree	C3	Perennial
Myrcia anacardiifolia Gardner	Frizzo e Porto (2004)	1_3	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Myrcia brasiliensis Kiaersk.	Zocche e Porto (1992); Lorenzi (2013)	4	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Myrcia pubipetala Miq.	Santos *et al.* (2007)	1_3	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Myrcia splendens (Sw.) DC.	Lorenzi (2013)	2	N	M	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Myrcia tijucensis Kiaersk.	Frizzo e Porto (2004)	1_3	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Myrcianthes gigantea (D. Legrand) D. Legrand	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial

Myrciaria floribunda (H. West ex Willd.) O. Berg	Santos *et al.* (2007)	1_3	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	Perennial
Myrrhinium atropurpureum Schott	Frizzo e Porto (2004)	2	N	M	Not studied	Pivot	Zoochory	Zoophilia	Shrub	C3	Perennial
Myrsine coriacea (Sw.) R. Br	Frizzo e Porto (2004); Klein *et al.* (2009); Klein (2006); Lorenzi (2013); Santos *et al.* (2007)	4	N	M	Not studied	Pivot	Zoochory	Anemophilia	Shrub	C3	Perennial
Myrsine parvula (Mez) Otegui	Santos *et al.* (2007)	2	N	No	Not studied	Pivot	Zoochory	Anemophilia	Tree	C3	Perennial
Myrsine umbellata (Mart. ex A. DC.) Mez	Klein (2006)	2	N	No	Not studied	Pivot	Zoochory	Anemophilia	Tree	C3	Perennial
Nanogalactia heterophylla (Gillies ex Hook. & Arn.) L.P. Queiroz	Machado (2018)	2	N	No	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Nectranda membranacea (Sw.) Griseb.	Klein *et al.* (2009)	1_3	N	M	Not studied	Fasciculated	Zoochory	Entomophilia/ Ornitophilia	Tree	C3	Perennial
Nectranda oppositifolia Nees et Mart.	Klein (2006); Klein *et al.* (2009)	1_3	N	No	Not studied	Fasciculated	Zoochory	Zoophilia	Tree	C3	Perennial
Neoblechnum brasiliense (Desv.) Garper & V.A.O Dittrich	Machado (2018)	1_3	N	No	Not studied	Pivot	NA	NA	Herb	C3	NA
Neomitranthes gemballae (D. Legrand) D. Legrand	Machado (2018)	1_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial

Nuttalanthus texanus (Scheele) D.A. Sutton	Zocche e Porto (1992)	1	E	No	Not studied	Pivot	NA	NA	Herb	C3	NA
Ocimum basilicum L.	Zocche e Porto (1992)	1	E	F/A	Not studied	Pivot	Autochory	Entomophilia/ Ornitophilia	NA	C3	Perennial/ Annual
Ocotea indecora (Schott) Mez	Frizzo e Porto (2004)	1_3	N	No	Not studied	Fasciculated	Zoochory	Zoophilia	Shrub	C3	NA
Ocotea mandioccana A. Quinet	Frizzo e Porto (2004)	3	N	No	Not studied	Fasciculated	Zoochory	Entomophilia	Tree	C3	NA
Ocotea puberula Nees	Frizzo e Porto (2004); Klein *et al.* (2009); Klein (2006)	4	N	M	Not studied	Fasciculated	Zoochory	Entomophilia	Tree	C3	Perennial
Ophioglossum *crotalophoroides* Walter	Zocche e Porto (1992)	1	N	No	Not studied	NA	NA	NA	Herb	NA	NA
Orthosia scoparia (Nutt.) Liede & Meve	Santos *et al.* (2007)	1_2	N	No	Not studied	Pivot	NA	NA	Liana/ Epiphyte	NA	Perennial
Orthosia urceolata E. Fourn.	Klein (2006)	3	N	No	Not studied	Pivot	NA	NA	Liana/ Epiphyte	NA	Perennial
Ossaea amygdaloides (DC.) Triana	Klein (2006); Santos *et al.* (2007)	1_2	N	No	Not studied	Pivot	NA	NA	Shrub	NA	NA
Ouratea parviflora (A.DC.) Baill.	Zocche e Porto (1992)	2	N	No	Not studied	Pivot	Zoochory	Zoophilia	Shrub	C3	Perennial
Oxalis articulata Savigny	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Oxalis bipartita A.St.-Hil.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Oxalis debilis Kunth.	Machado (2018)	1	N	F/A	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Oxalis perdicaria (Molina) Bertero	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Oxalis refracta A.St.-Hil.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Autochory	Entomophilia	Herb	C3	Perennial

Oxypetalum tomentosum Wight ex Hook. & Am.	Machado (2018)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Oxypetalum wightianum Hook. & Arn.	Klein (2006); Santos *et al.* (2007)	1_2	N	No	Not studied	Pivot	Anemochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Palhinhaea cernua (L.) Franco & Vasc.	Zocche e Porto (1992)	1_2	N	No	Not studied	NA	NA	NA	Herb	C3	Perennial
Panicum aquaticum Poir.	Costa (2007)	1	N	No	Yes	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Panicum gouinii E. Fourn.	Zocche e Porto (1992)	1_2	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Panicum racemosum (P. Beauv.) Spreng.	Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Panicum repens L.	Machado (2018)	1	E	M	Yes	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Panicum sellowii Ness	Costa (2007)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Parapiptadenia rigida (Benth.) Brenan	Frizzo e Porto (2004)	2	N	M	Not studied	Pivot	Autochory	Entomophilia	Tree	C4	Perennial
Paspalum conjugatum Bergius	Costa (2007); Machado (2018)	1	N	F/A	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum corcovadense Raddi	Costa (2007)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum dilatatum Poir.	Costa (2007)	1	N	M	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum intermedium Munro ex Morong & Britton	Costa (2007)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum mandiocanum Trin.	Costa (2007); Klein (2006)	1_2	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum nicorae Parodi	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial

Paspalum notatum Flugge	Frizzo e Porto (2004); Costa (2007)	1_2	N	M	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum paniculatum L.	Frizzo e Porto (2004); Machado (2018); Klein (2006)	1_2	N	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum plicatulum L.	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	NA	Perennial
Paspalum polyphyllum Nees ex Trin.	Klein (2006)	2	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	NA	Perennial
Paspalum pumilum Nees	Zocche e Porto (1992); Santos *et al.* (2007); Costa (2007)	1_2	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum regnellii Mez.	Costa (2007)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum urvellei Steud.	Costa (2007); Machado (2018)	1	N	M	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Paspalum vaginatum Sw.	Machado (2018)	1	N	M	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C3	Perennial
Passiflora alata Curtis	Machado (2018)	1	N	M	Not studied	Pivot	Zoochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Passiflora edulis L.	Zocche e Porto (1992)	1	N	F/A	Not studied	Pivot	Zoochory	Entomophilia	NA	C3	Perennial
Paullinia trigonia Vell.	Santos *et al.* (2007)	2	N	No	Not studied	Pivot	NA	NA	Liana/ Epiphyte	C3	NA
Pera glabrata (Schott) Poepp. ex Baill.	Zocche e Porto (1992); Lorenzi (2013)	4	N	No	Yes	Pivot	Zoochory	Anemophilia	Shrub	C3	Perennial
Persea americana L.	Zocche e Porto (1992)	2	E	F/A	Not studied	Fasciculated	NA	NA	NA	C3	Perennial
Persea willdenovii Kosterm.	Zocche e Porto (1992)	2	N	No	Yes	Fasciculated	Zoochory	Zoophilia	Tree	C3	Perennial
Pfaffia tuberosa (Spreng.) Hicken	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Autochory	Entomophilia	Herb	NA	Perennial
Phyllanthus tenellus Roxb.	Machado (2018)	1	N	M	Not studied	Pivot	NA	NA	Herb	NA	Annual

Phymatidium delicatulum Lindl.	Klein (2006)	2	N	No	Not studied	Fasciculated	Anemochory	Entomophilia	Herb	NA	Perennial
Phytolacca thyrsiflora Fenzl ex Schm.	Costa (2007)	1	N	No	Not studied	Pivot	NA	NA	Herb	NA	Annual
Pinus elliottii Engelm.	Klein *et al.* (2009)	2	I	M	Not studied	NA	Zoochory	NA	Tree	NA	Perennial
Piper aduncum L.	Zocche e Porto (1992); Lorenzi (2013)	4	N	F/A	Yes	Fasciculated	Zoochory	Entomophilia	Shrub	C3	Perennial
Piper gaudichaudianum Kunth	Klein *et al.* (2009); Klein (2006)	1_2	N	M	Not studied	Fasciculated	Zoochory	Entomophilia	Shrub	C3	Perennial
Plantago australis Lam.	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Zoochory	Entomophilia/ Ornitophilia	Herb	C3	Annual
Plantago major Lam.	Zocche e Porto (1992)	1	E	F/A	Not studied	Pivot	Zoochory	Entomophilia/ Ornitophilia	NA	C3	Annual
Plantago myosuros Lam.	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Zoochory	Entomophilia/ Ornitophilia	Herb	C3	Annual
Plantago tomentosa Lam.	Zocche e Porto (1992)	1	N	M	Yes	Pivot	Zoochory	Entomophilia/ Ornitophilia	Herb	C3	Annual
Pleopeltis hirsutissima (Raddi) de la Sota	Klein (2006)	2	N	No	Not studied	Pivot	Anemochory	NA	Herb	NA	Perennial
Pleopeltis lepidopteris (Langsd. & Fisch.) de la Sota	Klein (2006)	1_2	N	M	Not studied	Pivot	Anemochory	NA	Herb	NA	Perennial
Pleroma sellowianum (Cham.) P.J.F. Guim. & Michelang.	Zocche e Porto (1992)	4	N	No	Yes	Pivot	NA	NA	Tree	NA	NA
Poa annua L.	Santos *et al.* (2007)	2	E	M	Yes	Fasciculated	Anemochory	Anemophilia	Herb	NA	Annual
Polygala molluginifolia A.St.-Hil. & Moq.	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	NA	Entomophilia	Herb	NA	NA

Polygonum acuminatum Kunth	Machado (2018); Costa (2007)	1	N	No	Yes	Pivot	Autochory	Entomophilia	Herb	NA	NA
Polygonum hydropiperoides L.	Costa (2007); Machado (2018)	1	N	M	Yes	Pivot	Autochory	Entomophilia	Herb	NA	NA
Polygonum punctatum Elliott	Machado (2018)	1	N	M	Yes	Pivot	Autochory	Entomophilia	Herb	NA	NA
Pombalia parviflora (Mutis ex L.f.) Paula-Souza	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	NA	NA	Herb	NA	NA
Portulaca oleracea L.	Machado (2018)	1	E	F/A	Yes	Pivot	NA	NA	Herb	NA	Annual
Psidium cattleianum Sabine	Lorenzi (2013); Zocche e Porto (1992); Klein (2006)	4	N	F/A	Not studied	Pivot	Zoochory	Entomophilia	Shrub	NA	Perennial
Psidium guajava L.	Zocche e Porto (1992); Lorenzi (2013)	2_3	I	F/A	Yes	Pivot	Zoochory	Entomophilia	Tree	NA	Perennial
Pterocaulon lanatum Kuntze	Costa (2007)	1	N	No	Not studied	Pivot	NA	Entomophilia	Herb	NA	NA
Pterocaulon lorentzii Malme	Machado (2018)	2	N	M	Not studied	Pivot	NA	Entomophilia	Herb	NA	NA
Pterocaulon polystachyum DC.	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	NA	Entomophilia	Herb	NA	NA
Pyrostegia venusta (Ker Gawl.) Miers	Machado (2018)	1	N	M	Not studied	Pivot	Anemochory	Ornitophilia	Liana/Epiphyte	NA	NA
Quiina glaziovii Engl.	Frizzo e Porto (2004)	2_3	N	No	Yes	NA	NA	NA	Tree	C3	NA
Quillaja lancifolia D. Don	Frizzo e Porto (2004)	2	N	M	Not studied	NA	NA	NA	Tree	C3	NA
Rhynchospora barrosiana E.R. Guaglianone	Costa (2007)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
*Rhynchospora brittoni*i Gale	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Rhynchospora corymbosa (L.) Britton	Costa (2007); Machado (2018)	1	N	M	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial

Rhynchospora emaciata (Ness) Boeck.	Costa (2007)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Rhynchospora holoschoenoides (Rich.) Herter	Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Rhynchospora rugosa (Vahl) Gale	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Rhynchospora tenuis Link	Zocche e Porto (1992)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Perennial
Richardia brasiliensis Gomes	Costa (2007); Machado (2018)	1	N	M	Not studied	Pivot	NA	Fanelophilia	Herb	C3	Perennial
Richardia humistrata (Cham. & Schltdl.) Steud.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	Fanelophilia	Herb	C3	Perennial
Rollinia rugulosa Schltdl.	Costa (2007)	2_3	NA	No	Not studied	Fasciculated	NA	NA	NA	C3	Perennial
Rosmarinus officinalis L.	Frizzo e Porto (2004)	1	E	F/A	Yes	Pivot	Zoochory	Entomophilia/ Psychophilia	NA	C3	Perennial
Rudgea jasminoides (Cham.) Muell. Arg.	Zocche e Porto (1992); Lorenzi (2013)	4	N	No	Yes	Pivot	Zoochory	Zoophilia	Shrub	C3	Perennial
Rugoloa pilosa (Sw.) Zuloaga	Machado (2018)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Annual
Rumohra adiantiformis (G. Forst.) Ching	Klein (2006); Machado (2018); Santos *et al.* (2007)	4	N	M	Not studied	NA	NA	NA	Herb	C3	NA
Saccharum angustifolium (Nees) Trin.	Frizzo e Porto (2004)	2	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Annual
Sagittaria montevidensis Cham. & Schltdl.	Costa (2007)	2	N	M	Not studied	Fasciculated	NA	Entomophilia	Herb	C3	Perennial
Sapium glandulosum (L.) Morong	Santos *et al.* (2007)	3	N	M	Not studied	Pivot	Autochory	Zoophilia	Shrub	C3	NA

Schinus lentiscifolia Marchand	Frizzo e Porto (2004)	2	N	No	Not studied	Pivot	NA	NA	Shrub	C3	Perennial
Schizachyrium microstachyum (Desv.) Roseng., B. R. Arr. & Izag	Frizzo e Porto (2004); Santos *et al.* (2007); Costa (2007); Klein (2006)	4	N	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C3	Annual
Scleria distans Poir.	Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Scleria gaertneri Raddi	Machado (2018)	1	N	No	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Scleria hirtella Sw.	Costa (2007)	1	N	M	Not studied	Fasciculated	Autochory	Anemophilia	Herb	C3	Annual
Scoparia dulcis L.	Costa (2007); Santos *et al.* (2007); Machado (2018)	2_3	N	F/A	Yes	Pivot	NA	NA	Herb	NA	Annual
Senecio brasiliensis (Spreng.) Less.	Frizzo e Porto (2004); Santos *et al.* (2007); Machado (2018)	4	E	M	Yes	Pivot	Anemochory	Entomophilia	Shrub	C3	Annual
Senecio brasiliensis (Spreng.) Less.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Herb	C3	Perennial
Senecio heterotrichius DC.	Zocche e Porto (1992)	1	N	No	Yes	Pivot	Anemochory	Entomophilia	Herb	C3	Perennial
Senecio leptolobus DC.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Herb	C3	Perennial
Senecio selloi (Spreng.) DC.	Costa (2007)	1	I	No	Yes	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Senna multijuga (Rich.) H.S. Irwin & Barneby	Klein (2006)	2_3	N	M	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Setaria parviflora (Poir.) Kerguélen	Frizzo e Porto (2004); Costa (2007); Machado (2018)	2_3	N	M	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Annual

Sida rhombifolia L.	Costa (2007); Machado (2018); Zocche e Porto (1992)	1	N	F/A	Yes	Pivot	Autochory	Entomophilia	Herb	C3	Perennial/Annual
Sida spinosa L.	Zocche e Porto (1992)	1	N	F/A	Not studied	Pivot	Autochory	Entomophilia	Sub-shrub	C3	Perennial/Annual
Sisyrinchium micranthum Cav.	Costa (2007)	1	N	No	Not studied	Fasciculated	Autochory	Entomophilia	Herb	C3	Perennial
Sisyrinchium vaginatum Spreng.	Zocche e Porto (1992)	1	N	M	Not studied	Fasciculated	Autochory	Entomophilia	Herb	C3	Perennial
Solanum americanum Mill.	Costa (2007); Machado (2018)	1	N	F/A	Yes	Pivot	Zoochory	Entomophilia/ Cantarophilia	Herb	C3	Perennial/Annual
Solanum lacerdae Dusén	Costa (2007)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia/ Cantarophilia	Shrub	C3	Perennial
Solanum mauritianum Scop.	Machado (2018)	1	N	F/A	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Solanum pseudocapsicum L.	Costa (2007)	1	N	M	Not studied	Pivot	Zoochory	Entomophilia/ Cantarophilia	Shrub	C3	Perennial
Solanum pseudoquina A.St.-Hil.	Zocche e Porto (1992)	3	N	M	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Solanum reflexum Schrank	Klein (2006)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia	Sub-shrub	C3	Perennial
Solanum sanctae-catharinae Dunal	Costa (2007)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia	Tree	C3	Perennial
Solanum sisymbriifolium Lam.	Zocche e Porto (1992)	1	N	M	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Solanum variabile Mart.	Costa (2007)	2_3	N	No	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Solidago chilensis Meyen	Machado (2018); Santos *et al.* (2007); Costa (2007)	4	N	M	Not studied	Pivot	NA	Entomophilia	Sub-shrub	C3	Perennial
Soliva sessilis Ruiz & Pav.	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	NA	Herb	NA	NA
Sonchus asper (L.) Hill	Machado (2018)	1	E	F/A	Yes	Pivot	NA	Entomophilia	Herb	C3	Perennial

