GEOLOGICAL SURVEY OF CANADA

OPEN FILE 3838

Evaluation of Biogeochemistry as a Tool in Mineral Exploration and in Monitoring Environmental Mercury Dispersion in the Tapajós Gold District, Amazonia, Brazil

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ABSTRACT

In September 1998 a biogeochemical orientation survey was carried out around and in the vicinity of several artisan gold mining sites (i.e. garimpos) near Creporizão. At these sites mercury is used to recover gold, and as part of the process the gold/mercury amalgam is burnt, releasing mercury into the atmosphere. The depositional fate of this mercury in the surrounding forest was unknown, and so vegetation samples were collected for chemical analysis to investigate the possibility that a dispersal pattern may be detected.

A total of 180 vegetation samples of 23 species were collected from 62 sample stations. All samples were returned to Canada for preparation and multi-element analysis of dry tissues by instrumental neutron activation analysis. More than 5000 analytical determinations were obtained. Many of the 23 species collected are widespread throughout Amazonia, therefore they constitute a first baseline data set of multi-element concentrations in common plants from the Amazon forest and should serve as guidelines for future biogeochemical studies of this environmentally sensitive area, whether for exploration or environmental monitoring.

In general, most of the metals determined (including gold) proved to be more concentrated in samples of outer bark than in foliage. A significant exception was mercury. Median concentrations of mercury in dry tissue were approximately 40 ppb Hg, similar to those found in North America. However, around the garimpos mercury was enriched, attaining a maximum of 4600 ppb Hg in a sample of a common shrub, Vassoura de Botão, at garimpo Joel. Studies of other elements showed that this species is capable of accumulating moderate to high concentrations of several elements, notably gold. The maximum gold value was 542 ppb Au in dry tissue, representing a concentration factor of more than 1000 times common levels. This plant could, therefore, be used to assist in remediation of metal-rich tailings – i.e. 'phyto-extraction' of metals.

The two most common species in the survey area are Imbauba and Vassoura. Levels of gold and mercury in Imbauba were lower than those in Vassoura, but the general distribution patterns of *relative* enrichments among samples of each species were similar. Although each plant species has a different tolerance to metals and a different capacity to absorb and store them, a multi-species approach to mapping all values greater than the median of 40 ppb revealed a significant pattern of mercury enrichment associated with the garimpos. The indications are that mercury contamination of the forest occurs for at least 500 m from garimpos Joel and Mestre Antonio.

This orientation survey indicates that judicious collection and chemical analysis of plants in the Amazon can provide valuable information to assist in mineral exploration and environmental monitoring.

INTRODUCTION

In April 1995, Canada and Brazil entered into a three-year cooperative agreement, sponsored by the Canadian International Development Agency (CIDA), under which Canada would provide training and expertise to assist Brazil in achieving sustainable development of its mineral resources. As critical as exploitation of mineral resources is to economic development, such development needs to be conducted in an environmentally acceptable manner. Brazil has an extraordinarily diverse floral population that is a fundamental component of the complex and fragile Amazonian ecosystem. For the sake of current and future local and, indeed, worldwide populations, development of mineral resources should be as environmentally benign as can reasonably be expected.

This Open File summarizes results of an orientation survey conducted in September 1998, around active and abandoned artisan gold mining sites or *garimpos* (or artisan *garimpeiro* [artisan gold miner] operations) near Creporizão, about 200 km due south of Itaituba, in the Tapajós mineral province of Pará State (Fig. 1). At these sites mercury is used to recover gold, and the burning process results in release of mercury to the atmosphere. At the outset of this mission no information was available on the possible uptake and/or contamination of forest plants by this mercury. Samples of vegetation were collected for chemical analysis and subsequent data interpretation.