Sorocea bonplandii (Baill.) W.C. Burger *et al.*	Costa (2007)	2_3	N	No	Not studied	Pivot	Zoochory	Zoophilia	Shrub	C3	Perennial
Steinchisma decipiens (Ness ex Trin.) W. V. Br.	Zocche e Porto (1992); Costa (2007)	1	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	NA	Annual
Steinchisma hians (Elliott) Nash in Small	Frizzo e Porto (2004); Costa (2007)	2_3	N	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	NA	Annual
Stemodia verticillata (Mill.) Hassl.	Santos *et al.* (2007)	1	N	M	Not studied	Pivot	NA	NA	Herb	NA	NA
Stylosanthes leiocarpa Vogel	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	Zoochory	Entomophilia	Sub-shrub	C3	Perennial
Symphyopappus itatiayensis (Hieron.) R.M. King & H. Rob.	Frizzo e Porto (2004)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Shrub	C3	Perennial
Symphyopappus lymansmithii B.L. Rob.	Frizzo e Porto (2004)	1	N	No	Not studied	Pivot	Anemochory	Entomophilia	Shrub	C3	Perennial
Symphyotrichum squamatum (Spreng.) G.L. Nesom	Machado (2018)	1	N	No	Yes	Pivot	Anemochory	Entomophilia	Sub-shrub	C3	Annual
Symplocos tenuifolia Brand	Zocche e Porto (1992); Klein *et al.* (2009); Santos *et al.* (2007); Lorenzi (2013); Lorenzi (2013)	4	N	No	Not studied	Pivot	NA	NA	Shrub	C3	Perennial
Tagetis minuta L.	Costa (2007)	1	E	F/A	Yes	Pivot	NA	NA	Herb	C3	Perennial
Telmatoblechnum serrulatum (Rich.) Perrie, D.J. Ohlsen & Brownsey	Machado (2018)	1	N	No	Not studied	Pivot	NA	NA	Herb	NA	Perennial
Terminalia kleinii L.	Klein (2006)	2_3	N	No	Not studied	Pivot	NA	NA	Tree	C3	Perennial/ Annual

Tetrorchidium rubrivenium Poepp. & Endl.	Klein (2006)	2_3	N	No	Not studied	Pivot	Zoochory	Anemophilia	Tree	C3	Perennial
Tillandsia mallemontii Glaz. ex Mez	Klein (2006)	2	N	No	Not studied	Fasciculated	Anemochory	Catarophilia	Herb	CAM	Perennial
Tillandsia recurvata (Linnaeus) Linnaeus	Klein (2006)	2	N	M	Yes	Fasciculated	Anemochory	Autophilia	Herb	CAM	Perennial
Tillandsia stricta Lindl.	Klein (2006)	2	N	No	Yes	Fasciculated	Anemochory	Autophilia	Herb	CAM	Perennial
Tillandsia tenuifolia L.	Klein (2006)	2	N	No	Not studied	Fasciculated	Anemochory	Autophilia	Herb	CAM	Perennial
Tillandsia usneoides L.	Klein (2006)	2	N	M	Not studied	Fasciculated	Anemochory	Autophilia	Herb	CAM	Perennial
Trema micrantha Blume	Klein (2006); Santos *et al.* (2007)	4	N	No	Yes	Fasciculated	Zoochory	Entomophilia	Shrub	C3	Perennial
Trichilia casaretti C.DC.	Santos *et al.* (2007)	3	N	No	Not studied	Pivot	NA	NA	Shrub	C3	NA
Trichilia lepidota Mart.	Frizzo e Porto (2004)	2_3	N	No	Not studied	Pivot	Zoochory	Zoophilia	Tree	C3	NA
Trifolium polymorphum Poir.	Frizzo e Porto (2004)	2	N	M	Yes	Pivot	NA	Entomophilia	Herb	C3	Perennial
Turnera sidoides L.	Zocche e Porto (1992)	1	N	M	Not studied	NA	NA	NA	NA	C3	Perennial
Typha domingensis Pers.	Frizzo e Porto (2004)	2	N	F/A	Yes	Fasciculated	NA	NA	Herb	C3	Perennial
Urochloa arrecta (Hack. ex. T. Durand & Schinz) Morrone & Zuloaga	Machado (2018)	1	I	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Perennial
Urochloa brizantha (Hochst. ex. A. Rich.) R.D. Webster	Machado (2018)	1	I	F/A	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C4	Perennial

Urochloa decumbens (Stapf) R.D. Webster	Machado (2018)	1	I	No	Yes	Fasciculated	Anemochory	Anemophilia	Herb	C4	Perennial
Urochloa distachya (L.) T.Q. Nguyen	Machado (2018)	1	I	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Perennial
Urochloa humidicola (Rendle) Morrone & Zuloaga	Machado (2018)	1	I	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Perennial
Urtica spathulata Sm.	Costa (2007)	1	I	No	Not studied	Fasciculated	Anemochory	Anemophilia	Herb	C4	Perennial
Uruchloa plantaginea (Link) Webster	Zocche e Porto (1992)	1	N	No	Not studied	Pivot	NA	Entomophilia	Herb	C3	Perennial
Verbena bonariensis L.	Machado (2018)	1	N	M	Yes	Pivot	Autochory	Entomophilia	Herb	C3	Perennial
Verbena litoralis Kunth	Costa (2007); Machado (2018)	1	N	M	Not studied	Pivot	Autochory	Entomophilia	NA	C3	Perennial
Vernonanthura discolor (Spreng.) H. Rob.	Zocche e Porto (1992); Lorenzi (2013)	4	N	No	Not studied	Pivot	Anemochory	Zoophilia	Tree	NA	Perennial
Vernonanthura nudiflora (Less.) H. Rob.	Zocche e Porto (1992)	2_3	N	No	Not studied	Pivot	Anemochory/Zoochory	Entomophilia	Shrub	NA	Perennial
Vernonanthura polyanthes (Sprengel) Vega & Dematteis	Machado (2018)	1	N	No	Not studied	Pivot	Anemochory/Zoochory	Entomophilia	Shrub	NA	Perennial
Vernonia tweediana Baker	Costa (2007); Santos *et al.* (2007); Klein (2006)	2_3	N	No	Not studied	Pivot	Anemochory/Zoochory	Entomophilia	Shrub	NA	Perennial
Vicia graminea Sm.	Frizzo e Porto (2004)	1	N	No	Not studied	Pivot	NA	Entomophilia	Herb	C3	Perennial
Vicia sativa L.	Machado (2018)	1	E	M	Yes	Pivot	Autochory	Entomophilia	Herb	C3	NA
Vigna longifolia (Benth.) Verdc.	Machado (2018)	1	N	No	Not studied	Pivot	Autochory	Entomophilia	Liana/ Epiphyte	C3	Perennial

Vigna luteola (Jacq.) Benth.	Costa (2007)	1	N	F/A	Not studied	Pivot	Autochory	Entomophilia	Liana/ Epiphyte	C3	Perennial
Virola bicuhyba (Schott ex Spreng.) Warb.	Klein *et al.* (2009); Klein (2006)	2_3	N	M	Not studied	Fasciculated	Zoochory	Zoophilia	Tree	C3	Perennial
Vitex megapotamica (Spreng.) Moldenke	Frizzo e Porto (2004)	2_3	N	F/A	Not studied	Pivot	Zoochory	Entomophilia	Shrub	C3	Perennial
Vriesea gigantea Gaudichaud	Klein (2006)	2	N	No	Not studied	Fasciculated	Anemochory	Ornitophilia	Herb	C3	Perennial
Vriesea rodigasiana E. Morren	Klein (2006)	2	N	No	Not studied	Fasciculated	Anemochory	Ornitophilia	Herb	C3	Perennial
Vriesea vagans (L. B. Smith) L. B. Smith	Klein (2006)	2	N	No	Not studied	Fasciculated	Anemochory	Ornitophilia	Herb	C3	Perennial
Xylopia brasiliensis Spreng.	Klein *et al.* (2009); Klein (2006)	2_3	N	M	Not studied	Fasciculated	NA	Catarophilia	Tree	C3	Perennial
Xylosma prockia (Turcz.) Turcz.	Frizzo e Porto (2004)	2_3	N	No	Not studied	Pivot	NA	NA	Shrub	C3	NA
Youngia japonica (L.) DC.	Machado (2018)	1	E	F/A	Yes	Pivot	NA	Autophilia	Herb	C3	Annual
Zanthoxylum rhoifolium Lam.	Frizzo e Porto (2004)	4	N	M	Not studied	Pivot	NA	NA	Tree	C3	NA
Zingiber officinale L.	Klein (2006)	2	E	F/A	Yes	Fasciculated	Zoochory	Entomophilia	NA	C3	Perennial

5 CHAPTER 4: IS IT SAFE TO CONSUME MEDICINAL PLANTS IN MINED AREAS? IMPACT OF MINING ON CONSUMPTION OF A MEDICINAL PLANT[3]

Graziela Dias Blanco[a]*, Mari Lucia Campos[b], Priscilla Dors[b], Noellen Menegon[b], Natalia Hanazaki[a]

[a]Department of Ecology and Zoology, Federal University of Santa Catarina (UFSC), 88040-900, Florianopolis, Santa Catarina, Brazil.
[b]Department of Soils and Natural Resources, State University of Santa Catarina (UDESC), 88035-901, Lages, Santa Catarina, Brazil
∗Corresponding author: graziela.blanco@posgrad.ufsc.br - https://orcid.org/0000-0003-2458-957X

Abstract

Background: Mineral extraction areas are a significant environmental concern due to soil, water, and plant food resources contamination. Some medicinal plant species, such as those of the genus *Baccharis*, potentially bioaccumulate toxic elements. Thus, this study aimed to evaluate the trace elements content from coal mining activity present in *Baccharis sagittalis*; and whether this plant consumption represents a risk to human health.
Results: Cd and Pb presented levels that exceed those recommended by three global health agencies. 53.8% of the interviewees mentioned the consumption of *B. sagittalis* as tea.
Conclusion: These results indicate that the consumption of metal-contaminated *B. sagittalis* can cause health problems as those metals accumulate in the human body. However, studies on Al, Ba, Cr, Cu, Mn, Ni, and Zn acceptable levels in plants consumed by humans are scarce. Additionally, few studies evaluate the contamination of species with associated traditional use in mining areas, increasing food security vulnerability of people who live near those areas and are constantly exposed to these agents, using plants obtained in the region.

Keywords: Mining, Food security, Traditional communities, Ethnobotany, Human health.

---

[3] A formatação do texto e das referências do capítulo I seguem as normas da revista na qual foi submetida: *Acta Botanica Brasilica*.

5.1 INTRODUCTION

Mineral extraction has a vital role in the economy, especially in developing countries, yet it is responsible for environmental stress such as soil and water resources contamination (Brisbois *et al.* 2019; Weiler *et al.* 2015). Investment in mining and the search for new extraction areas has grown in recent years. Studies point that by 2050, mineral extraction fields and the number of trace element-contaminated locations will have doubled (Candeias *et al.* 2019; Farjana *et al.* 2019; Schrecker *et al.* 2018).In countries such as China, South Africa, and Brazil, the extraction of mineral resources presents environmental concerns due to an increase in contaminated areas (Elyamine *et al.* 2018; Kemper *et al.* 1994; Maitland *et al.* 2016; Quinn *et al.* 2011; Zeng *et al.* 2019).Environmental impacts caused by mining range from changes in the landscape (e.g., removal of plant species and soil layers) to changes in ecological interactions dynamics (e.g., favoring of species that manage to survive in the impacted area and the removal of essential vegetable species for the local fauna), and contamination from different trace elements (Blanco *et al.* 2020a; Feng *et al.* 2020). However, even though these countries are increasing economic investments in the mineral sector, there is insufficient knowledge about the levels at which these elements are available in the environment, whether plants absorb them, and whether they represent a risk to human health (Brisbois *et al.* 2019).

Some trace elements are released into the environment as byproducts during extraction (Della Bosca and Gillespie, 2018). In coal extractions, for example, pyrite release generates acid drainage that intensifies mineral weathering, producing high quantities of these minerals in the water and soil. Some of these trace elements, such as copper (Cu), manganese (Mn), and zinc (Zn) (Ashraf *et al.* 2019; Campos *et al.* 2003; Duffus 2002; Li *et al.* 2020), contribute to biologically essential functions like nitrogen availability in the soil for plants' growth and development. When available in low quantities, they do not present a risk to the functioning of ecosystem dynamics and human health (Licina *et al.* 2007; Oti 2015). However, at high levels (*i.e.*, Cu above 29 $mg.kg^{-1}$ and Zn above 39 $mg.kg^{-1}$ in soil) (Ashraf *et al.* 2019) or in unexploitable forms (*i.e.*, lacking a biological function in the system) such as cadmium (Cd) and lead (Pb), these trace elements can cause toxic effects to the ecosystem and human health (Duffus 2002). This toxicity is directly related to the exposure time and considers levels that exceed those recommended by health agencies (Li *et al.* 2020).

A few plant species that grow in mining areas can accumulate trace elements at levels greater than those recommended by national and international surveillance centers (Ashraf *et al.* 2019). Species of the genus *Baccharis*, with occurrence in North and South America, have been studied for their medicinal qualities and their capacity to grow naturally in mining areas due to their ability to accumulate trace elements (Carreira 2007; Haque *et al.* 2008. Menezes *et al.* 2013; Paula *et al.* 2016; Souza *et al.* 2007).In coal mining areas in southern Brazil, *B. trimera* contained high levels of Mn (*i.e.*, above 2.3 mg in 200 mL) and Zn (*i.e.*, above 11 mg in 200 mL) in their leaves, compared to these trace elements' availability in the soil (Souza *et al.* 2007).The aqueous extract of *B. trimera* from coal mining areas displayed a mutagenic effect in animal cells, with high levels of cellular damage (Menezes *et al.* 2015), along with genotoxic effects in *in vitro* blood cells (Menezes *et al.* 2015; Paula *et al.* 2016). In *B. sarothroides* leaves, present in copper mining areas in the United States, scientists observed hyperaccumulation of Cu, Pb, chromium (Cr), Zn, arsenic (As), and nickel (Ni) (Haque *et al.* 2008). In addition to this situation, some species of the genus *Baccharis* are known widely and used for medicinal purposes in Brazil, being recognized as such by the National Health Surveillance Agency (ANVISA) and presented in the National List of Medicinal Plants of Interest to the Unified Health System (RENISUS) from Brazil (Marmitt *et al.* 2015).

The proximity increase of mining areas to human populations, including indigenous peoples and traditional and local communities, has grown in the last 20 years, generating territorial conflicts and food insecurity (Briones *et al.* 2018; Horowitz *et al.* 2018; Vega *et al.* 2018). Ensuring food security is a challenge in the 21st century since, in addition to providing food for everyone, guaranteeing its safety is also needed (Marrugo-Negrete *et al.* 2020). However, due to the proximity increase to contaminated areas, indigenous peoples and traditional and local communities' health and food security are threatened; these populations are 3-4 times more vulnerable to diseases from unhealthy or unsafe food (Brisbois *et al.* 2019; Marrugo-Negrete *et al.* 2020). This vulnerability is partially due to food contamination from trace elements produced by mineral extraction (Brisbois *et al.* 2019). In countries such as China, which accounts for one of the largest volumes of coal mining worldwide, solutions to ensure food safety (Juric *et al.* 2018; Sun *et al.* 2019) include an environmental safety law and a resolution for acceptable levels of trace elements in food and tea (Ghose 2014; Yi *et al.* 2018). However, few studies have analyzed food security and the contamination of food and medicinal plants consumed by local communities living close to mined areas (Blanco *et al.* 2020a; Brisbois *et al.* 2019).

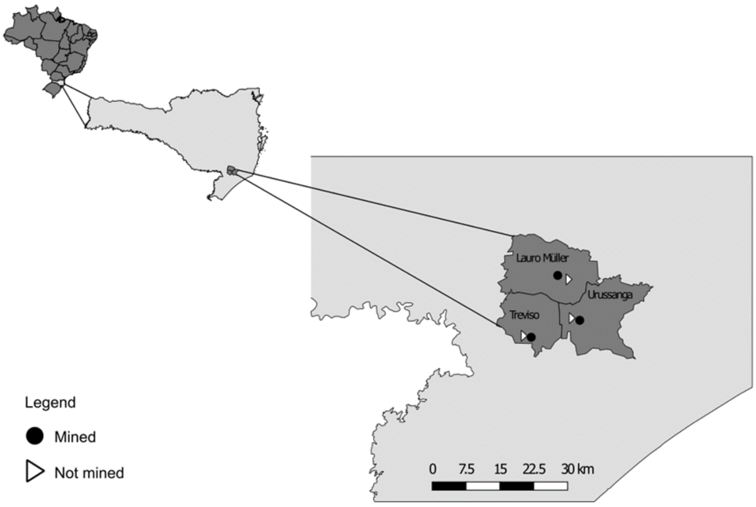
In coal extraction areas in southern Brazil, there is a mosaic of mining areas within human communities that use vegetable species for food and medicine (Blanco *et al.* 2020a). Many of these rural and urban neighborhoods established themselves specifically to support mining activity, occupying regions extremely close to the mines (Blanco *et al.* 2020a, b). In these areas, many *Baccharis* species known as *carqueja* are found, including *Baccharis sagittalis*, *B. trimera*, and *B. sarothroides,* all traditionally used as medicine (Karam *et al.* 2013; Santos *et al.* 2008; Stolz *et al.* 2014) *B. sagittalis* (Less.) DC., commonly consumed as tea, is abundant and occurs spontaneously in these areas (Blanco *et al.* 2020a). Thus, this study aimed to investigate the contents of aluminum (Al), barium (Ba), Cd, Cr, Cu, Mn, Ni, Pb, and Zn in *B. sagittalis*, the frequency of this species' consumption by local people, and whether it represents a risk. The tested hypothesis is that in mining areas, *B. sagittalis* contains high levels of those trace elements, and its consumption can endanger human health.

5.2 MATERIALS AND METHODS

5.2.1 Data collection

Data was acquired in the Santa Catarina coal basin, the second biggest coal-mining region in Brazil.Six mined areas with *B. sagittalis* occurrence were selected; three of these areas (S 28°32'34.6" W 049°29'34.8" Lauro Muller, S 27°31'56.9" W 048°30'44.4" Urussanga, and S 28°29'54.1" W 049°22'57.9" Treviso) experienced extensive coal mining activity (until coal depletion). In these areas, Al, Ba, Cd, Cr, Cu, Pb, Mn, and Zn presence in the soil had already been detected (Campos *et al.* 2010; Hugen *et al.* 2013; Souza *et al.* 2016), with no record of other anthropic activities affecting soil composition. The other three areas (S 28°32'33.2" W 049°20'53.6" Lauro Muller, S 28°32'34.5" W 049°29'34.8" Urussanga, and S 28°29'54.7" W 049°22'57.5" Treviso) were close to the mining areas ones but sustained no record of mineral exploration or anthropogenic activity (Figure 1). The distance between mined and unmined areas spanned a maximum of 10 Km. Two transects were covered in each of the six collection areas, comprising 10 whole individuals collected 15 to 20 m apart. For each plant, the soil was obtained through three sub-samples, collected with the aid of an auger, at a depth of 20 cm. These subsamples were combined into a single sample for each individual of *B. sagittalis* and then air dried. To avoid contamination of samples from one collection to another, the auger was cleaned after each collection. In total, 60 individuals and 60 soil samples were obtained (*i.e.*, 30 samples from mined areas and 30 samples from unmined areas).

Fig. 1 Map of samples areas in southern Brazil. Ten samples of *B. sagittalis* and soil were collected in each of the six locations identified on the map. Triangles represent unmined areas and circles represent mined ones.



5.2.2 Preparation and analysis of soil samples

After pulverizing the samples to a fine powder in an agate mortar and straining them in a 0.149 mm sieve, they were subjected to acid digestion following the USEPA 3050 B method (USEPA 1996). Method reliability measurement was performed using a reference soil material CRM-Agro E2002a (EMBRAPA 2015) and cell samples for the Qualitative Limit of Detection (QLD) (Table 1). Then, The Instrument Detection Limits (IDL) according to APHA was calculated (APHA 2017). All analyses were performed in duplicate (Table 1).

Table 1. Reference obtained values of the elements Al, Ba, Cd, Cr, Cu, Mn, Ni, Pb and Zn of the reference sample CRM-Agro E2002a (EMBRAPA 2015) and Instrumental Detection Limit (IDL)(APHA 2017). Trace elements were quantified by ICP-OES, except for Ni, which was quantified by F-AAS.

Trace element	Obtained Contents (mg.kg^{-1})	Reference Contents (mg.kg^{-1})	IDL
Al	58.20 (g.kg^{-1})	†	0.61
Ba	7.12	†	0.04
Cd	86.02	94.0 ± 11.4	0.03
Cr	77.49	120.0 ± 30	0.03
Cu	8.56	8.8 ± 4.0	0.09
Mn	76.28	130.0 ± 20	1.18
Ni	6.87	†	0.12
Pb	104.50	173.8 ± 18.8	0.51
Zn	6.09	†	0.19

Note: The symbol (†) means that the trace element was not presented in the CRM-Agro E2002a reference material Brazilian Agricultural Research Company (EMBRAPA 2015).

At last, Al, Ba, Cd, Cr, Cu, Pb, Mn, and Zn contents were quantified in an inductively coupled plasma optical emission spectrometer (ICP-OES); and Ni content in an air-acetylene flame atomic absorption spectrometer (F-AAS).

5.2.3 Preparation and analysis of plant material

Analysis in *B. sagittalis* samples comprised the same trace elements quantified in soil samples. The plants were weighed and dried in a greenhouse at 45°C for 42 hours, and dried again in 12 hours intervals to constant weight. The samples were macerated and stored for subsequent opening via the USEPA 3050 B method (USEPA 1996). The reliability of the analytical method was assessed using a reference sample from the CRM-Agro E1001a - *BrachiariaBrizantha* leaves (EMBRAPA 2013) (Table 2).

Table 2. Reference obtained values of the elements Al, Ba, Cd, Cr, Cu, Mn, Ni, Pb and Zn of the reference sample CRM-Agro E1001a - *BrachiariaBrizantha* leaves(EMBRAPA 2013) and Instrumental Detection Limit (IDL) (APHA 2017). Trace elements were quantified by ICP-OES, except for Ni, which was quantified by F-AAS.

Trace element	Obtained Contents (mg.kg^{-1})	Certified Contents (mg.kg^{-1})	IDL
Al	25.3	†	0.61
Ba	3.24	†	0.08
Cd	10.91	19.9 ± 5.1	0.03
Cr	1.41	3.3 ± 1.66	0.03
Cu	3.18	4.00 ± 0.7	0.09
Mn	53.34	70.19 ± 18.00	0.95
Ni	0.59	†	0.47
Pb	2.41	4.00 ± 1.80	0.11
Zn	6.13	9.90 ± 1.60	0.26

Note: The symbol (†) means that the trace element was not presented in the CRM-Agro E1001a reference material l Brazilian Agricultural Research Company (EMBRAPA, 2013).

5.2.4 Interviews and daily ingestion

After getting their informed consent, semi-structured interviews were conducted with residents of the communities found at a maximum distance of 300 m from the mined areas, individually, between February and March 2018. A total of 14 local communities (Vila Funil, Rio Carvão, Barreiros, Guaitá, Cidade Alta, Vila Visconde, São Sebastião Alto, Vila São Jorge, Rio Fiorita, Volta Redonda, Campo Morozini, Santa Luzia, Santa Augusta, and São Sebastião), belongingto 6 municipalities (Criciúma, Forquilhinha, Siderópolis, Treviso, Urussanga, and

Lauro Müller) were selected to take part in the study, giventheirhistorical background in mining activity. Within each community, house visits were paid only once, and interviews were conducted exclusively with those interested in participating in the research. Interviewees were questioned if they knew and consumed *B. sagittalis*, where they usually collected it, and asked about its consumption frequency. For measurement of *B. sagittalis* consumption frequency, each interviewee answered how many cups (200 mL) they ingested per week (see S1 for the questionnaire used). Three levels (De Godoy *et al.* 2013) were used to classify residents' frequency of *B. sagittalis*ingestion: small (*i.e.*, once a week or less), medium (*i.e.*, 2-3 times over the week), and frequent (*i.e.*, 4-7 times a week or more).Based on worldwide information on the consumption of 1 tea bag (on average each bag is 2 g) per tea preparation. A consumption projection of 2 g per cup (200 ml) was performed and the estimate was calculated, as a rule of three, of the intake associated with Cd, Cr, Cu and Pb (based on the values indicated by international and national agencies (ANVISA 2013; Soliman 2016; Westman 2018).

5.2.5 Statistical Analysis

Generalized linear models (GLMs) were used to compare the differences in trace elements concentrations in *B. sagittalis* leaves from mined and unmined areas. All models met the premises of normality and homoscedasticity, and for each trace element, a model was created using a gamma distribution family. For graphical representation, boxplots were generated. Parameters followed ANVISA RDC resolution nº 42 of August 29, 2013, for Brazil (ANVISA 2013), as well as maximum contaminants levels for China (Westman 2018)and the European Union (Soliman 2016), given that both provide reference values for acceptable levels of many trace elements in herbs and teas (ANVISA 2013; Soliman 2016; Westman 2018).

5.3 RESULTS

The average contents of trace elements quantified in the soil samples are reported in Table 3. Al, Mn, and Pb were present in higher concentrations in soil from mined areas (16.453 ± 2235.53 mg.kg^{-1}, 308.22 ± 224.96 mg.kg^{-1}, and 15.80 ± 9.69 mg.kg^{-1}, respectively) when compared to unmined areas (14594.98 ± 5132.04 mg.kg^{-1}, 87.92 ± 69.49 mg.kg^{-1}, and 11.86 ± 5.51 mg.kg^{-1}, respectively) ($p < 0.05$). The samples from unmined areas showed higher contents of Cr, Cu, and Ni (10.46 ± 2.98 mg.kg^{-1}, 41.63 ± 12.11 mg.kg^{-1}, and 18.05 ± 5.50 mg.kg^{-1}, respectively) in comparison to samples from mined ones (8.18 ± 3.48 mg.kg^{-1}, 22.13 ± 9.91

mg.kg^{-1}, and 13.86 ± 4.23 mg.kg^{-1}, respectively) ($p < 0.05$). The contents of Ba, Cd, and Zn showed nonsignificant variations between the two sampled groups ($p \geq 0.05$).

Al and Mn had the highest mean concentration in mined soil with a high standard deviation (16453.97 ± 2235.53 mg.kg^{-1} and 308.22 ± 224.96 mg.kg^{-1}, respectively). Considering reference levels from Santa Catarina state, Cr and Cd showed values above the acceptable level (5 mg.kg^{-1} and 0.12 mg.kg^{-1}, respectively) (Hugen *et al.* 2013; Souza 2016), both in mined and unmined soil. In addition, Cu also presented concentration levels above the allowed, in unmined areas (29 mg.kg^{-1}) (Hugen *et al.* 2013) (Table 3).

Table 3. Average contents (mg.kg-1) and standard deviation of Al, Ba, Cd, Cr, Cu, Pb, Mn and Zn in the soil of mined and unmined areas of Santa Catarina. Both P and T values of comparisons between trace element concentrations in mined and unmined areas are presented, as well as total trace element concentrations allowed for the state of Santa Catarina. SD: Standard Deviation; VRQ SC: Quality reference values for Santa Catarina.

Trace elements in soil	Unmined area Soil (mg.kg^{-1})	SD	Mined area Soil (mg.kg^{-1})	SD	P Value	T Value	VRQ SC (mg.kg^{-1})
Al	14594.98	5132.04	16453.97	2235.53	0.03	3.7	†
Ba	68.80	36.78	88.85	68.09	0.15	1.43	106.5‡
Cd	0.29	0.08	0.23	0.02	0.10	1.65	0.12‡
Cr	10.46	2.98	8.18	3.48	0.01	2.5	5§
Cu	41.63	12.11	22.13	9.91	0.03	2.2	29§
Mn	87.92	69.49	308.22	224.96	0.03	3.0	†
Ni	18.05	5.50	13.86	4.23	0.01	3.29	23.48‡
Pb	11.86	5.51	15.80	9.69	0.04	2.09	†
Zn	33.88	8.12	27.41	14.79	0.05	1.93	39§

In plant specimens, Ba, Cd, Mn, and Zn showed higher concentrations in leaves of individuals collected in mined areas (11.69 ± 10.25 mg.kg^{-1}, 0.30 ± 0.09 mg.kg^{-1}, 335.8 ± 212.60 mg.kg^{-1}, and 23.34 ± 9.51 mg.kg^{-1}, respectively) when compared to those obtained from unmined ones (3.64 ± 1.84 mg.kg^{-1}, 0.25 ± 0.04 mg.kg^{-1}, 263.87 ± 79.58 mg.kg^{-1}, and 17.83 ± 3.81 mg.kg^{-1}, respectively) ($p < 0.05$). Al and Cr were the only trace elements that showed a higher content in plant leaves collected from unmined areas in comparison to samples from mined areas (Table 4).

Table 4. Average contents (mg.kg^{-1}) of Al, Ba, Cd, Cr, Cu, Pb, Mn and Zn in *B. sagittalis* leaves from unmined and mined areas of Santa Catarina. Both Pand T values of comparisons between trace element concentrations in mined and unmined areas are presented, SD: Standard Deviation.

Trace elements in plant samples	Unmined areas (mg.kg^{-1})	SD	Mined areas (mg.kg^{-1})	SD	P value	T value
Al	55.25	60.67	29.25	17.36	0.00	0.24
Ba	3.64	1.84	11.69	10.25	0.00	4.45
Cd	0.25	0.04	0.30	0.09	0.00	2.82
Cr	0.57	0.20	0.54	0.21	0.80	3.6
Cu	6.18	1.79	6.45	1.45	0,52	0.64
Mn	263.87	79.58	335.8	212.60	0.05	1.88
Ni	3.55	1.24	3.99	1.11	0.15	1.44
Pb	3.80	1.02	4.00	1.64	0.56	0.57
Zn	17.83	3.81	23.34	9.51	0.00	3.209

Concerning maximum concentrations of Cd (0.40 mg.kg^{-1}) and Pb (0.60 mg.kg^{-1}) allowed for herbs and teas in Brazil (ANVISA 20123), these trace elements presented showed levels higher than recommended for consumption (Table 5). As so, when comparing results to international parameters (*i.e.*, China and the European Union) (Soliman 2016; Westman 2018), Cd and Pb also showed higher levels than recommended for these regions (Cd: above 1 mg.kg^{-1} for China and 0.05 mg.kg^{-1} forEuropean Union; Pb: above 5 mg.kg^{-1} for China and 1 mg.kg^{-1} forEuropean Union) (Table 5). References for Al, Ba, Cr, Cu, Mn, Ni, and Zn maximum contents in teas were not found throughout the literature. Both trace elements with a significant difference in concentration between mined and unmined areas and trace elements with concentrations higher than recommended (Soliman 2016; Westman 2018) can be observed in Fig. 2.