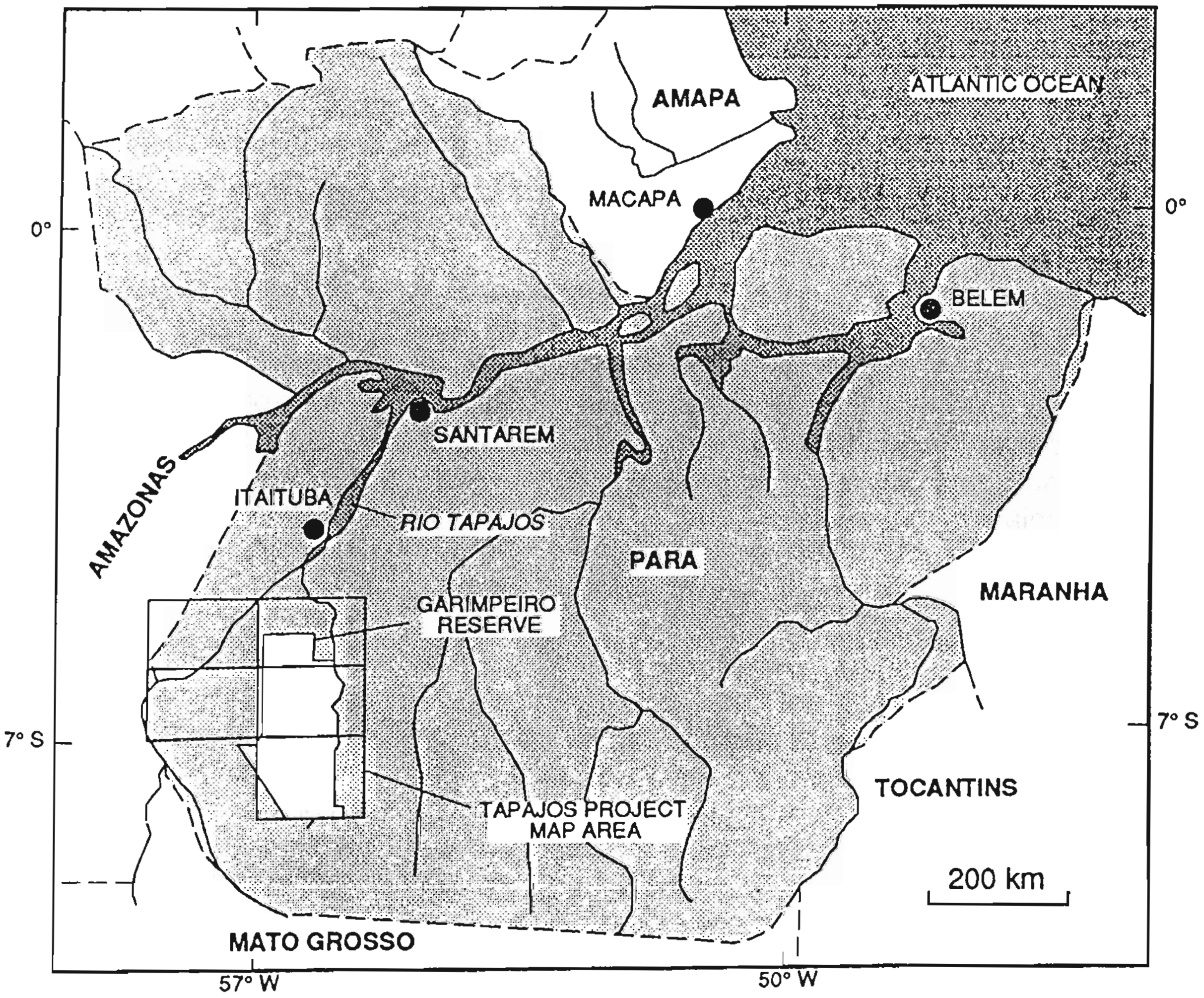


Fig. 1: Location Map

BIOGEOCHEMICAL SURVEYS

General Comment

The trace element chemical composition of the flora is an area of scientific knowledge that is extremely scant in Amazonia. Databases on even the common trees and shrubs are virtually absent. Knowledge of this 'biogeochemical' make up of the forests is of paramount importance for:

- Establishing baseline data on the chemistry of common flora;
- Determining tolerances of common flora to the introduction of potentially toxic metals (some plant species from elsewhere are known to tolerate and accumulate remarkably high levels of 'toxic' metals);
- Monitoring environmental pollution from industrial, agricultural and other anthropogenic activities;
- Establishing common plant species which, from sampling and subsequent analysis of their tissues, can be used to assist in mineral exploration with a minimum of environmental disruption;
- Identifying plant species which may be used in remediation of mine tailings;
- Identifying any plant species which can hyperaccumulate metals (Brooks, 1998) and which may possibly be planted and harvested as a crop for phytoextraction of metals (i.e. let the plants do the work of extracting metals).

Rationale for Biogeochemical Studies

The underlying rationale for applying biogeochemical methods to mineral exploration and environmental studies is that trees and shrubs absorb metals present in the ground and transfer these metals via their root systems to the growing plant. Metals are absorbed from soil, from groundwater, and locally from bedrock in those environments where roots penetrate faults, joints and cleavages. In geochemical exploration, the significant advantage of applying biogeochemical methods is that the root system of a large tree may penetrate through many cubic metres of the substrate. Consequently, the root system can integrate the geochemical signature of a large volume of all soil horizons, the contained groundwater, and bedrock where it is covered by only a few metres of unconsolidated soils. Deciduous species, such as those found throughout Amazonia commonly, but not always, have quite deep root systems. Figure 2 shows the immense roots of a large tree from garimpo JL, approximately 20 km southeast of Creporizão.

In general, the more arid the environment, the deeper that roots of trees and shrubs can penetrate into the substrate, while continually drawing nutrients and other elements. However, depth of root penetration is not the only factor which may give rise to a biogeochemical response, because root systems can access elements that migrate upward from considerable depth by various combinations of methods such as in solution, by diffusion, by capillary action, from microbubbles, and in electrochemical cells. The biogeochemical signature is an integrated signature of the substrate and, locally, of atmospheric contamination.

Fig. 2 Extensive and massive root system of Muirapiranga (*Manilkara huberi*) exposed at recently trenched garimpo JL, approximately 20 km by road southeast from Creporizão

Orientation

The first step in preparing to conduct a biogeochemical survey is to establish which are the most widespread species within the area of interest. If the biogeochemist has no prior experience of the survey area it is advisable to conduct some preliminary investigations by reading available literature, and, where possible visit botanical gardens, and local botanists at museums and universities.

From visits to bookstores and libraries in Canada it was found that there was no readily available information on the flora of the Tapajós area. Consequently, arrangements were made to visit appropriate institutions in Belém, including the University of Belém and the botanical gardens of the Museu Paraense Emilio Goeldi. This provided a first assessment of the common flora that might be present in the Creporizão area.

A survey area should always be reconnoitred prior to sample collection, in order to assess which species are dominant. The afternoon of our first day was spent with local guides walking through the jungle to establish the species most appropriate for sample collection. The field knowledge of local guides proved invaluable, and provided the framework that could be used to identify the botanical names of common plants by reference to publications purchased in Belém. Of particular value were two small publications by Professor Paulo B. Cavalcante: 'Guia Botânico do Museu Goeldi' and 'Frutas Comestíveis da Amazônia' (Cavalcante 1983, 1996).

During the following five days of fieldwork, vegetation samples were collected from around the garimpos, from relatively undisturbed jungle, and from background areas near Itaituba. The collection comprised a total of 180 samples of 23 species from 62 locations. Of these, the 4 most common species are listed in Table 1, and illustrated in Figures 3, 4, 5 and 6. Table 2 is a complete list of the species collected and analyzed.

Table 1 The four most common plant species in the Creporizão area, arranged in order of decreasing frequency of occurrence.

Common Name	Tissue Sampled*	Botanical Name
Imbaúba	Foliage	*Cecropia sp.*
Vassoura de Botão	Twigs and foliage	*Borreria verticillata*
Boa Macaca	Foliage	*Parkia ulea*
Banana Braba	Foliage	*Ravenala guianensis*

*See footnote to Table 2

Table 2 List of all species collected in the Creporizão area, arranged alphabetically by common name and the type of tissue sampled

Common Name	Botanical Name	Tissue
Acacia	*Rasga gibão*	Foliage*
Andiroba	*Carapa guianensis*	Foliage
Atameju	*Duguetia racemosa*	Outer bark
Banana Braba	*Ravenala guianensis*	Foliage
Boa Macaca	*Parkia ulea*	Foliage
Caapeba	*Pothomorpha peltata*	Foliage
Cachimbeira	*Ficus sp.*	Outer bark
Café Brabo	*Psycotria sp.*	Foliage
Castanha-do-pará	*Berthelletia excelsa*	Outer bark
Chá Preto	*Cordia multiplicata*	Foliage
Costela de Vaca	*Miconia sp.*	Foliage
Envireira	*Rolina exsucca*	Outer bark
Imbaúba	*Cecropia palmata*	Foliage
Imbaúba	*Cecropia leucocoma*	Foliage
Imbaúba	*Cecropia scyadophylla*	Foliage
Jurubeba	*Solanum toxicarium*	Foliage
Maçaranduba	*Manilkara huberi*	Outer bark
Muirapiranga	*Clarisa racemosa*	Outer bark
Negramina	*Siparuna amazonica*	Foliage
Peruana	*Palicuria guianensis*	Foliage
Tauari	*Couratari pulchra*	Outer bark
Vassoura de Botão	*Borreria verticillata*	Twigs & foliage