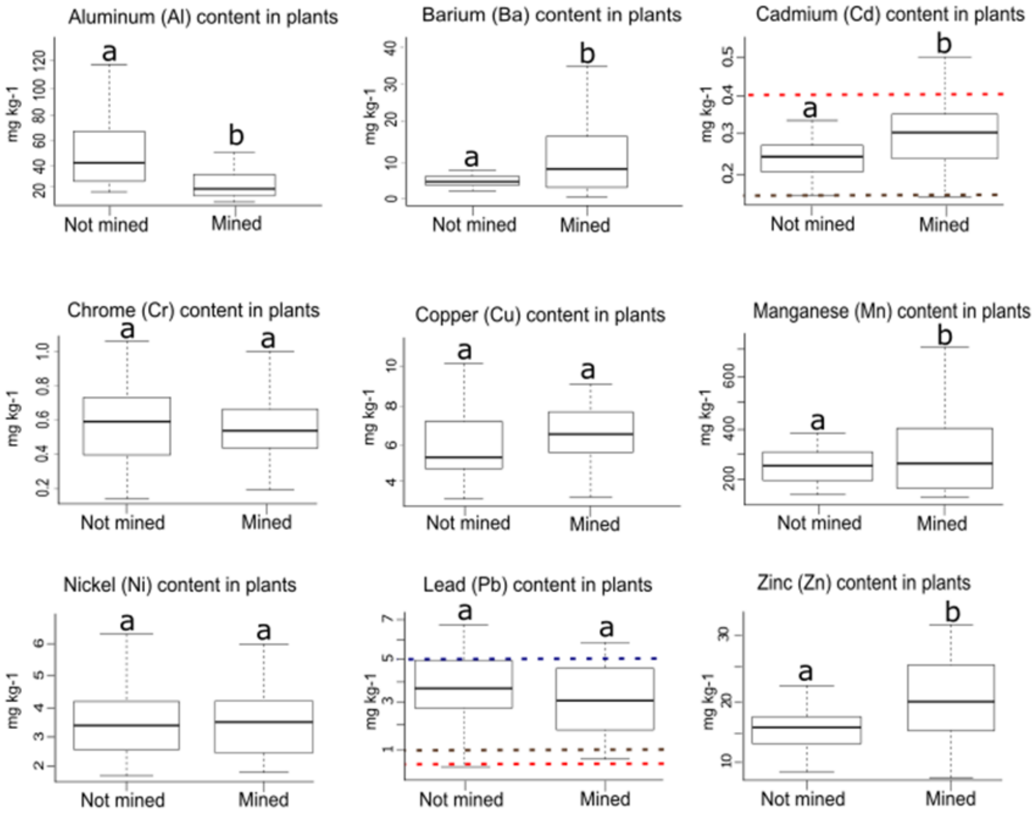
Pb presented values above the allowed limits in Brazil and European Union (above 0.60 mg.kg-1 and 1 mg.kg-1, respectively) (Soliman 2016; Westman 2018). Similar to the observed in soil, Mn and Pb contents were higher in leaf samples from mined areas, while leaf samples from unmined ones showed higher values of Al (Table 4).

Table 5. Average contents (mg.kg^{-1}) of Cd, Cr, Cu, and Pb found in *B. sagittalis*leaves and their maximum recommended values in herbs consumption in Brazil, China, and the European Union.

Trace elements in plant samples	Sample site		Maximum contents recommended in tea consumption		
	Unmined areas (mg.kg^{-1})	Mined areas (mg.kg^{-1})	Brazil (mg.kg^{-1})†	China (mg.kg^{-1})‡	European Union (mg.kg^{-1})§
Cd	0.25	0.3	0.40	1	0.05
Cr	0.57	0.54	--	5	--
Cu	6.18	6.45	--	30	15.0
Pb	3.8	4	0.60	5	1

Note: (†) ANVISA (2013); (‡) Westman (2018); (§) Soliman (2016).

Fig. 2. Boxplot of Al, Ba, Cd, Cr, Cu, Mn, Ni, Pb and Zn contents (mg. Kg^{-1}) in plants from mined and unmined areas in Santa Catarina. The red dotted line indicates the maximum reference values allowed for Cd and Pb in Brazil, according to ANVISA resolution[45] (2013); the blue dotted line indicates the maximum reference values allowed for Cd and Pb for China, according to Westman[46] resolution (2018); and the brown dotted line indicates the maximum allowable reference levels for Pb in the European Union according to the resolution of Soliman[47] (2016). Different letters indicate significant difference ($p < 0.05$) of the element concentration between plants from unmined and mined areas



In total, 195 residents were interviewed, with an average of 14 residents (± 5.4) per location. Their age ranged from 15 to 86 years old, with a mean of 53 years (± 17.8). Among the interviewees, 130 were women (68%), and 66 were men (32%). Of all, 105 (53.8%), who were mainly over 50 years old (74.2%) and women (70.4%), claimed to consume B. sagittalis as tea (infusion). Within this group, 96 interviewees (91.4%) mentioned a small consumption frequency (once a week), 1.9% reported an average one (2-3 times a week), and 6.6% of respondents mentioned a frequent B. sagittalis tea consumption (4-7 times a week or more). Intake amount varied from 1 to 2 cups for most of the interviewees (95.7%), with the intake of one cup (200 mL) being the most mentioned (46.6%), followed by 1-2 cups (200 mL each) (44.7%). Among interviewees who declared to consume B. sagittalis, 8.5% do it with the infusion of yerba mate or "chimarrão" (Ilex paraguariensis A. St. Hil).

Using published information on the use of 2 g of B. sagittalis per tea preparation and based on indicators (ANVISA 2013; Soliman 2016; Westman 2018), estimates of Cd, Cr, Cu, and Pb consumption per respondent were calculated (Table 6). Cd value was higher than the limit recommended by European Union (< 0.10 x 10-3 mg.kg-1 in 2 g of vegetable dry matter) (Soliman 2016) (Table 6). Pb value was higher than those recommended by both Brazil (< 1.12 x 10-3 mg.kg-1 in 2 g of vegetable dry matter) (ANVISA 2013) and the European Union (< 2 x 10-3 mg.kg-1 in 2 g of vegetable dry matter) (Soliman 2016) (Table 6). However, all projections (Table 6) considered values of B. sagittalis dry leaves instead of its leaf infusion; therefore, depending on the method of infusion preparation, these results can vary.

Table 6. Estimates of daily intake in mg of Cd, Cr, Cu, and Pb in 2 g of *B. sagittalis* dry matter, and acceptable trace element concentration values in herbs consumption in Brazil, China, and the European Union. Based on the values in Table 5, a rule of three was used to predict the amount of intake of elements per preparation.

	Acceptable trace element concentration within tea			**Estimates of trace elements daily intake within 2 g of *B. sagittalis*dry matter**	
Trace elements	**Brazil (mg in 2 g of vegetable dry matter)†**	**China (mg in 2 g of vegetable dry matter)‡**	**European Union (mg in 2 g of vegetable dry matter)§**	**From unmined areas (mg in 2 g of vegetable dry matter)**	**From mined areas (mg in 2 g of vegetable dry matter)**
Cd	$0.8 . 10^{-3}$	$2 . 10^{-3}$	$0.10 . 10^{-3}$	$0.5 . 10^{-3}$	$0.6 . 10^{-3}$
Cr	--	$10 . 10^{-3}$	--	$1.14 . 10^{-3}$	$1.08 . 10^{-3}$
Cu	--	$60 . 10^{-3}$	$30 . 10^{-3}$	$12.36 . 10^{-3}$	$12.90 . 10^{-3}$
Pb	$1.2 . 10^{-3}$	$10 . 10^{-3}$	$2 . 10^{-3}$	$7.6 . 10^{-3}$	$8 . 10^{-3}$

Note: (†) ANVISA (2013); (‡) Westman (2018); (§) Soliman (2016).

5.4 DISCUSSION

Individuals of *B. sagittalis* from both mined and unmined areas in Santa Catarina presented high contents of trace elements that can be toxic to human health if consumed. However, the concentration of analyzed trace elements differed between soil and plants samples from mined and unmined areas. Al, Mn, and Pb had higher percentages in the mined area soil, while Ba, Cd, Mn, and Zn prevailed in plant samples in the mined area. Meanwhile, Cr, Cu, Ni and Zn have higher soil concentrations in unmined areas, in the plant of these same areas only Al showed higher concentrations. According to reference values for Santa Catarina, Cd and Cr concentrations in soil were above the recommended in both mined and unmined areas (Souza *et al.* 2016) (above 0.12 $mg.kg^{-1}$ and 5 $mg.kg^{-1}$, respectively). Cu concentration in the soil was also above the recommended levels in the state, but in unmined areas only (above 29 $mg.kg^{-1}$) (Hugen *et al.* 2013). Also, in estimates considering consumption of 2 g of *B. sagittalis*dry matter, Cd and Pb, also had values above the recommended in the European Union (ANVISA 2013) (*i.e.*, Cd < 0.10x 10^{-3} $mg.kg^{-1}$ (Soliman 2016) and Pb < 2 x 10^{-3} $mg.kg^{-1}$ (Soliman 2016)), and Pb above the recommended in the Brazil (*i.e.*, Pb < 1.2 x 10^{-3} $mg.kg^{-1}$ [47] (ANVISA 2013)) (Table 6). These figures are worrisome, as 53.8% of respondents said they consume this species as infusion in the region.

Among the trace elements with elevated concentrations in the soil and *B. sagittalis* leaves, Al and Mn stood out. Aluminum results may be due to Santa Catarina's soil traits, with naturally higher availability of this element, a feature observed in other soils as well (Cunha 2018; Echart and Cavalli-Molina 2001; Quitaes 2000; Suppi 2018). In addition, anthropogenic actions may alter the ways in which Al is available in the environment, ultimately changing plants' capacity to absorb this trace element (Echart and Cavalli-Molina 2001). Such effect could be accountable for the high concentrations of Al found in plants from unmined areas, even though levels of this trace element were higher in the soil samples from mined areas (Cunha 2018; Suppi 2018). Al consumption may be related to the development of kidney problems and early stages of Alzheimer's disease (ATSDR 2008a; Walton 2011).Still, the effects of daily Al consumption are yet to be determined (ATSDR 2008a).In the United States, estimates point that an average adult ingests around 7 to 9 mg of Al every day through food, which can be contaminated in numerous ways, such as mining activity (ATSDR 2008a; Landry 2014).

The human body is unable to use Al. On the other hand, Mn is an important element for many physiological functions in humans, such as mitochondria oxidative stress prevention, digestion, and immune response (Röllin and Nogueira). However, when in elevated concentrations, it can cause several problems, including damage to the nervous system in prenatal stages and early childhood (Miah *et al.* 2020; Röllin and Nogueira). Since Mn was the element with the highest concentration found in *B. sagittalis* (263.87 mg.kg^{-1} in unmined areas and 335.8 mg.kg^{-1} in mined ones), the people living near these locations, who are consuming this plant, are being subjected to a vulnerable health situation.

As Al, Ba is a non-essential trace elements for the human body and can be toxic on some occasions; however, the lack of known parameters for Ba contaminated food ingestion complicates the comprehension of its effects on human health (Lu *et al.* 2019; Pi *et al.* 2019). Studies conducted in China have shown that people who consumed rice from areas with Ba contamination presented low contamination levels (Lu *et al.* 2019). This result suggests that there might be some biochemical pathways (in plants, human beings or both) that can lower Ba concentration and reduce its possible harmful effects (Lu *et al.* 2019). Still, to answer this question, further investigation is required. For instance, can the consumption of leaf infusion from bioaccumulating plants grown in Ba tainted areas also present the same results?

In acidic and altered soils (product of mining activities, for example), Cd content and mobility rise, affecting soil microbiota functioning and enhancing its absorption by plants (Feng *et al.* 2019; Oti 2015). In the study region, soil measurements of pH ranged from 3.5 to 5.5 in mined areas and 4.5 to 6.5 in unmined ones, revealing its acidity. Indeed, high Cd concentration in soil was found (029-0.23 mg.kg^{-1}), as well as in *B. sagittalis* leaves (0.25-0.30 mg.kg^{-1}) and in consumption estimates projected considering ingestion of 2 g of *B. sagittalis* dry matter (Cd < 0.10 x 10^{-3} mg.kg^{-1} (Soliman 2016). Such results were observed in mined and unmined areas, possibly related to soil origin in the region, with naturally higher Cd availability (Guo *et al.* 2013). However, high levels of Cd, already observed in rice and corn species consumed by the Chinese, may present a risk to food security, considering its harmful effects on human health, like nutrient absorption and kidney function alterations (Ata-Ul-Karim *et al.* 2020; Baye and Hymete 2010; Staessen 1994; Sun 2008). Cadmium is the most abundant trace element found in coal mining areas, and its high concentration is a concern for food security (Qi *et al.* 2014; Zhang *et al.* 2015).

Levels of Cu, Ni, and Zn in unmined soil were higher than in mined soil (22.13 mg.kg^{-1}, 13.86 mg.kg^{-1} and 27.41 mg.kg^{-1}, respectively). This result is possibly due to soil leaching and increased mobility in soils with a pH lower than 4.0 (Elbana and Selim 2011; Krämer and Clemens 2008).Plants use Cu, Ni, and Zn for numerous metabolic activities. For example, photosynthesis and respiration require Cu, Ni is essential to Ni's metabolic process, and Zn is crucial to protein binding (Fabiano *et al.* 2015; Krämer and Clemens 2008; Yruela 2005). As observed for plants, these trace elements also play a major role in human beings' health. Copper assists in neurological formation, while Ni is crucial for proper muscular development (Bost *et al.* 2016; Plum *et al.* 2010). However, when at high concentrations, Cu and Ni may be toxic to humans; in fact, Cu can cause kidney diseases, and Ni can induce pulmonary fibrosis (Bost *et al.* 2016; Krämer and Clemens 2008). Additionaly, Zinc is an important trace element for the immune system and has positive effects in cellular apoptosis control. Besides, it has a low intoxication rate and requires a high dosage to cause harm, such as digestive intoxication or stomach wall damage (Plum *et al.* 2010).

Even though projections for daily consumption were based on dry *B. sagittalis* leaves and not on its infusion, Cd and Pb presented concentrations far above the recommended levels for consumption (Cd $< 0.10 \times 10^{-3}$ $mg.kg^{-1}$ (Soliman 2016), Pb $< 1.2 \times 10^{-3}$ $mg.kg^{-1}$ (ANVISA 2013) and $< 2 \times 10^{-3}$ $mg.kg^{-1}$ (Soliman 2016)) and should be further investigated. Just as Cd, Cr (0.57 $mg.kg^{-1}$) has been found in high concentrations in mining areas and in food items grown in former coal mining areas, such as rice (*Oryza* spp.) in China rice plantations (Achmad and Budiawan 2017; Sun *et al.* 2018). Cr can be found in different forms: Cr(III), Cr(IV), Cr(VI), and despite its importance for lipid and protein metabolism in humans, this trace element can cause severe damage to human health, increasing chances of uterine cancer development, and causing severe respiratory symptoms (Achmad and Budiawan 2017; ATSDR 2008b). Considering its ability to accumulate in the food chain, added to its high absorption by plants, Cr presence in high concentrations is concerning (ATSDR 2008b).

Given that estimated levels of Cd, Cr, and Pb ingestion within 2 g of *B. sagittalis*infusion were already higher than recommended (Cd $< 0.10 \times 10^{-3}$ $mg.kg^{-1}$ (Soliman 2016), Pb $< 1.2 \times 10^{-3}$ $mg.kg^{-1}$ (ANVISA 2013) and $< 2 \times 10^{-3}$ $mg.kg^{-1}$ (Soliman 2016)). Along with that, reports on *Baccharis* species increasing availability in the region within the last 10-15 years also call for attention to potential growth in residents' consumption. An increase in the *Baccharis* population can be related to the fact that it is a pioneer species (Heiden 2006) that can easily develop in contaminated areas (Menezes 2013, 2016). With risen numbers of abandoned and unrecovered coal mining areas in the Santa Catarina coal region (Blanco *et al.* 2020a; Rocha-Nicoleite *et al.* 2017), an increase in this species availability can be expected. Consumption of *B. sagittalis* was reported mainly by women (*i.e.*, 70.4% of respondents who claimed to use this plant), which reveals women's greater vulnerability in the region. Overall, this result acknowledges the worldwide panorama that shows that women are the most affected by contaminated environments and have a higher food security vulnerability (Lutomia 2019).

Food safety and human health risks related to food grown near mining areas are rather recent concerns; in China, the focus has been on *Oryza* spp. (rice) and *Camellia sinensis* (green tea), both of which may present bioaccumulative potential and be harmful to human health (Huang *et al.* 2017; Li *et al.* 2017; Zhang *et al.* 2015). In India, Japan, and Europe, research regarding *C. sinensis*bioaccumulative potential has shown that it can gather high levels of heavy trace elements (Soliman 2016). In Canada and the United States, toxic trace elements from mining have been stocking up in some moose and sheep species that feed on bioaccumulating plants, being subsequently consumed by people (Loring and Whitely 2019; Schuster *et al.* 2011). Research in northern Brazil has shown that the consumption of fish contaminated by gold mining activities has caused mercury to accumulate in indigenous women's breast milk (Carvalho *et al.* 2009; Spurway and Soldatic 2016).

Since these trace elements are invisible contaminants (without odor, taste or physical alteration) that cannot be detected by human senses (Spurway and Soldatic 2016; Vyner 1988), their perception by human communities is challenging (Vyner 1988). The lack of parameters concerning food contamination by mining activity and the possible health effects resulting from their consumption only aggravates this difficulty (Vyner 1988). Giving that trace element content in the human body rise at a slow rate, requiring a long period of exposure to accumulate, relating human health issues to high trace element concentrations is an arduous task (Candeias *et al.* 2019; Gifford 2011).Also, there is a considerable amount of diseases these trace elements can cause, including abdominal pain, headaches, and slowly developing cancers, increasing difficulties to diagnose diseases' sources (Candeias *et al.* 2019; Gifford 2011; Vyner 1988). Altogether, these complexities make it hard for people to be aware of trace element contamination and food insecurity to which they are exposed.

The impact of mining activity on edible plants is evident, yet only a few studies provide data on safe ingestion rates for humans (Brisbois *et al.* 2019). A recent review regarding mining impacts on human health revealed that most research focuses on direct exposure to toxic agents in developed countries (Brisbois *et al.* 2019). Still, most mining areas are in developing or undeveloped countries, but literature is scarce on food safety, especially associated to indigenous people and local communities (Blanco *et al.* 2020a; Vyner 1988).

Baccharis is widely known and consumed in Brazil (Schripsema *et al.* 2019), but its traditional consumption is also frequently reported in Uruguay (Abad and Bermejo, 2007), Argentina (Abad and Bermejo, 2007), Chile (Morales *et al.* 2008), Colombia(Abad and Bermejo, 2007), Mexico(Abad and Bermejo, 2007), United States (Haque *et al.* 2008), and Canada (Freire *et al.* 2007). Likewise, *Baccharis* occurrence, as well as its trace element bioaccumulation have been reported in mining areas (Carreira 2007; Haque 2008; Oti 2015). For instance, in the United States, Pb absorption and translocation to leaves of another species of the genus *Baccharis* (*B. sarothroides*) were observed (Haque 2008). In 2020, medicinal plants use had a significant increase worldwide since the COVID-19 pandemic caused people to turn to medicinal plants more than in the former period (Nugraha *et al.* 2020).

All described situations increase food insecurity and human health vulnerability in traditional and local communities that live close to mining areas and contaminated environments. A study limitation was that, since the analyzed plants were not in a controlled environment, it was not possible to determine trace elements' original soil concentrations and compare them to the values absorbed by the plant. However, Cd and Pb levels (0.25-0.3 $mg.kg^{-1}$ and 3.8-4 $mg.kg^{-1}$) were above the reference levels (ANVISA 2013; Soliman 2016; Westman 2018) in plants from both mined and unmined areas. Additionally, Cd and Pb estimate consumption ($Cd < 0.10 \times 10^{-3}$ $mg.kg^{-1}$ (Soliman 2016), $Pb < 1.2 \times 10^{-3}$ $mg.kg^{-1}$ (ANVISA 2013) and $< 2 \times 10^{-3}$ $mg.kg^{-1}$ (Soliman 2016)), are higher than recommended. Thus, *B. sagittalis* medicinal consumption in this area is not safe, as it poses a threat to food security and local communities' health.

5.5 CONCLUSION

Studies on food and medicinal plants contamination through mining activities are scarce and require greater attention. This study results revealed contamination in a plant of native occurrence in mined areas and in surrounding areas without mining activity, which is traditionally used as medicine. High levels of Al, Cd, Mn, and Pb were observed in *B. sagittalis*, showing that collecting this species from mined regions for consumption is not safe. It also adds concerns regarding the lack of knowledge on safe consumption levels of contaminated plants. The importance of studies like this must be highlighted, since they are crucial to provide a better understanding of mining impacts on food security and human health of populations living close to mined regions.

5.6 REFERENCES

Abad MJ and Bermejo P (2007) *Baccharis* (compositae): A review update. Arkivoc 2007(7):76-96.

Achmad RT and Budiawan AEI (2017) Effects of chromium on human body. Annu Res RevBio

17(2):1-8.

ANVISA (2013). Resolução RDC nº 42, de 29 de agosto de 2013. Agência Nacional de Vigilância Sanitária. https://bvsms.saude.gov.br/bvs/saudelegis/anvisa/2013/rdc0042_29_08_2013.html. Accessed07 July 2021.

APHA (2017) Generation Public Health. American Public Health Association 89. https://www.apha.org/what-is-public-health/generation-public-health. Accessed 07 July 2021.

Ashraf S, Ali Q, Zahir ZA, Ashraf S and Asghar HN (2019) Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. Ecotoxicol Environ Saf 174:714-727.

Ata-Ul-Karim ST, Cang L, Wang Y and Zhou D (2020) Effects of soil properties, nitrogen application, plant phenology, and their interactions on plant uptake of cadmium in wheat. J Hazard Mater 384:121452.

ATSDR (2008a) Public Health Statement for Aluminum. Washington, DC: Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/ToxProfiles/tp22-c1-b.pdf. Accessed 07 July 2021.

ATSDR (2008b) Chromium (Cr) Toxicity. Atlanta, Georgia: Department of Health and Human Services Agency for Toxic Substances and Disease Registry Division of Toxicology and Environmental Medicine. https://www.atsdr.cdc.gov/csem/chromium/docs/chromium.pdf. Accessed 08 July 2021.

Baye H and Hymete A (2010) Lead and Cadmium accumulation in medicinal plants collected from environmentally different sites. Bul Environ ContToxicol 3:197-201.

Blanco GD, Hanazaki N, Cunha SMB, Cremer MJ and Campos ML (2020b) Exploring the interfaces between ethnobiology and ecotoxicology: A novel approach. Ethnobiol Lett 11:29-37.

Blanco GD, Sühs RB, Brizola E, Corrêa PF, Campos ML and Hanazaki N (2020a) Invisible contaminants and food security in former coal mined areas of Santa Catarina, southern Brazil. J EthnobiolEthnomed 16:1-11.

Bost M, Houdart S, Oberli M, Kalonji E, Huneau JF and Margaritis I (2016) Dietary copper and human health: Current evidence and unresolved issues. J Trace Elem Med Biol 35:107-115.

Briones Alonso E, Cockx L and Swinnen J (2018) Culture and food security. Glob Food Sec 17:113-127.

Brisbois BW, Reschny J, Fyfe TM *et al.* (2019) Mapping research on resource extraction and health: A scoping review. ExtrIndSoc 8:250-259.

Campos ML, Almeida JÁ and Souza LS (2003) Avaliação de três áreas de solo construído após mineração de carvão a céu aberto em Lauro Müller, Santa Catarina. RevBras Ciência do Solo

27:1123-1137.

Campos ML, Almeida JA de, Berto C *et al.* (2010) Impactos no solo provocados pela mineração e depósito de rejeitos de carvão mineral. Rev Ciência Agroveterinária 9:198-205.

Candeias C, Ávila P, Coelho P, Teixeira JP (2019) Mining activities: Health impacts. In: Nriagu JO (ed)Encyclopedia of Environmental Health, Elsevier, Amsterdam, pp 415–435.

Carreira RC (2007) *Baccharistrimera* (Less.) DC. (Asteraceae): estudo comparativo dos óleos voláteis, atividade biológica e crescimento de estacas de populações ocorrentes em áreas de Cerrado e Mata Atlântica. Thesis, Botanical Institute of São Paulo University.

Carvalho ASC, Santos AS, Pereira SFP and Alves CN (2009) Levels of As, Cd, Pb and Hg found in the hair from people living in Altamira, Pará, Brazil: Environmental implications in the Belo Monte area. J Braz ChemSoc 20:1153-1163.

Cunha GO de M, Almeida JA de, Ernani PR *et al.* (2018) Chemical Species and aluminum concentration in the solution of acid soils cultivated with soybean and corn under liming. Rev Bras Ciência do Solon 42:1-16.

De Godoy RCB, Deliza R, Gheno LB, Licodiedoff S, Frizon CNT and Ribani RH (2013) Consumer perceptions, attitudes and acceptance of new and traditional mate tea products. Food Res Int 53:801-817.

Della Bosca H and Gillespie J (2018) The coal story: Generational coal mining communities and strategies of energy transition in Australia. Energy Policy 120:734-740.

Duffus J (2002) “Heavy metals” - A meaningless term? Pure Appl Chem 74:793-807.

Echart CL and Cavalli-Molina S (2001) Aluminum phytotoxicity: effects, tolerance mechanisms and its genetic control. Ciência Rural 31:531-541.

Elbana TA and Selim HM (2011) Copper mobility in acidic and alkaline soils: miscible displacement experiments. Soil Sci Soc Am J 75:2101-2110.

Elyamine A, Moussa M, Ismael M, *et al.* (2018) Earthworms, Rice Straw, and Plant Interactions Change the Organic Connections in Soil and Promote the Decontamination of Cadmium in Soil. Int J Environ Res Public Health 15(11):2398.

EMBRAPA (2015) Brazilian Agricultural Research Company. Materiais de Referência para a Agricultura, Pecuária e Toxicologia: Solo Código: RM-Agro E2002a. Embrapa, Brazil

EMBRAPA. Brazilian Agricultural Research Company. Materiais de Referência para a Agricultura, Pecuária e Toxicologia: *BrachiariaBrizantha* cv Marandu Código: RM-Agro E1001a. Embrapa, Brazil

Fabiano CC, Tezotto T, Favarin J, Polacco JC and Mazzafera P (2015) Essentiality of nickel in plants: A role in plant stresses. Front Plant Sci 6:2013-2026.

Farjana SH, Huda N, Parvez Mahmud MA and Saidur R (2019) A review on the impact of mining and mineral processing industries through life cycle assessment. J Clean Prod 231:1200-1217.

Feng L, Yan H, Dai C *et al.* (2020) The systematic exploration of cadmium-accumulation characteristics of maize kernel in acidic soil with different pollution levels in China. Sci Total Environ 729:138972.

Feng Y, Wang J, Bai Z and Reading L (2019) Effects of surface coal mining and land reclamation on soil properties: A review. Earth-Science Rev 191:12-25.

Freire SE, Urtubey E and Giuliano DA (2007) Caracteres epidérmicos de lasespeciesdel género *Baccharis* (Asteraceae) usadas enla medicina popular. Caldasia 29(1):23-38.

Genchi G, Carocci A, Lauria G, Sinicropi MS and Catalano A (2020) Nickel: Human health and environmental toxicology. Int J Environ Res Public Health 17:679-700.

Ghose B (2014) Food security and food self- sufficiency in China: From past to 2050. Food Energy Secur 3:86-95.

Gifford R (2011) The dragons of inaction: psychological barriers that limit climate change mitigation and adaptation. Am Psychol 66:290-302.

Guo L, Lin H, Fan B, Cui X and Chen J (2013) Impact of root water content on root biomass estimation using ground penetrating radar: Evidence from forward simulations and field controlled experiments. Plant Soil 371:503-520.

Haque N, Peralta-Videa JR, Jones GL, Gill TE and Gardea-Torresdey JL (2008) Screening the phytoremediation potential of desert broom (*Baccharis sarothroides* Gray) growing on mine tailings in Arizona, USA. EnvironPollut 153:362-378.

Heiden G (2006) Comercialização de carqueja por ervateiros da zona central de Pelotas, Rio Grande do Sul. Rev Biol e Ciências da Terra 6:50-7.

Horowitz LS, Keeling A, Lévesque F, Rodon T, Schott S and Thériault S (2018) Indigenous peoples’ relationships to large-scale mining in post/colonial contexts: Toward multidisciplinary comparative perspectives. Extr Ind Soc 5:404-414.

Huang JJ, Wei W, Cui Q and Xiei W (2017) The prospects for China’s food security and imports: Will China starve the world via imports? J Integr Agric 16:2933-2944.

Hugen C, Miquelluti DJ, Campos ML *et al.* (2013) Cu and Zn contents in soil profiles of different lithologies in Santa Catarina. Rev Bras Eng Agric Ambient 17(6):622-638.

Juric AK, Batal M, David W *et al.* (2018) Risk assessment of dietary lead exposure among First Nations people living on-reserve in Ontario, Canada using a total diet study and a probabilistic approach. J HazardMater 344:55-63.

Karam TK, Dalposso LM, Casa DM and De Freitas GBL (2013) Carqueja (*Baccharistrimera*): Utilização terapêutica e biossíntese. Rev Bras Plantas Med 15:280-286.

Kemper C, Gibbs P, Obendorf D, Marvanek S and Lenghaus C (1994) A review of heavy metal and organochlorine levels in marine mammals in Australia. Sci Total Environ 154:129-39.

Krämer U and Clemens S (2008) Functions and homeostasis of zinc, copper, and nickel in plants. Top Curr Genet 20:215–271.

Landry K (2014) Human health effects of dietary aluminum. Rev Interdiscip des Sci la santé - Interdiscip J Heal Sci 4(1):39.

Li C, Sanchez GM, Wu Z *et al.* (2020) Spatiotemporal patterns and drivers of soil contamination with heavy metals during an intensive urbanization period (1989–2018) in southern China. Environ Pollut 260:114075.

Licina V, Antic-Mladenovic S and Kresovic M (2007) The accumulation of heavy metals in plants (*Lactuca sativa* L., *Fragaria vesca* L.) after the amelioration of coalmine tailing soils with different organo-mineral amendments. Arch Agron Soil Sci 53:39-48.

Liu B, Ai S, Zhang W, Huang D and Zhang Y (2017) Assessment of the bioavailability, bioaccessibility and transfer of heavy metals in the soil-grain-human systems near a mining and smelting area in NW China. Sci Total Environ 609:822-829.

Loring PA and Whitely C (2019) Food security and food system sustainability in North America. Encycl Food Secur Sustain 3:1261-133.

Lu Q, Xu X, Liang L *et al.* (2019) Barium concentration, phytoavailability, and risk assessment in soil-rice systems from an active barium mining region. Appl Geochemistry 106:142-148.

Lutomia CK, Obare GA, Kariuki IM and Muricho GS (2019) Determinants of gender differences in household food security perceptions in the Western and Eastern regions of Kenya. Cogent Food Agric 5:1694-1755.

Maitland BM, Poesch M, Anderson AE and Pandit SN (2016) Industrial road crossings drive changes in community structure and instream habitat for freshwater fishes in the boreal forest. FreshwBiol 61:1-18.

Marmitt DJ, Rempel C, Goettert MI and Silva AC (2015) Plantas com potencial antibacteriano da relação nacional de plantas medicinais de interesse do sistema único de saúde: revisão sistemática. Rev SaúdePública St Catarina 8(2):135-151.

Marrugo-Negrete J, Vargas-Licona S, Ruiz-Guzmán JA, Marrugo-Madrid S, Bravo AG and Díez S (2020) Human health risk of methylmercury from fish consumption at the largest floodplain in Colombia. Environ Res 182:109050.

Menezes APS, da Silva J, Fisher C *et al.* (2016) Chemical and toxicological effects of medicinal *Baccharis trimera* extract from coal burning area. Chemosphere 146:396-404.

Menezes APS, Da Silva J, Roloff J *et al.* (2013) *Baccharis trimera* (Less.) DC. as genotoxicity indicator of exposure to coal and emissions from a thermal power plant. ArchEnviron Contam Toxicol 65:434–441.

Menezes APS, Da Silva J, Rossato RR*et al.* (2015) Genotoxic and biochemical changes in *Baccharis trimera* induced by coal contamination. Ecotoxicol Environ Saf 114:9-16.

Miah MR, Ijomone OM, Okoh COA *et al.* 2020 The effects of manganese overexposure on brain health. Neurochem Int 135:104688.

Morales G, Paredes A, Sierra P and Loyola LA (2008) Antimicrobial activity of three *Baccharis* species used in the traditional medicine of Northern Chile. Molecules 13(4):790-794 (2008).

Nugraha RV, Ridwansyah H, Ghozali M, Khairani AF and Atik N (2020) Traditional herbal medicine candidates as complementary treatments for COVID-19: A review of their mechanisms, pros and cons. Evid Based Complement Altern Med 1-12.

Oti WO (2015) Bioaccumulation factors and pollution indices of heavy metals in selected fruits and vegetables from a derelict mine and their associated health implications. Int J Environ Sustain 4:15-23.

Paula A, Menezes S, Fisher C *et al.* (2016) Chemical and toxicological effects of medicinal *Baccharis trimera* extract from coal burning area. Chemosphere 146:396-404.

Pi X, Jin L, Li Z *et al.* (2019) Association between concentrations of barium and aluminum in placental tissues and risk for orofacial clefts. Sci Total Environ 652:406-412.

Plum LM, Rink L and Hajo H (2010) The essential toxin: Impact of zinc on human health. Int J Environ Res Public Health 7:1342-1365.

Qi Y, Huang B and Darilek JL (2014) Effect of drying on heavy metal fraction distribution in rice paddy soil. PLoS One 9:3-10.

Quinn CH, Ziervogel G, Taylor A, Takama T and Thomalla F (2011) Coping with multiple stresses in rural South Africa. EcolSoc 16:1-21.

Quintaes KD (2000) Utensílios para alimentos e implicações nutricionais. Rev Nutr 13:151-156.

Rocha-Nicoleite E, Overbeck GE and Müller SC (2017) Degradation by coal mining should be priority in restoration planning. PerspectEcolConserv 15:202-215.

Röllin HB and Nogueira CMCA (2011) Manganese: Environmental pollution and health effects. In: Nriagu JO (ed) Encyclopedia of Environmental Health. Elsevier Academic Press, New York, pp. 229-242.

Santos R dos, Citadini-Zanette V, Leal-Filho LS and Hennies WT (2008) Spontaneous vegetation on overburden piles in the coal basin of Santa Catarina, Brazil. RestorEcol 16:444-452.