* 'Foliage' usually involved the collection of twigs and leaves, which were later separated in the laboratory, and the leaf tissue analyzed. In the case of plants with large leaves (e.g. Banana Braba – Fig. 6) only the leaves were collected

** Vassoura is a shrub with very little foliage (Fig. 4), hence the samples comprised mostly woody tissue

Fig. 3: Two views of Imbauba – a fast growing tree which commonly is the first to grow in cleared areas of the Amazon forest. Small tree at the top is probably only 1 – 2 years old. Leaves show signs of stress (brown and yellowing) because it is close to metal-rich tailings at the Joel garimpo. The lower photo shows 15 m tall trees which are estimated to be only about 5 years old.

Fig. 4: Vassoura de Botão – Common shrub along roadside, on tailings debris from mining activities and in areas of disturbed ground

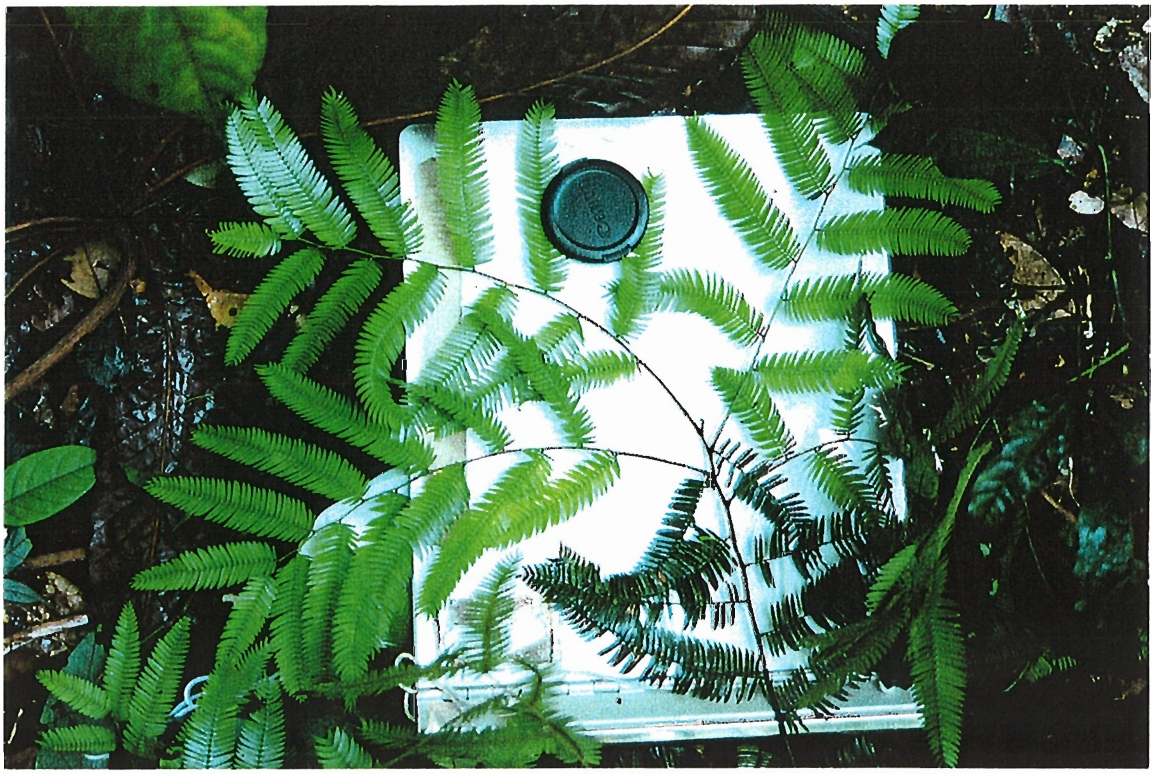


Fig. 5: Boa Macaca – One of the common trees of the Creporizão area

Fig. 6: Leaves of Banana Braba – a common plant of the Creporizão area

SAMPLE COLLECTION

Samples from various species were collected at 58 locations, mostly to the east of Creporizão (Fig. 7). Four sites from outside Itaituba were selected as background reference sites for the collection of additional samples of some of the same species as those from the Creporizão area.

In order to determine mercury distribution patterns that might be related to the garimpeiro workings, samples were collected:

- Around past and present garimpeiro operations - garimpos Joel, Jenipapo, Mestre Antonio, and JL. Of these, the former two have ceased operations and the latter two are still operating. The JL garimpo is the most recent operation and is currently exploring new zones of mineralization.
- North/south along cut lines centred upon garimpo Joel
- A regional survey eastward from Creporizão, collecting samples near the roadside at intervals of approximately 1 km
- Where available, 'air plants' (i.e. plants located in tree branches that obtain their nutrition and moisture largely from the atmosphere). These were only found and accessible at three sites in the Creporizão area and two more at the background sites near Itaituba. No attempt was made to identify these samples which appeared to be of diverse species.