Schrecker T, Birn AE and Aguilera M (2018) How extractive industries affect health: Political economy underpinnings and pathways. Heal Place 52:135-47.

Schripsema J, Lemos MA, Dagnino D and Luna FJ (2019) Carqueja (*Baccharis* sect.

Caulopterae), a critical review of its history, phytochemistry and medicinal use: problems of ethnopharmacology in Latin America. Phytochem Rev 18:1181-1209.

Schuster RC, Wein EE, Dickson C and Chan HM (2011) Importance of traditional foods for the food security of two first nations communities in the Yukon, Canada. Int J Circumpolar Health 70:286-300.

Soliman N (2016) Metals Contents in black tea and evaluation of potential human health risks to consumers. HealEconOutcome Res Open Access 2:2-5.

Souza LC de, Campos ML, Reichert G and Moura CN (2016) Teores de Arsênio em solos de três regiões do estado de Santa Catarina. RevAmbient e Agua 9:445-458.

Souza PZ de, Costa S andZocche JJ (2007) *Baccharistrimera*Less. DC. como indicadora da recuperação de áreas mineradas de carvão. Rev Bras Biociências 5:702–704.

Spurway K and Soldatic K (2016) “Life just keeps throwing lemons”: the lived experience of food insecurity among Aboriginal people with disabilities in the West Kimberley. Local Environ 21(9):1118-1131.

Staessen JA, Amery A, Lauwerys RR, Roels HA, Ide G and Vyncke G (1994) Renal function and historical environmental cadmium pollution from zinc smelters. Lancet 343:1523-1537.

Stolz ED, Müller LG, Trojan-Rodrigues M *et al.* (2014) Survey of plants popularly used for pain relief in Rio Grande do Sul, southern Brazil. Brazilian J Pharmacogn 24:185-196.

Sun Y, Li H, Guo G, Semple KT and Jones KC (2019) Soil contamination in China: Current priorities, defining background levels and standards for heavy metals. J Environ Manage 251:1-7.

Sun Y, Zhou Q and Diao C (2008) Effects of cadmium and arsenic on growth and metal accumulation of Cd-hyperaccumulator *Solanum nigrum* L. Bioresource Techn 99:1103-1110.

Sun Z, Xie X, Wang P, Hu Y and Cheng H (2018) Heavy metal pollution caused by small-scale metal ore mining activities: A case study from a polymetallic mine in South China. Sci Total Environ 639:217-227.

Suppi IM, Campos ML, Miquelluti DJ and Bueno DK (2018) Cobalt and manganese content in soils of Santa Catarina. Rev CienciasAgroveterinarias 17:579-588.

USEPA. United States Environmental Justice Implementation (1996) Enforcement and Compliance Plan Assurance (220 1 A). Washington, DC: Office of Environmental Justice 1996. https://www.epa.gov/sites/production/files/2015-02/documents/implementation_plan_ej_1996.pdf. Accessed 07 July 2021.

Vega CM, Orellana JDY, Oliveira MW, Hacon SS and Basta PC (2018) Human mercury exposure in yanomami indigenous villages from the Brazilian Amazon. Int J Environ Res Public Health 15:1-13.

Vyner HM (1988) The psychological dimensions of health care for patients exposed to radiation and the other invisible environmental contaminants. Soc Sci Med 27(10):1097-1103.

Walton JR (2011) Bioavailable aluminum: Its effects on human health. In: Nriagu JO (ed) Encyclopedia of Environmental Health. Elsevier Academic Press, Amsterdam, pp.315-327.

Weiler AM, Hergesheimer C, Brisbois B *et al.* (2015) Food sovereignty, food security and health equity: A meta-narrative mapping exercise. Health Policy Plan 30:1078-1092.

Westman W (2018) China releases the standard for maximum levels of contaminants. Beijing, China: China Food and Drug Administration. https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=China%20Releases%20the%20Standard%20for%20Levels%20of%20Contaminants%20in%20Foods%20_Beijing_China%20-%20Peoples%20Republic%20of_5-9-2018.pdf. Accessed 08 July 2021.

Yi K, Fan W, Chen J *et al.* (2018) Annual input and output fluxes of heavy metals to paddy fields in four types of contaminated areas in Hunan Province, China. Sci Total Environ 634:67-76.

Yruela I (2005) Copper in plants. J Plant Physiol 17:145-156.

Zeng L, Guo J, Wang B, Jun LV and Wang Q (2019) Analyzing sustainability of Chinese coal cities using a decision tree modeling approach. Resour Policy 64:1-12.

Zhang L, Mo Z, Qin J *et al.* (2015) Change of water sources reduces health risks from heavy metals via ingestion of water, soil, and rice in a riverine area, South China. Sci Total Environ 531:163-170.

5.7 SUPLEMENTARY MATERIAL

Supplementary material 1: Interview questionnaire model. Translated questions (interviews were done in Portuguese) that were asked to 16 the interviewees and that served as a basis for the consumption analysis of *B. sagittalis.*

Date:
Interview number:
Interviewee name: [confidential information]
Age:
Gender: F ( ) M ( )
Location (Municipality, Street and House #):

1. Do you know the carqueja (Baccharis)? * Show one of the boards to facilitate the identification of the carqueja (Baccharis). Y ( ) or N ( )

2. What do you use the carqueja (Baccharis) for?

3. Where do you collect or buy the carqueja (Baccharis)? If it collects, in which places does it collect? * Show the map of the region.

4. Is it easy to get carqueja (Baccharis)? Do you find it easily available or not? Environmental Management

5. How often does the carqueja (Baccharis) consume? Does not consume ( )
Frequently ( ) * 4-7 times a week or more
Medium ( ) * 2-3 times over the week
Little ( ) * once a week or less

6. When you consume carqueja (Baccharis), do you drink 1 cup (200ml) or more?

7. Have you noticed that there are different types of carqueja (Baccharis)? * Show the boards with the images to see if the interviewee differentiates some type of carqueja (Baccharis), and write only the number of the image that appears on the board.

8. Have you ever seen cattle eating carqueja (Baccharis)? Y ( ) or N ( )

6 DISCUSSÃO GERAL E CONCLUSÃO

A mineração de minérios sólidos tem impactos ambientais e para a saúde humana em diferentes escalas, conforme tratados nesta tese. Numa escala global, a presença de atividades de mineração, os elementos-traço oriundos dessa atividade, o baixo desenvolvimento humano e o pequeno investimento em políticas e ações ambientais, são fatores que impactam negativamente a soberania e segurança alimentar de comunidades em diferentes países (capítulo I). No longo prazo, as atividades de mineração impactam a disponibilidade de recursos alimentares e nutricionais dos povos indígenas e comunidades tradicionais (PICL), em decorrência, por exemplo, do desmatamento e diminuição da riqueza de espécies (YADAV *et al.*, 2019). Aliada a esta situação, a falta de pesquisas para a compreensão dos impactos da mineração na saúde humana causados pelo consumo de alimentos oriundos destes ambientes, agrava a insegurança alimentar (WEGENAST; BECK, 2020), especialmente dos grupos humanos mais vulneráveis, como os PICL. Além do chumbo, o elemento-traço mais estudado por seus impactos no meio ambiente e na saúde humana (KUMAR *et al.*, 2020), ainda são necessários esforços para compreender a ação de outros contaminantes em alimentos consumidos pelos PICL, como o arsênio e o mercúrio.

A contaminação por elementos-traço oriundos de atividades de mineração em diferentes partes do mundo, em plantas com uso alimentício e medicinal associado, direcionou o questionamento central do capítulo II. Na escala regional das áreas mineradas no cordão carbonífero de Santa Catarina, concluímos que as comunidades locais do entorno dessas áreas consomem diversos recursos vegetais obtidos nesses locais, mesmo sendo ambientes visivelmente impactados pela mineração. Constatamos que características como a invisibilidade dos elementos-traço (*i.e.*, não exalam odor, gosto ou alteração visual nos recursos vegetais) podem ser fatores de agravamento para o uso de recursos vegetais por pessoas que moram perto destes ambientes.

Outros fatores, como por exemplo, a falta de informação sobre as causas e possíveis efeitos diretos da contaminação das áreas mineradas para a saúde humana pelo consumo de alimentos oriundos destas regiões, são preocupantes. Aliada a esta falta de informação, fatores culturais e de tempo de moradia no local influenciaram no maior uso das espécies destes ambientes. Santa Catarina, assim como outras áreas em vários estados brasileiros, é culturalmente heterogênea, o que pode afetar o conhecimento e o uso das plantas de um dado local. A influência de diferentes culturas e a mistura de conhecimentos são combinadas e integradas nas gerações mais recentes (ABREU *et al.*, 2015). No nosso estudo, quanto mais tempo uma pessoa residia na área correlacionava-se com mais espécies citadas: os residentes mais velhos usam uma maior riqueza de espécies de plantas, coletadas ou plantadas, tanto devido ao tempo de vida e aprendizagem nesses ambientes (GAOUE *et al.*, 2017; KOHSAKA; ROGEL, 2019). Estes fatores indicam que o uso destes recursos são práticas importantes e fazem parte da cultura diária e local, indicando uma preocupação ainda maior para a saúde e soberania e segurança alimentar destes grupos de pessoas.

O impacto dos elementos-traço liberados pelas atividades de mineração preocupa também em relação à estruturação das comunidades vegetais nestas áreas que foram mineradas para extração de carvão e foram abandonadas sem os devidos cuidados de restauração. No capítulo III descrevemos as características morfofisiológicas e o potencial bioacumulador das espécies vegetais que ocorrem em áreas de extração de carvão mineral abandonadas no sul do Brasil. Apesar das limitações de uma investigação a partir de dados secundários (listas de espécies), ao longo do tempo, observamos o aumento da ocorrência de espécies com potencial bioacumulador. Investigando características das espécies vegetais como as vias metabólicas, tipos de raiz, as síndromes de polinização e dispersão e seu potencial de uso alimentício ou medicinal para as pessoas, discutimos que os elementos-traço que são bioacumulados podem influenciar desde a fisiologia individual das espécies até a dinâmica e funcionamento como um todo das comunidades. Além disso, estes elementos-traço podem ser distribuídos ao longo da cadeia alimentar, através do néctar, pólen, folhas, frutos e cascas das plantas, não ficando restritos à área onde houve a mineração. As espécies que bioacumulam estes elementos-traço também podem representar um risco à saúde humana, como, por exemplo, as espécies utilizadas tradicionalmente na medicina local.

Neste sentido, em uma escala local, no capítulo IV analisamos o teor de concentração de elementos-traço em *B. sagittalis.* Encontramos níveis preocupantes de Cd e Pb nesta espécie e no solo, tanto de áreas que foram mineradas para extração de carvão mineral, como em áreas que não haviam sido mineradas e nem sofreram impactos antropogênicos diretos, mas que estão na mesma região estudada. O Pb também foi um dos elementos mais encontrados nos estudos globais, no levantamento bibliográfico realizado no capítulo I, e sua elevada concentração no ambiente e recursos alimentares está associada a doenças crônicas (ĆWIELĄG-DRABEK *et al.*, 2020).

A presente tese reforça que questões ambientais e sociais, em áreas de mineração, devem ser revistas com urgência e debatidas, a fim de compreender seus impactos na soberania e segurança alimentar dos PICL dos países. Assim, ações estratégicas devem ser adotadas pelos governos e pela sociedade civil, em nível nacional e regional, que considerem a participação efetiva dos PICL na tomada de decisões sobre atividades mineradoras. O desenvolvimento e implementação de pesquisa e comitês participativos, que direcionem de forma efetiva na formulação de estratégias sociais e de políticas públicas, é uma ação importante urgente, e tem mostrado bons resultados, como na Bolívia e Tailândia (CONCEIÇÃO *et al.*, 2011; SCHILLING *et al.*, 2020)

Ainda há a necessidade de compreender melhor a contaminação dos recursos e seu impacto no meio ambiente e na sociedade. Esses resultados também revelam a falta de informações sobre a contaminação, bem como a falta de ações que incluam as comunidades locais nas estratégias de restauração de áreas contaminadas. Assim sendo, uma ação necessária para resolver este problema, é o incentivo a pesquisa e o desenvolvimento de protocolos que analisem as áreas contaminadas, para sabermos quais alimentos estão contaminados e quais os níveis representam um risco para a saúde humana. Assim como, consultas e entrevistas nas comunidades, para saber quais alimentos são consumidos e com qual frequência.

Outro desafio neste ambiente minerados e abandonados são os impactos nas comunidades ecológicas que se estabelecem nestes ambientes ao longo do tempo. O povoamento por espécies vegetais em áreas de extração mineral para o carvão que foram abandonadas pode ser fortemente afetado pela presença de elementos-traço, como os metais pesados. Ao longo do tempo, estes elementos podem estar selecionando espécies e impactando na riqueza das comunidades vegetais, que serão potenciais focos de dispersão de elementos tóxicos para áreas que não foram mineradas. O estudo sobre espécies bioacumuladoras ainda necessita ser ampliado, principalmente para aquelas as espécies mais frequentes nestes ambientes e que apresentam uso alimentício ou medicinal associados.

O aumento de áreas mineradas e o abandono destas áreas é uma preocupação global e o Brasil vem na contramão das discussões internacionais sobre mudanças climáticas. O relatório “Brasil: o legado tóxico da Engie Diamante fram Capital” (ARAYARA, 2021) e os dados apresentados na COP26, em 2021, mostram a urgência de revertermos os danos causados pelas atividades de extração mineral de carvão. O plano de “Carvão Sustentável” até 2050, é uma política nacional que busca estender as atividades das carboníferas e a extração mineral no país, mas este incentivo coloca em risco os acordos climáticos internacionais assinadas pelo Brasil de diminuição de emissão de CO_2 e agrava o quadro das mudanças climáticas. Especialmente, em relação à extração de carvão mineral no sul do Brasil, os dados mostram danos severos ao Bioma da Mata Atlântica e contaminação em larga escala destes ambientes. Entre as recomendações apresentadas, a recuperação e diminuição das atividades de extração mineral da região, assim como a indenização das comunidades locais por parte das mineradoras é o primeiro passo a ser realizado e deve ser feito com urgência. Nesta tese apresentei dados preocupantes sobre o potencial de dispersão dos elementos-traço no ambiente e sua contaminação em áreas que não foram mineradas. Estes dados indicam que a contaminação dos solos e recursos hídricos de ambientes próximos a áreas mineradas pode estar ocorrendo e necessita acompanhamento e monitoramento. Também é necessária a comunicação e capacitação das comunidades locais sobre os riscos destas áreas à sua saúde, bem como a devida responsabilização por esses danos à saúde ambiental e humana. Neste contexto, os dados apresentados reforçam a importância do estudo toxicológico e etnoecológico dos alimentos consumidos pelas comunidades locais.

A presente tese também destaca a necessidade de estudos futuros para efetuar o mapeamento das áreas de sobreposição e proximidade de comunidades humanas e com áreas de mineração, entrevistas com as comunidades sobre o consumo de espécies para fins medicinais e alimentícios provenientes de áreas de mineração e estudos que analisem a toxicidades de elementos-traço nestas espécies. Tais estudos permitirão um panorama mais robusto da vulnerabilidade destes grupos humanos.

Por fim, devido aos resultados encontrados na tese, que apresentam importantes implicações socioambientais, foram organizadas devolutivas dos resultados em diferentes áreas da sociedade. Primeiramente, através de divulgação científica escrita, palestras e *lives*, para divulgar e conscientizar a população sobre os resultados encontrados. Além disso, está sendo preparado um material escrito, que será enviado para gestores políticos e tomadores de decisão, acerca dos impactos da mineração na segurança alimentar e no ambiente.

REFERÊNCIAS

ABAD, M. J.; BERMEJO, P. *Baccharis* (compositae): A review update. **Arkivoc**, n. 7, p. 76–96, 2007.

ABREU, D. B. D. O.; SANTORO, F. R.; ALBUQUERQUE, U. P. de; LADIO, A. H.; MEDEIROS, P. M. de. Medicinal plant knowledge in a context of cultural pluralism: A case study in Northeastern Brazil. **Journal of Ethnopharmacology**, n. 175, p. 124–130, 2015. DOI: https://doi.org/10.1016/j.jep.2015.09.019.

ADAMS, J.; GOODEY, N. M.; GALLAGHER, F. Plant e soil interactions in metal contaminated soils. **Soil Biology and Biochemistry**, n. 80, p. 224–231, 2015. DOI: https://doi.org/10.1016/j.soilbio.2014.10.011.

ADEWUMI, A. J. P. *et al.* Exposure of children to heavy metals from artisanal gold mining in Nigeria: evidences from bio-monitoring of hairs and nails. **Acta Geochimica**, v. 39, n. 4, p. 451–470, 1 ago. 2020.