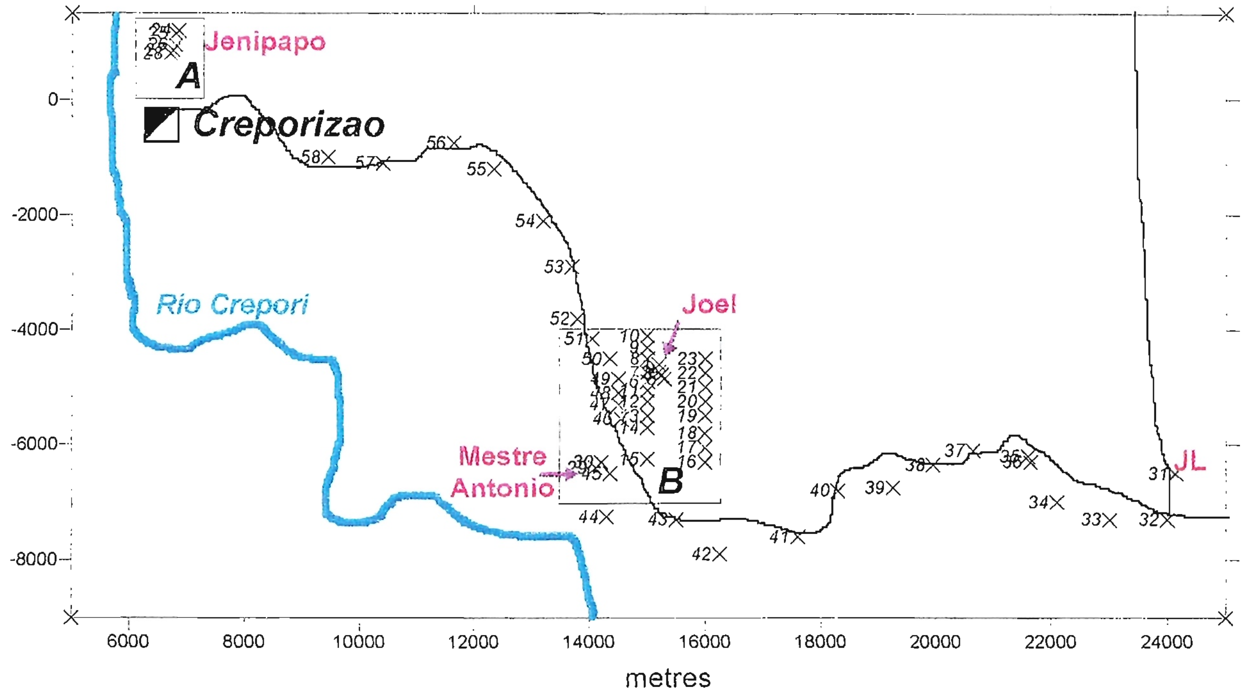


Fig. 7: Sketch Map of the Creporizao Area Showing Vegetation Sample Sites, Roads, Rio Crepori, and Garimpeiro Operations (in red). Areas 'A' and 'B' are Discussed separately. Area 'B' is is Shown in Detail in Figs. 13 and 16

SAMPLE PREPARATION AND ANALYSIS

All samples were shipped directly to the GSC laboratories in Ottawa. They were then left in their original sample bags in a warm dry environment for six weeks to fully dry out. This slow drying was necessary because an element of particular interest was mercury, and if samples were dried in an oven the mercury would volatilize.

Once fully dried, the foliage could be separated from twigs and the samples then passed through a macerator to grind them into small particles. Approximately 8 g of dried macerated tissue from each sample was submitted to Activation Laboratories Ltd. ('ActLabs', Ancaster, ON) for analysis. Appropriate duplicate splits (1 in each batch of 20) were inserted for establishing analytical precision, and GSC vegetation standard V6 (1 in each batch of 20 samples) inserted for establishing analytical accuracy. Quality control data are presented in the Appendices.

At ActLabs samples were compressed using a 35-ton press to produce a briquette, which was then shrink-wrapped to maintain sample integrity. Analysis was by instrumental neutron activation (INAA) for 35 elements. Samples were subjected to a longer irradiation and counting procedure than is usual for INAA, in order to obtain a low level of detection for mercury (10 ppb Hg). A full listing of the analytical data and quality control parameters is given in Appendix A.

RESULTS

The first Table in the Appendix - Table 'Vegetation 1' – lists all the analytical data and coordinates of the sample sites. These data were obtained by INAA determinations on dry tissue and concentrations are presented on this basis. There is a wealth of information contained within this list of analytical data, with more than 5000 analytical determinations on 151 samples of various tissues from 23 of the most common plant species of the survey area. Many of these 23 plant species are widespread throughout Amazonia. Therefore they constitute a first baseline data set of multi-element concentrations in common plants from the Amazon forest and should serve as guidelines for future biogeochemical studies of this environmentally sensitive area, whether for exploration or environmental monitoring.

Typically, different plant species and their various organs (stems, leaves, bark etc.) contain different concentrations of trace elements. That is, each species has a unique balance of trace elements required for its normal development, and therefore a different ability to selectively absorb the elements that it requires while tolerating other potentially toxic elements. Subsequently, once chemical elements are in the plant system, each plant part has a different ability to store these elements – some are used to assist in plant growth, while others are stored out of harm's way in dead tissue (e.g. bark) where they may concentrate as inorganic mineral phases.

Chemical Variations Among and within Plants

A variety of plant species were sampled above unexploited gold mineralization at the JL garimpo (Site 31 – Fig. 7), and data from these samples provide an example of the multi-species diversity in elements (Table 3). At this site samples of outer bark were scraped from 7 trees (Fig. 8), and leaf samples collected from 7 plants. Data in Table 3 are arranged alphabetically by species, first with the bark samples, then the leaves.

Fig. 8: Collection of outer bark of Castanha do Pará (Brazil nut tree) at the JL Garimpo (Site 31). A paint scraper is used to remove the outer scaly tissue

Tissue	Species	Au ppb	As ppm	Ba ppm	Br ppm	Ca %	Cr ppm	Fe %	Hf ppm	Hg ppm	K %	Mo ppm	Na ppm	Rb ppm	Sb ppm
Bark	Atameju	-0.1	-0.02	10	17	0.58	-0.3	0.006	-0.05	0.1	0.119	-0.05	38.8	4	0.008
Bark	Cachimbeira	0.7	0.15	26	19	0.91	0.8	0.05	0.26	0.24	0.055	0.09	38.1	2	0.015
Bark	Castanha-do-Pará	5	0.25	960	16	0.41	1.9	0.204	0.92	0.21	0.123	-0.05	45	5	0.013
Bark	Envireira	2.1	-0.02	11	15	0.02	0.3	0.014	0.07	0.23	0.075	-0.05	48	1	0.009
Bark	Maçaranduba	2.1	0.15	60	22	0.98	0.9	0.153	0.91	0.13	0.139	-0.05	49.4	7	0.022
Bark	Muirapiranga	22.1	0.12	9	20	0.1	1	0.063	0.24	0.07	0.057	0.08	56.2	3	0.01
Bark	Tauari	0.3	-0.02	280	36	2.37	-0.3	0.013	0.1	0.1	0.17	0.06	46.5	5	0.007
Leaf	Anjiroba	0.9	-0.02	13	60	0.55	-0.3	-0.005	-0.05	0.3	1.02	-0.05	45.7	23	-0.005
Leaf	Banana braba	0.7	-0.02	-5	42	0.12	-0.3	0.008	-0.05	0.15	0.813	-0.05	47.1	37	-0.005
Leaf	Boa macaca	0.4	0.02	40	3.4	1.24	-0.3	-0.005	-0.05	0.21	0.547	-0.05	68.4	17	-0.005
Leaf	Imbaúba2	0.5	0.04	-5	6.1	0.28	-0.3	-0.005	-0.05	0.15	1.42	-0.05	45.1	83	-0.005
Leaf	Muirapiranga	0.9	-0.02	-5	17	0.26	-0.3	-0.005	-0.05	0.15	0.5	-0.05	53	12	0.012
Leaf	Peruana	-0.1	-0.02	29	120	0.31	-0.3	-0.005	-0.05	0.18	1.71	-0.05	52.1	40	-0.005
Leaf	Peruana2	0.9	-0.01	17	44	0.85	-0.3	-0.005	-0.05	0.34	1.57	-0.05	75.9	36	0.007