ADEWUMI, A. J.; LANIYAN, T. A. Contamination, sources and risk assessments of metals in media from Anka artisanal gold mining area, Northwest Nigeria. **Science of the Total Environment**, v. 718, p. 137235, 2020. DOI: https://doi.org/10.1016/j.scitotenv.2020.137235.

ALDAY, J. G. *et al.* Functional groups and dispersal strategies as guides for predicting vegetation dynamics on reclaimed mines. **Plant Ecology**, v. 212, n. 11, p. 1759–1775, nov. 2011.

ALI, H.; KHAN, E.; ILAHI, I. Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. **Journal of Chemistry**, v. 2019, 2019.

ARAUJO, ELIANA ROCHA. **Fechamento de minas no Brasil não tem legislação federal específica e coloca em risco o ambiente e populações locais**. Brasília: CETEM; Ministério da Ciência, Tecnologia e Inovação, 2015. p. 1-26.

ARAUJO, ELIANE R; CHAVES FERNANDES, F. R. Mineração no Brasil: crescimento econômico e conflitos ambientais. *In:* GUIMARÃES, P. E.; CEBADA, J. D. P. (eds.). **Conflitos ambientais na indústria mineira e metalúrgica: o passado e o presente**. Évora; Rio de Janeiro: CETEM; CICP, 2016. p. 65–88.

ARAYARA. **Brasil**: Legado Tóxico da Engie Diamante Fran Capital. [*S.l.*], 2021. Acesso em: 30 nov. 2021. Disponível em: https://coalwatch.org/wp-content/uploads/2021/11/O-Legado-To%CC%81xico-da-Engie-Diamante-Fran-Capital-no-Brasil_PT-ARAYARA_v.1.1.pdf

ASHRAF, S. *et al.* Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. **Ecotoxicology and Environmental Safety**, v. 174, p. 714–727, 2019.

ATA-UL-KARIM, S. T. *et al.* Effects of soil properties, nitrogen application, plant phenology, and their interactions on plant uptake of cadmium in wheat. **Journal of Hazardous Materials**, v. 384, p. 121452, 2020.

ATA-UL-KARIM, S. T.; CANG, L.; WANG, Y.; ZHOU, D. Effects of soil properties, nitrogen application, plant phenology, and their interactions on plant uptake of cadmium in wheat**.** **Journal of Hazardous Materials**, v. 384, p.121452, 2020.

BELLOLI, M.; QUADROS, J.; GUIDI, A. **História do carvão de Santa Catarina**. 1a ed. Criciúma: Imprensa Oficial do Estado de Santa Catarina, 2002.

BERTHIER-FOGLAR, S.; GAUDICHAUD, F.; TOLAZZI, S. Recursos minerais nas Américas: Mutações de um continente. **IdeAs,** v. 8, p. 1–6, 2016.

BLANCO, G. D. *et al.* Exploring the interfaces between ethnobiology and ecotoxicology: A novel approach. **Ethnobiology letters**, v. 11, p. 29–37, 2020a.

BLANCO, G. D. *et al.* Invisible contaminants and food security in former coal mined areas of Santa Catarina, southern Brazil. **Journal of Ethnobiology and Ethnomedicine**, v. 16, p. 1–11, 2020b.

BORTEY-SAM, N. *et al.* Human health risks from metals and metalloid via consumption of food animals near gold mines in Tarkwa, Ghana: Estimation of the daily intakes and target hazard quotients (THQs). **Ecotoxicology and Environmental Safety**, v. 111, p. 160–167, 2015.

BRIONES ALONSO, E.; COCKX, L.; SWINNEN, J. Culture and food security. **Global Food Security**, v. 17, p. 113–127, 2018.

BRISBOIS, B. W. *et al.* (2019). Mapping research on resource extraction and health: A scoping review. **Extractive Industries and Society**, v. 8, p. 250–259, 2019.

BURDEN, C. M. *et al.* Acute sublethal exposure to toxic heavy metals alters honey bee (*Apis mellifera*) feeding behavior. **Scientific Reports**, v. 9, n. 1, p. 1–10, 12 mar. 2019.

CALDAS, E. D.; MACHADO, L. L. Cadmium, mercury and lead in medicinal herbs in Brazil. **Food and Chemical Toxicology**, v. 42, n. 4, p. 599–603, 2004.

CAMPOS, M. L.; ALMEIDA, J. A.; SOUZA, L. S. Avaliação de três áreas de solo construído após mineração de carvão a céu aberto em Lauro Müller, Santa Catarina. **Revista Brasileira de Ciência do Solo**, v. 27, n. 6, p. 1123–1137, 2003.

CANDEIAS, C. *et al.* **Mining activities:** Health impacts. Encyclopedia of Environmental Health, p. 415–435, 2019. DOI: https://doi.org/10.1016/B978-0-12-409548-9.11056-5.

CEPAL. **Panorama Social da América Latina 2020**. Chile: CEPAL, 2020. Disponível em: www.cepal.org/apps. Acesso em: 16 out. 2021.

CHEN, L. *et al.* Shifts in microbial community composition and function in the acidification of a lead/zinc mine tailings. **Environmental Microbiology**, v. 15, n. 9, p. 2431–2444, 2013.

CIANCIARUSO, M. V.; SILVA, I. A.; ANTÔNIO BATALHA, M. Diversidades filogenética e funcional: novas abordagens para a Ecologia de comunidades. **Biota Neotropica**, v. 9, n. 3, 2009.

CONDE, M. Resistance to mining: A review. **Ecological Economics**, v. 132, p. 80–90, 2017.

CONTI, I. L.; COELHO-DE-SOUZA, G. Povos e comunidades tradicionais: a produção de políticas públicas de segurança alimentar e nutricional. **Amazônica - Revista de Antropologia,** v. 5, n. 3, p. 780, 2014.

CORRÊA, J. Atividade minerária no sul de Santa Catarina: Impactos ambientais decorrentes da exploração do carvão. **Revista de Direitos Difusos**, p. 507-522, 1934. Disponível em: http://www.buscalegis.ufsc.br/revistas/files/anexos/26429-26431-1-PB.pdf. Acesso em: 25 jul. 2021.

CORRÊA, P. F. *et al.* **Mineração de carvão no Brasil: uma análise ciênciométrica**. Viçosa, MG: [*s.n.*], 2016. Disponível em: https://www.researchgate.net/publication/311767325_Mineracao_de_carvao_no_Brasil_uma_analise_cienciometrica. Acesso em: 10 set. 2021.

COSTA, A. C. G. da. **Atributos florais e transição entre polinização abiótica e biótica em espécies de *Rhyncosporavahl* (Cyperaceae).** 2017. Tese (Doutorado em Biologia Vegetal) – Universidade Federal de Pernambuco, 147f. 2017. Disponível em: https://repositorio.ufpe.br/handle/123456789/28418. Acesso em: 14 set. 2021.

CUI, C. Q. *et al.* Waste mine to emerging wealth: Innovative solutions for abandoned underground coal mine reutilization on a waste management level. **Journal of Cleaner Production**, v. 19, p. 119748, 2020.

CUNHA, F. A. B. *et al.* Cytoprotective effect of *Eugenia uniflora* L. against the waste contaminant mercury chloride. **Arabian Journal of Chemistry,** v. 12, n. 8, p. 4197–4203, 1 dez. 2019.

ĆWIELĄG-DRABEK, M. *et al.* Risk of cadmium, lead and zinc exposure from consumption of vegetables produced in areas with mining and smelting past. **Scientific Reports**, v. 10, n. 1, 2020. DOI: https://doi.org/10.1038/s41598-020-60386-8.

DALLÓ, G. C. **Interações entre espécies de abelhas sem ferrão (Apidae: Meliponini) do Rio Grande do Sul e plantas melitófilas nativas.** 20f. 2018. Monografia (Bacharelado em Ciências Biológicas) – Universidade Federal do Rio Grande do Sul. Disponível em: https://lume.ufrgs.br/handle/10183/198204. Acesso em: 14 set. 2021.

DAWID MOROŃ *et al.* Abundance and diversity of wild bees along gradients of heavy metal pollution. **Journal of Applied Ecology**, v. 49, p. 118–125, 2012.

DAY, S. D. *et al.* Contemporary concepts of root system architecture of urban trees. **Arboriculture & Urban Forestry**, v. 36, n. 4, p. 149–159, 2010.

DE MEDEIROS, C. A.; CINTRA, M. R. V. P. Impacto da ascensão chinesa sobre os países latino-americanos. **Revista de Economia Politica**, v. 35, n. 1, p. 28–42, 2015.

EBRAHIMI, M.; TAHERIANFARD, M. The effects of heavy metals exposure on reproductive systems of cyprinid fish from Kor River. **Iranian Journal of Fisheries Sciences,** v. 10, n. 1, p. 13-24, 2011.

EDRAKI, M. *et al.* Designing mine tailings for better environmental, social and economic outcomes: A review of alternative approaches. **Journal of Cleaner Production**, v. 84, n. 1, p. 411–420, 2014.

ERICSSON, M.; LÖF, O. Mining's contribution to national economies between 1996 and 2016. **Mineral Economics**, v. 32, p. 223–250, 2019.

FAN, G. *et al.* Impacts of underground coal mining on the roots of xeromorphic plant: A case study. **Environmental Engineering Science**, v. 38, n. 6, p. 500–512, 1 jun. 2021.

FENG, X. *et al.* Human exposure to methylmercury through rice intake in mercury mining areas, Guizhou province, China. **Environmental Science and Technology**, v. 42, n. 1, p. 326–332, 2008.

FENG, Y. *et al.* Effects of surface coal mining and land reclamation on soil properties: A review. **Earth-Science Reviews**, v. 191, p. 12–25, 2019. DOI: https://doi.org/10.1016/j.earscirev.2019.02.015

FERNÁNDEZ, S. *et al.* Phytoremediation capability of native plant species living on Pb-Zn and Hg-As mining wastes in the Cantabrian range, north of Spain. **Journal of Geochemical Exploration**, v. 174, p. 10-20, 2017.

FERNÁNDEZ-LLAMAZARES, Á. *et al.* A State-of-the-Art Review of Indigenous Peoples and Environmental Pollution. **Integrated Environmental Assessment and Management**, v. 16, n. 3, p. 324–341, 2020.

FICKEN, K. L. G.; BYRNE, P. G. Heavy metal pollution negatively correlates with anuran species richness and distribution in south-eastern Australia. **Austral Ecology**, v. 38, n. 5, p. 523–533, 1 ago. 2013.

FIGUEIREDO, M. A. *et al.* Germination of native grasses with potential application in the recovery of degraded areas in Quadrilátero Ferrífero, Brazil. **Biota Neotropica**, v. 12, n. 3, 2012.

FINKELMAN, R. B.; WOLFE, A.; HENDRYX, M. S. The future environmental and health impacts of coal. **Energy Geoscience**, v. 2, n. 2, p. 99–112, 1 abr. 2021.

FREIRE, S. E.; URTUBEY, E.; GIULIANO, D. A. Caracteres epidérmicos de lasespeciesdel género *Baccharis* (Asteraceae) usadas enla medicina popular. **Caldasia**, v. 7, n. 1, p. 23–38, 2007.

FREITAS, J. R.; CIANCIARUSO, M. V; BATALHA, M. A. Functional diversity, soil features and community functioning: a test in a cerrado site. **Brazilian Journal of Biology**, v. 72, n. 3, p. 464, 2012.

FRENCH, M. *et al.* Community exposure and vulnerability to water quality and availability: a case study in the mining-affected Pazña Municipality, Lake Poopó Basin, Bolivian Altiplano.

Environmental Management, v. 60, p. 555-573, 2017.

GAOUE, O. G. *et al.* (2017). Theories and major hypotheses in ethnobotany. **Economic Botany**, v. 71, n. 3, p. 269–287. DOI: https://doi.org/10.1007/s12231-017-9389-8.

GARDNER, T. A. *et al.* Understanding the biodiversity consequences of habitat change: The value of secondary and plantation forests for neotropical dung beetles. **Journal of Applied Ecology**, v. 45, n. 3, p. 883–893, 1 nov. 2008.

GASPER, A. L. DE *et al.* Inventário florístico florestal de Santa Catarina: espécies da Floresta Ombrófila Mista. **Rodriguésia**, v. 64, n. 2, p. 201–210, 2013.

GEORGE-LAURENTIU, M.; FLORENTINA-CRISTINA, M.; ANDREEA-LORETA, C. The assessment of social and economic impacts associated to an abandoned mining site case study: Ciudanovita (Romania). **Procedia Environmental Sciences**, v. 32, p. 420–430, 2016.

GLAUSER, S. *et al.* The challenges of sustainability in mining regions: The coal mining region of Santa Catarina, Brazil. **Natural Resources Forum**, v. 29, p. 1–11, 2005.

GOMES, Carlos Valério Aguiar; ALENCAR, Ane; VADJUNEC, Jacqueline Michelle; PACHECO, Leonardo Marques. Extractive Reserves in the Brazilian Amazon thirty years after Chico Mendes: Social movement achievements, territorial expansion and continuing struggles. **Desenvolvimento Meio Ambiente**, v. 48, p. 4-98, 2018.

GRAU-PEREZ, M. *et al.* Arsenic exposure, diabetes-related genes and diabetes prevalence in a general population from Spain. **Environmental Pollution**, v. 235, p. 948–955, 2018.

GRESSLER, E.; PIZO, M. A.; MORELLATO, L. P. C. Pollination and seed dispersal of Brazilian Myrtaceae. **Brazilian Journal of Botany**, v. 29, n. 4, p. 509–530, out. 2006.

GUISLON, A. V. **Composição florística e estrutural da comunidade arbórea da floresta ombrófila densa montana no Parque Estadual da Serra Furada, Santa Catarina**. 41f. 2015. Monografia (Bacharelado em Ciências Biológicas) - Universidade do Extremo Sul Catarinense, 2015. Disponível em: http://repositorio.unesc.net/handle/1/2936. Acesso em: 14 set. 2021.

GUO, C. *et al.* Effects of meteorology and soil on the herb species diversity in plantations in a reclamation area of coal mine after 6 years. **Environmental Science and Pollution Research**, v. 27, n. 19, p. 24231–24241, 1 jul. 2020.

GUTIÉRREZ, P. **Biomonitoreo de metales pesados enhojas y frutos de guayabo (*Psidiumguajava* L.) y de guamúchil (*Pithecellobiumdulce* (Roxb.) Benth.) em el Área Metropolitana de Guadalajara**. 111 f. 2015. Dissertação (Mestrado em Ciências em Biosistemática e Manejo de Recursos Naturais e Agrícolas) – Universidade de Guadalajara, 2015.

HADDAWAY, N. R. *et al.* Evidence of the impacts of metal mining and the effectiveness of mining mitigation measures on social–ecological systems in Arctic and boreal regions: a systematic map protocol. **Environmental Evidence**, v. 8, n. 1, p. 1–11, 21 fev. 2019.

HERNÁNDEZ, A. J.; PASTOR, J. Relationship between plant biodiversity and heavy metal bioavailability in grasslands overlying an abandoned mine. **Environmental Geochemistry and Health**, v. 30, n. 2, p. 127–133, 2008.

HERNÁNDEZ, A. J.; PASTOR, J. Relationship between plant biodiversity and heavy metal bioavailability in grasslands overlying an abandoned mine. **Environ Geochem Health**, v. 30, n. 2, p. 127-33, 2008.

HLADUN, K. R.; PARKER, D. R.; TRUMBLE, J. T. Cadmium, Copper, and Lead accumulation and bioconcentration in the vegetative and reproductive organs of *Raphanus sativus*: implications for plant performance and pollination. **Journal of Chemical Ecology**, v. 41, n. 4, p. 386–395, 7 abr. 2015.

HOGAN, C. M.; TREMBLAY, G. A. Abandoned Mines in Canada. *In:* BARNHISEL, R.I. (eds.). INTERNATIONAL CONFERENCE ON ACID ROCK DRAINAGE (ICARD), 7., 2006. **Anais […]** United States of America: American Society of Mining and Reclamation (ASMR), 2006. p. 774-784.

MEDEIROS, João de Deus; SAVI, Maurício; BRITO, Bernardo Ferreira Alves de. DNA extraction from basidiomata. Seleção de áreas para criação de Unidades de Conservação na Floresta Ombrófila Mista. **Biotemas**, v. 18, p. 33–50, 2005.

MAÇANEIRO, J. P. *et al.* Regeneração de uma Floresta Ombróila Mista no Planalto Catarinense. **Biotemas**, v. 29, p. 31–42, 2016.

JOSÉ, S.; TIMÓTEO, A. The impact of habitat degradation on seed dispersal networks: implications for habitat management in montado forests. Coimbra: UC, 2014. Disponível em: https://eg.uc.pt/handle/10316/47413. Acesso em: 14 set. 2021.