Tissue	Species	Sc ppm	Se ppm	Sr ppm	Ta ppm	Th ppm	U ppm	Zn ppm	La ppm	Ce ppm	Nd ppm	Sm ppm	Yb ppm	Lu ppm
Bark	Atameju	0.02	0.3	99	-0.05	-0.1	-0.01	3	0.09	0.3	-0.3	0.007	-0.005	-0.001
Bark	Cachimbeira	0.18	0.4	59	-0.05	0.6	-0.01	6	0.9	1.4	0.3	0.055	0.047	0.007
Bark	Castanha-do-Pará	0.58	0.2	58	0.08	3.9	0.27	22	3.6	11	1.5	0.21	0.11	0.017
Bark	Envireira	0.04	0.2	-10	-0.05	0.2	-0.01	3	0.24	0.5	-0.3	0.016	0.012	0.002
Bark	Maçaranduba	0.41	0.3	140	0.11	2.1	0.22	6	3.3	4.4	1.1	0.18	0.093	0.017
Bark	Muirapiranga	0.17	0.4	19	-0.05	0.9	0.08	6	1.1	2.5	-0.3	0.064	0.031	0.006
Bark	Tauari	0.04	0.2	160	-0.05	0.2	0.02	6	0.34	0.9	-0.3	0.017	0.013	0.002
Leaf	Anjiroba	-0.01	0.1	90	-0.05	-0.1	-0.01	12	0.02	-0.1	-0.3	-0.001	-0.005	-0.001
Leaf	Banana braba	0.02	0.3	12	-0.05	-0.1	-0.01	12	0.1	0.1	-0.3	0.007	-0.005	-0.001
Leaf	Boa macaca	-0.01	-0.1	190	-0.05	-0.1	-0.01	9	0.05	-0.1	-0.3	0.005	0.005	-0.001
Leaf	Imbaúba2	-0.01	-0.1	38	-0.05	-0.1	-0.01	11	-0.01	-0.1	0.4	-0.001	-0.005	-0.001
Leaf	Muirapiranga	-0.01	0.2	21	-0.05	-0.1	-0.01	13	0.02	-0.1	-0.3	0.002	-0.005	-0.001
Leaf	Peruana	-0.01	0.1	88	-0.05	-0.1	0.02	10	0.03	-0.1	-0.3	-0.001	-0.005	-0.001
Leaf	Peruana2	-0.01	-0.1	210	-0.05	-0.1	-0.01	14	0.04	0.2	-0.3	0.003	-0.005	-0.001

Table 3: Comparison of element concentrations in bark and leaves from trees growing within a radius of 50 m over undeveloped gold mineralization at garimpo JL (Site 31)

Fig. 9: Muirapiranga at Garimpo JL (Site 31) showing unusually bright red colour of the inner bark after removal of outer bark for analysis, and sample of leaves from the same tree.

		Bark	Leaf			Bark	Leaf
Au	ppb	22.1	0.9	Se	ppm	0.4	0.2
As	ppm	0.12	-0.02	Sr	ppm	19	21
Ba	ppm	9	-5	Ta	ppm	-0.05	-0.05
Br	ppm	20	17	Th	ppm	0.9	-0.1
Ca	%	0.1	0.26	U	ppm	0.08	-0.01
Cr	ppm	1	-0.3	W	ppm	-0.05	-0.05
Fe	%	0.063	-0.005	Zn	ppm	6	13
Hf	ppm	0.24	-0.05	La	ppm	1.1	0.02
Hg	ppm	0.07	0.15	Ce	ppm	2.5	-0.1
K	%	0.057	0.5	Nd	ppm	-0.3	-0.3
Mo	ppm	0.08	-0.05	Sm	ppm	0.064	0.002
Na	ppm	56.2	53	Eu	ppm	-0.05	-0.05
Ni	ppm	-2	-2	Tb	ppm	-0.1	-0.1
Rb	ppm	3	12	Yb	ppm	0.031	-0.005
Sb	ppm	0.01	0.012	Lu	ppm	0.006	-0.001
Sc	ppm	0.17	-0.01				

Table 4: Element concentrations in dry samples of outer bark and leaves from a single tree of Muirapiranga rooted in gold-bearing rocks at garimpo JL (Site 31)

From one of these trees - a recently felled Muirapiranga (Fig. 9 on previous page) - both bark and leaf samples were collected. Table 4 shows that for this tree, as is typical for trees in general, many metals are more concentrated in the bark than in the leaves: notably Au, As, Ba, Cr, Fe, Hf, Sc, Th, U, and the rare earth elements (La – Lu). However, this is not true for all elements. Some, such as Ca, Hg, K, Rb, and Zn are significantly more enriched in the leaves, whereas others (Br, Na, and Sr) have similar values in both tissue types. Of note in these analyses is the unusually high concentration of gold in the bark. This tree was rooted in gold-bearing saprolitic rock thereby indicating that gold has been absorbed by the root system, and translocated to its extremities where it has accumulated. This phenomenon is typical of bark, making it a valuable exploration medium in many parts of the world. Furthermore, in dense forest or jungle it is not always practical to sample foliage because it is too high up to reach, yet the trunk (hence the bark) can be easily sampled.

Notable Enrichments of Elements Among the Various Species Investigated

Table 'Vegetation 1' in the Appendix provides data which can be examined to determine the propensity of the various species to accumulate metals. The focus for this study is on gold and mercury for which the following observations are made.

Fig. 10: Joel garimpo – view southwestward down-drainage from the abandoned sluicing operation. Vassoura shrub flourishing in the foreground is highly enriched in gold and mercury.

Gold

The median value for the entire data set is 0.8 ppb. Plant tissues that yield in excess of 5 ppb Au are shown in Table 5. Of particular note is a maximum value of 542 ppb that was obtained from a sample of Vassoura. Figure 10 shows the shrub from which this sample was collected, growing on tailings derived from sluice boxes at garimpo Joel.

The patch of shrubs in the background of Fig. 10 also consists of Vassoura, from which a sample yielded 206 ppb Au. It is noteworthy that this was the only species capable of growing on this disturbed and metal-rich site. Such concentrations are remarkable and significant in that they have the potential to be used to remediate metalliferous mine tailings and, although they have low biomass, could be reduced to ash and minor quantities of gold and other metals recovered. The gold yield of the ash would be approximately 10g/tonne in the sample shown in the foreground of Fig. 10.

Species	Tissue	Au ppb
Vassoura de Botão	*All*	542
Vassoura de Botão	*All*	206
Papaya	*Leaf*	63.4
Muirapiranga	*Bark*	22.1
Imbauba	*Leaf*	5
Castanha do Pará	*Bark*	5

Table 5: Tissues yielding gold concentrations >5 ppb Au

Mercury

The determination of mercury concentrations was a prime objective of the survey, because the garimpeiros use mercury to extract the gold from the sediments, and they burn the gold/mercury amalgam in the open air. Thus, the mercury has been dispersed as a vapour into the atmosphere and there is the potential for serious environmental contamination. As mercury content of the vegetation was of such importance to the project, care was taken to ensure that samples were not subjected to temperatures above 50°C in case mercury present in the samples might volatilise. Also, a special analytical technique by neutron activation was employed, that required a specific irradiation and counting regime to obtain a low detection level of 10 ppb Hg.

The median concentration for the data set is 40 ppb (0.04 ppm) Hg. This level is similar to background concentrations found in plants from non-mineralized areas of North America, and is identical to the concentration in GSC vegetation standard V6, which is a composite of pine tissues from the green belt around Ottawa. Thirteen samples contain more than 200 ppb Hg (Table 6) and 39 have more than 100 ppb Hg. The maximum concentration of 4600 ppb (4.6 ppm) also occurs in the sample of Vassoura that has the highest concentration of gold (Fig. 10). The sample of Papaya leaf was collected from a young tree growing out of a roadside garbage pile about 1 km east of Creporizão. This same sample yielded 63 ppb Au and so it appears that the Papaya, because it flourishes in polluted areas, is capable of scavenging and tolerating high levels of metals. Papaya, therefore, is a plant that could be used in environmental monitoring.

Species	Tissue	Hg ppb
Vassoura de Botão	*All*	4600
Vassoura de Botão	*All*	1400
Imbauba2	*Leaf*	510
Vassoura de Botão	*All*	450
Papaya	*Leaf*	370
Peruana	*Leaf*	340
Anjiroba	*Leaf*	300
Vassoura de Botão	*All*	240
Imbauba2	*Leaf*	240
Cachimbeira	*Bark*	240
Envireira	*Bark*	230
Castanha do Pará	*Bark*	210
Boa macaca	*Leaf*	210

Table 6: Samples containing concentrations in excess of 200 ppb (0.2 ppm) Hg

'Air plants' are epiphytic plants that hang from tree branches and obtain most of their nutrients from the atmosphere. Therefore, they might be expected to provide an integrated measure of the flux of atmospheric mercury through time. During earlier surveys by GSC personnel in the Creporizão area it was noted that air plants were present (K. Telmer, personal communication, 1998). For this biogeochemical survey it was hoped that the air plants were sufficiently abundant to collect them across the study area. This proved not to be the case. Only three samples could be collected in the survey area (some were out of reach on high branches), and each was a different species. All were within 500 m of garimpo Joel. In addition, two samples were collected from a background site, far from any garimpo, to the west of Itaituba. Data in Table 7 show that there is a fairly narrow range in mercury content both in the survey area and west of Itaituba, and that values are a little above the median value of 40 ppb Hg obtained for the main collection of vascular plants.

Site #	Easting	Northing	Hg ppb
Between 6 and 7	15000	-4700	44
Near 5	15000	-4500	55
Near 14	15500	-5000	60
West of Itaituba			47
West of Itaituba			45

Table 7: Concentrations of mercury in dry tissue of epiphytic 'Air Plants' from the survey area and from background sites west of Itaituba

Regional Distributions of Key Elements

In this section variations in plant chemistry are shown of the two most common species in the survey area – Imbauba and Vassoura. Each map shows element concentrations in symbols sized proportionally to the relative concentration of metals – the larger the symbol, the higher the concentration. From these patterns it is possible to establish the element enrichments associated with the different garimpos, and the extent of airborne contamination derived from the processing of the gold ore with mercury.

<u>Imbauba (Genus *Cecropia*)</u>

More than 50 species of this genus are known (Pio Corrêa, 1984). In the survey area there appeared to be two distinct morphologies – lobed fused leaves similar to the species *Cecropia palmata* (white fruits) or possibly *C. bifurcata*; and another with distinct separate leaves similar to *Cecropia sciadophylla* (red fruits). In addition a few trees had whitish fruits, furry leaves and milky sap (*Cecropia leucocoma?)*. These three are referred to as Imbauba, Imbauba2, and Imbauba3, respectively. Samples of each were collected, on an opportunistic basis, where they grew alongside each other in order to compare their chemical compositions. The data in Table 'Vegetation 1' show some differences in composition among these species such that a more rigorous survey should attempt to collect samples of only one species. In the present survey the majority of the trees were the first of the three, and all species have been plotted as the one genus. Data were inadequate to attempt any normalization.

Figure 11 shows plots of gold and mercury in Imbauba. Figure 12 shows plots of arsenic and zinc. Gold enrichment is noticeable around garimpos Joel and Mestre Antonio, and relative enrichment of mercury is locally present at each of the four garimpos. Arsenic levels are mostly low, reaching a maximum of only 0.1 ppm As at Joel, where there is also weak enrichment of zinc. Figure 13 shows detail of the gold and mercury concentrations around garimpos Joel and Mestre Antonio. Mercury levels are highest at the latter where gold is actively being processed and enrichments may reflect vapours from burning the amalgam.