KEW NAMES MATCHING SERVICE. [*S.l.*]: Kew Names Matching Service, 2021. Disponível em: http://namematch.science.kew.org/. Acesso em: 14 set. 2021.

KIRMER, A. *et al.* Importance of regional species pools and functional traits in colonization processes: Predicting re-colonization after large-scale destruction of ecosystems. **Journal of Applied Ecology**, v. 45, n. 5, p. 1523–1530, out. 2008.

KLANOVICZ, J. Minas de carvão: trabalho também de mulheres. **Revista Estudos Feministas**, v. 12, n. 2, p. 247–250, 2004.

KLEIN, A. S. **Áreas degradadas pela mineração de carvão no sul de Santa Catarina:** vegetação versus substrato. 93 f. 2006. Dissertação (Mestrado em Ciências Ambientais) - Universidade do Extremo Sul Catarinense, 2006.

KLEIN, A. S. *et al.* Natural regeneration in an area degraded by coal mining in Santa Catarina State, Brazil. **Revista Escola de Minas**, v. 62, n. 3, p. 297-304, 2009.

KOHSAKA, R.; ROGEL, M. Traditional and local knowledge for sustainable development: empowering the indigenous and local communities of the world. *In*: LEAL FILHO, W. *et al.* (eds.). **Partnerships for the Goals. Encyclopedia of the UN Sustainable Development Goals**. Springer, 2019. DOI: https://doi.org/10.1007/978-3-319-71067-9.

KUMAR, A *et al.* Lead toxicity: Health hazards, influence on food Chain, and sustainable remediation approaches. **International Journal of Environmental Research and Public Health,** v. 17, n. 7, 2020. DOI: https://doi.org/10.3390/ijerph17072179.

LAJAYER, Behnam Asgari; GHORBANPOUR, Mansour; NIKABADI, Shahab. Heavy metals in contaminated environment: Destiny of secondary metabolite biosynthesis, oxidative status and phytoextraction in medicinal plants. **Ecotoxicology and Environmental Safety,** v. 145, p. 377-390, 2017.

LEMKE, D. *et al.* Invasion of a mined landscape: what habitat characteristics are influencing the occurrence of invasive plants? **International Journal of Mining, Reclamation and Environment**, v. 27, n. 4, p. 275–293, ago. 2013.

MARMITT, J. *et al.* Plantas Medicinais da RENISUS com potencial anti-inflamatório: revisão sistemática em três bases de dados científicas. **Revista Fitoterápicos**, v. 9, n. 2, p. 73–159, 2015. DOI: https://doi.org/10.5935/2446-4775.20150011.

MARRUGO-NEGRETE, J. L.; RUIZ-GUZMÁN, J. A.; RUIZ-FERNÁNDEZ, A. C. Biomagnification of mercury in fish from two gold mining-impacted tropical marshes in northern Colombia. **Archives of Environmental Contamination and Toxicology**, v. 74, n. 1, p. 121–130, 2018. DOI: https://doi.org/10.1007/s00244-017-0459-9.

MAUS, V. *et al.* A global-scale data set of mining areas. **Scientific Data**, v. 7, p. 289, 2020.

MAZZELLA, D. C. ***Baccharistrimera* (Less.) DC. y *Baccharis crispa*Spreng. especies de carquejas utilizadas con fines medicinales, caracterización y análisis genéticos de poblacionesen Lavalleja, Uruguay.** 161 f. 2012. Dissertação (Mestrado em Ciências Ambientais) - Programa de Pós-Graduação em Ciências Ambientais, Univercidad de La República Uruguay, 2012.

MELLO, João R.B.; MELLO, Fernanda B.; LANGELOH, Augusto. Toxicidade pré-clínica de fitoterápico contendo *Gentianalutea, Rheumpalmatum, Aloe ferox, Cynarascolymus, Atropa belladona, Peumusboldus* e *Baccharistrimera* em coelhos Nova Zelândia. **Latin American Journal of Pharmacy**, v. 27, n. 5, p. 1-5, 2008.

MENENDEZ-BACETA, G. *et al.* The importance of cultural factors in the distribution of medicinal plant knowledge: A case study in four Basque regions. **Journal of Ethnopharmacology**, v. 161, p. 116–127, 2015. DOI: https://doi.org/10.1016/j.jep.2014.12.007.

MENEZES, A. P. S. *et al. Baccharis trimera* (Less.) DC as genotoxicity indicator of exposure to coal and emissions from a thermal power plant. **Archives of Environmental Contamination and Toxicology**, v. 65, n. 3, p. 434–441, 2013.

MENTON, M. *et al.* The COVID-19 pandemic intensified resource conflicts and indigenous resistance in Brazil. **World Development**, v. 138, p. 105222, 1 fev. 2021.

MILLER, J. R.; VILLARROEL, L. F. Bolivia: Mining, River Contamination, and Human Health. **Encyclopedia of Environmental Health**, p. 421–441, 2011.

MITTAL, A. K. Abandoned mines: Information on the number of hard rock mines, cost of cleanup, and value of financial assurances. **Natural Resources Committee Opinion**, p. 1–13, 2011.

MORAES, V. **Avaliação do potencial mutagênico e bioacumulador de metais pesados de *Baccharis trimera* Less e *Equisetum hyemale* L.** 48 f. 2014. Dissertação (Mestrado em Biociências) - Universidade Estadual Paulista, Faculdade de Filosofia, Ciências e Letras de Assis, 2014.

MOREIRA, J. C. Threats by heavy metals: Human and environmental contamination in Brazil. **Science of the Total Environment**, v. 188, 1996. DOI: https://doi.org/10.1016/0048-9697(96)05277-1.

NAWAB, J. *et al.* Health risk assessment from contaminated foodstuffs: a field study in chromite mining-affected areas northern Pakistan. **Environmental Science and Pollution Research,** v. 23, n. 12, p. 12227–12236, 2016. DOI: https://doi.org/10.1007/s11356-016-6379-9.

NERO, B. F. Structure, composition and diversity of restored forest ecosystems on mine-spoils in South-Western Ghana. **PlosOne**, v. 16, n. 6, p. e0252371, 2021. DOI: https://doi.org/10.1371/JOURNAL.PONE.0252371.

NGUYEN, N.; BORUFF, B.; TONTS, M. Fool's gold: Understanding social, economic and environmental impacts from gold mining in Quang Nam province, Vietnam. **Sustainability** (Switzerland), v. 10, n. 5, 1 maio 2018.

OLUMAYOWA OLUWASOLA, H. *et al.* (2021). Geochemical and health risk assessment of heavy metals concentration in soils around Oke-Ere mining area in Kogi State, Nigeria. **International Journal of Environmental Analytical Chemistry,** 2021. DOI: https://doi.org/10.1080/03067319.2020.1862817

OTERO, X. L. *et al.* Arsenic in rice agrosystems (water, soil and rice plants) in Guayas and Los Ríos provinces, Ecuador. **Science of the Total Environment**, v. 573, p. 778–787, 2016.

PAULA, A. *et al.* Chemical and toxicological effects of medicinal *Baccharis trimera* extract from coal burning area. **Chemosphere,** v. 146, p. 396–404, 2016.

PERON, A. P. *et al.* Avaliação mutagênica das plantas medicinais *Baccharis trimera* Less. e *Solanum melongena* L. em células de medula óssea de ratos Wistar. **Revista Brasileira de Biociências**, v. 4849, p. 127–130, 2008.

PHILLIPS, B. B. *et al.* Impacts of multiple pollutants on pollinator activity in road verges. **Journal of Applied Ecology**, v. 58, n. 5, p. 1017–1029, 1 maio 2021.

PHIMOL, P.; VISUTHISMAJARN, P.; LIN, C.; RUKKUR, S. (2017). Assessment of arsenic concentrations and estimated daily intake of arsenic from rice (*Oryza sativa*) in Ron Phibun District, Southern Thailand. **International Journal of Environmental Science and Development**, v. 8, n. 7, p. 517–520.

QUINTELA-SABARÍS, C. *et al.* Plant functional traits on tropical ultramafic habitats affected by fire and mining: Insights for reclamation. **Diversity**, v. 12, n. 6, 1 jun. 2020.

RAMOS, A. R. A.; OLIVEIRA, K. A. DE; RODRIGUES, F. DOS S. Mercury-based mining in Yanomami indigenous lands and accountabilities. **Ambiente e Sociedade**, v. 23, p. 1–22, 2020.

RECH, Adir Ubaldo; SANTOS, Sandrine Araujo. Desastres ambientais de Mariana e Brumadinho: a mitigação dos riscos pelo plano diretor do município. **Revista Direito Ambiental e Sociedade**, v. 9, n. 3, p. 7-32, 2019.

REICH, P. B. *et al.* The evolution of plant functional variation: traits, spectra, and strategies. **International Journal of Plant Sciences**, v. 164, n. 3, p. 143–164, 2003.

ROCHA, C.; LIBERATO, R. S. Food sovereignty for cultural food security: The case of an indigenous community in Brazil. **Food, Culture and Society**, v. 16, n. 4, p. 589–602, 2013.

ROCHA-NICOLEITE, E.; OVERBECK, G. E.; MÜLLER, S. C. Degradation by coal mining should be priority in restoration planning**. Perspectives in Ecology and Conservation**, v. 15, n. 3, p. 202–205, 2017.

RUSINOWSKI, S. *et al.* Cultivation of C4 perennial energy grasses on heavy metal contaminated arable land: Impact on soil, biomass, and photosynthetic traits. **Environmental Pollution**, v. 250, p. 300–311, 1 jul. 2019.

SAHA, D. *et al.* Investigation of environmental-concern trace elements in coal and their combustion residues from thermal power plants in Eastern India. **Natural Resources Research**, v. 28, n. 4, p. 1505–1520, 1 out. 2019.

SANTOS, R. *et al.* Spontaneous vegetation on overburden piles in the coal basin of Santa Catarina, Brazil. **Restoration Ecology**, v. 16, n. 3, p. 444–452, 2008.

SARMA, K.; BARIK, S. K. Coal mining impact on vegetation of the Nokrek Biosphere Reserve, Meghalaya, India. **Biodiversity,** v. 12, n. 3, p. 154–164, set. 2011.

SETHY, S. K.; GHOSH, S. Effect of heavy metals on germination of seeds. **Journal of Natural Science, Biology and Medicine**, v. 4, n. 2, p. 272, jul. 2013.

SHAFAQAT, R. *et al.* Use of Maize (*Zea mays* L.) for phytomanagement of Cd-contaminated soils: a critical review. **Environmental Geochemistry and Health**, v. 39, p. 259–277, 2017.

SILVA, R. M. G. *et al.* Genotoxic activity and toxicity of *Baccharis trimera* Less. regarding the bioaccumulation of heavy metals. **Journal of Medicinal Plant Research**, v. 6, n. 26, p. 4321–4327, 2012.

SIVAKOFF, F. S.; GARDINER, M. M. Soil lead contamination decreases bee visit duration at sunflowers. **Urban Ecosystems**, v. 20, n. 6, p. 1221–1228, 1 dez. 2017.

SIVARAM, A. K. *et al.* Comparison of plants with C3 and C4 carbon fixation pathways for remediation of polycyclic aromatic hydrocarbon contaminated soils. **Scientific Reports**, v. 8,

n. 1, 1 dez. 2018.

SIZENANDO, J. W. **Mineração e espacialidade socioambiental**: Exploração Carbonífera e ocupação territorial em Criciúma, Santa Catarina. 73 f. 2011. Dissertação (Mestrado em Ciências Ambientais) - Programa de Pós-Graduação em Ciências Ambientais, Universidade do Extremo Sul Catarinense, 2011.

SOBRAL-SOUZA, C. E. *et al.* Cytoprotective effect against mercury chloride and bioinsecticidal activity of *Eugenia jambolana* Lam. **Arabian Journal of Chemistry**, v. 7, n. 1, p. 165–170, 1 jan. 2014.

SONEGO, R. C.; BACKES, A.; SOUZA, A. F. Descrição da estrutura de uma Floresta Ombrófila Mista, RS, Brasil, utilizando estimadores não-paramétricos de riqueza e rarefação de amostras 1. **Acta Botanica Brasilica,** v. 21, n. 4, p. 943-955, 2007.

SOUZA, L. C. DE *et al.* Teores de Arsênio em solos de três regiões do estado de Santa Catarina. **Revista Ambiente e Água,** v. 9, n. 3, p. 445–458, 2016.

SRIVASTAVA, J. *et al.* Response of C3 and C4 plant systems exposed to heavy metals for phytoextraction at elevated atmospheric CO_2 and at elevated temperature. **Environmental Contamination**, p. 3-17, 2012.

SUPPI, I. M. *et al.* Cobalt and manganese content in soils of Santa Catarina. **Revista de Ciencias Agroveterinarias**, v. 17, n. 4, p. 579–588, 2018.

TEMPER, L.; BENE, D.; MARTINEZ-ALIER, J. Mapping the frontiers and front lines of global environmental justice: the EJ Atlas. **Journal of Political Ecology,** v. 22, p. 255-278, 2015. Disponível em: http://jpe.library.arizona.edu/volume_22/Temper.pdf. Acesso em: 17 out. 2021.

TCHOUNWOU, P. B. *et al.* Heavy metal toxicity and the environment. **In EXS,** v. 101, p. 133–164, 2012. DOI: https://doi.org/10.1007/978-3-7643-8340-4_6.

UNITED STATES GOVERNMENT ACCOUNTABILITY OFFICE. Information on number of mines, expenditures, and factors that limit efforts to address hazards. Accessible Version United States Government Accountability Office. Disponível em: https://www.gao.gov/products/gao-20-238. Acesso em: 25 ago. 2021.

VAN OOSTDAM, J. *et al.* Human health implications of environmental contaminants in Arctic Canada: A review. **Science of the Total Environment**, v. 351–352, p. 165–246, 2005.

CITADINI-ZANETTE, V.; BOFF, V.P. Levantamento florístico em áreas mineradas a céu aberto na região carbonífera de Santa Catarina, Brasil. [*S.l.*]: Biblioteca do INPA, 1992. Disponível em: https://koha.inpa.gov.br/cgi-bin/koha/opac-detail.pl?biblionumber=7651. Acesso em: 20 jul. 2020.

WEGENAST, T.; BECK, J. Mining, rural livelihoods and food security: A disaggregated analysis of sub-Saharan Africa. **World Development**, v. 130, p. 104921, 2020. DOI: https://doi.org/10.1016/j.worlddev.2020.104921.

WEILER, A. M. *et al.* Food sovereignty, food security and health equity: A meta-narrative mapping exercise. **Health Policy and Planning**, v. 30, p. 1078–1092, 2015.

WORLANYO, A. S.; JIANGFENG, L. Evaluating the environmental and economic impact of mining for post-mined land restoration and land-use: A review. **Journal of Environmental Management**, v. 279, p. 111623, 1 fev. 2021.

WU, Z. *et al.* Spatial distribution of the impact of surface mining on the landscape ecological health of semi-arid grasslands. **Ecological Indicators**, v. 111, p. 105996, 1 abr. 2020.

XUN, E. *et al.* Heavy metals in nectar modify behaviors of pollinators and nectar robbers: Consequences for plant fitness. **Environmental Pollution**, v. 242, p. 1166-1175, 2018.

YADAV, A. K.; BHAGAT, R. B.; YADAV, V. (2019). Does coal mining affect household food security? An empirical study of Dhanbad, India. **Agriculture and Food Security**, v. 8, n. 1, 2019. DOI: https://doi.org/10.1186/s40066-018-0244-7.

YAN, B. *et al.* Leachability characteristic of heavy metals and associated health risk study in typical copper mining-impacted sediments. **Chemosphere,** v. 239, 2020. DOI: https://doi.org/10.1016/j.chemosphere.2019.124748.

YAN, M. *et al.* Vegetation type and plant diversity affected soil carbon accumulation in a postmining area in Shanxi Province, China. **Land Degradation & Development**, v. 31, n. 2, p. 181–189, 30 jan. 2020.

ZANELATTO, J.; JUNG, G.; OZÓRIO, R. Índios e brancos no processo colonizador do Sul Catarinense na obra "Histórias do Grande Araranguá", de João Leonir dall'Alba. **Revista de História Comparada**, v. 9, n. 1, p. 174–202, 2015.

ZANK, S.; HANAZAKI, N. The coexistence of traditional medicine and biomedicine: A study with local health experts in two Brazilian regions. **PlosOne**, v. 12, n. 4, p. e0174731, 1 abr. 2017. DOI: https://doi.org/10.1371/journal.pone.0174731.

ZHAO, F. J. *et al.* Soil contamination in China: Current status and mitigation strategies. **Environmental Science and Technology**, v. 49, n. 2, p. 750–759, 2015.

ZOCCHE, J. J. *et al.* Elemental composition of vegetables cultivated over coal-mining waste. **Anais da Academia Brasileira de Ciências**, v. 89, n. 3, p. 2383–2398, 2017.