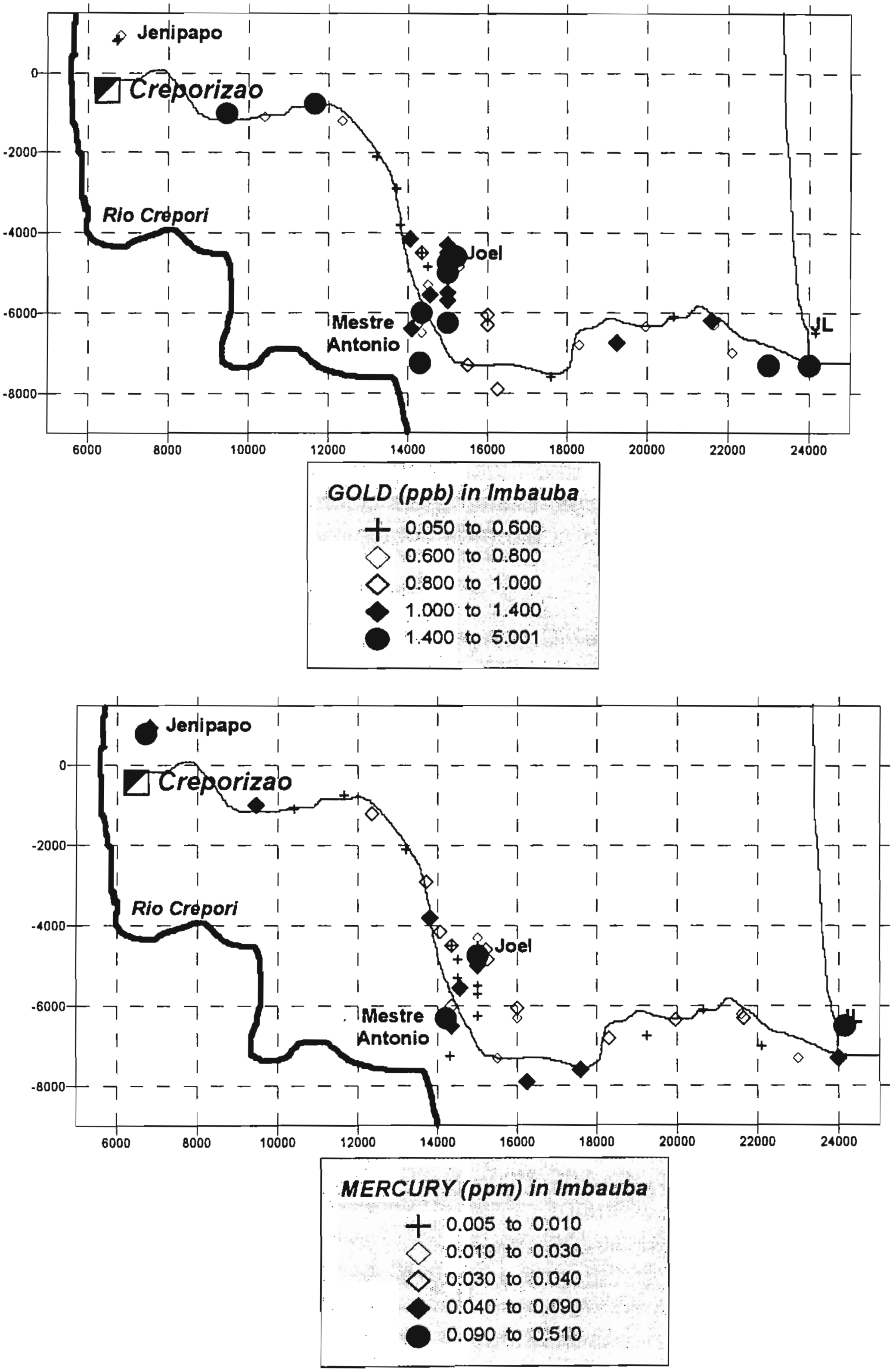


Fig. 11: Gold and Mercury in Dried Leaves of Imbauba

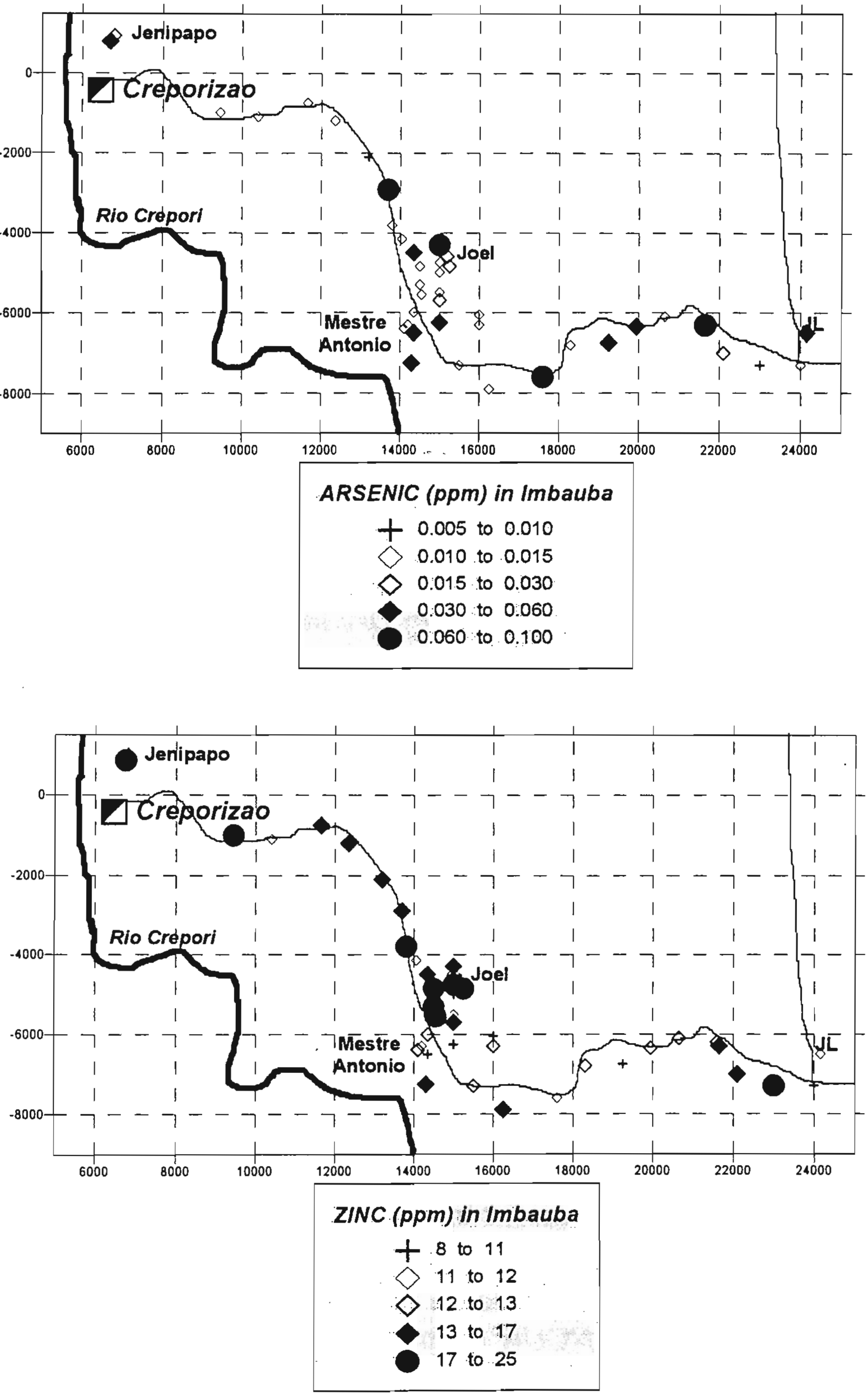
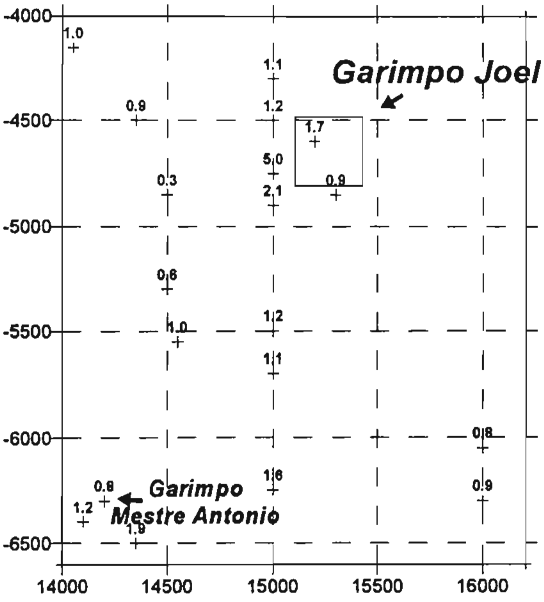
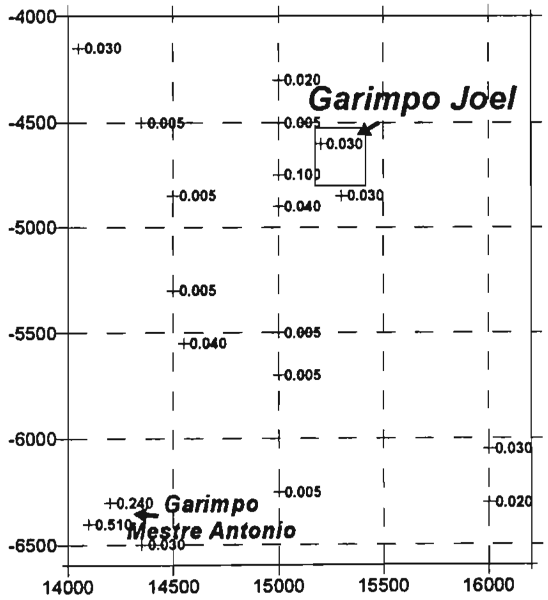


Fig. 12: Arsenic and Zinc in Dried Leaves of Imbauba



Detail of Area 'B' (Fig. 7)
GOLD (ppb) in Dry Imbauba Leaves

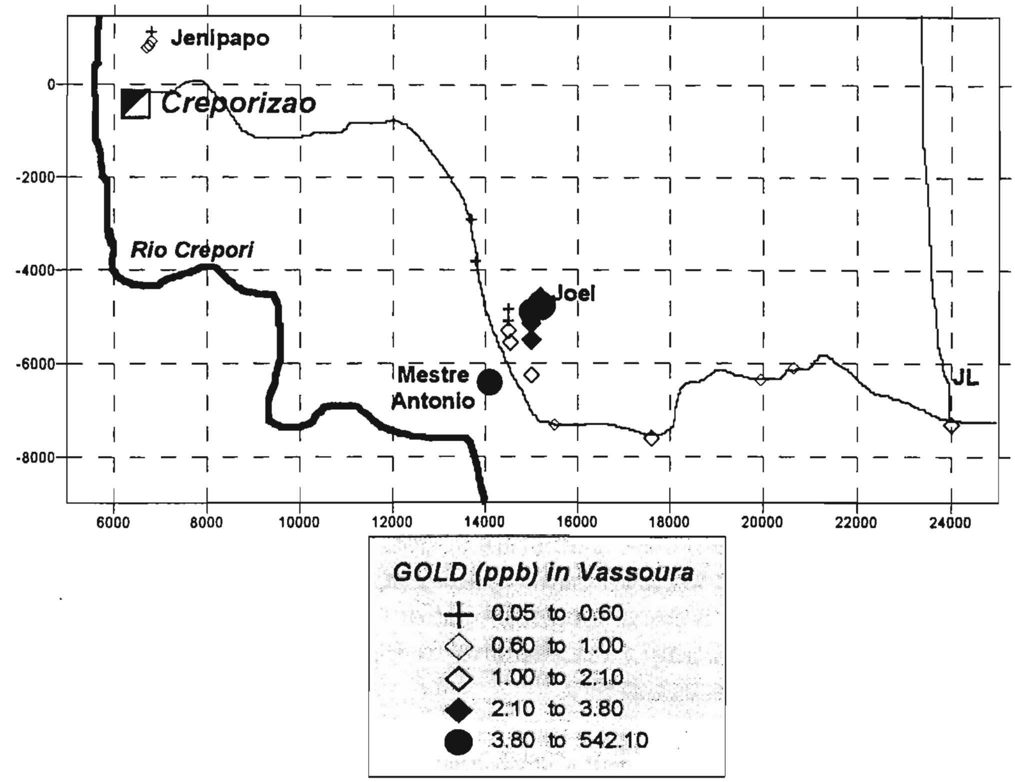


Detail of Area 'B' (Fig. 7)
MERCURY (ppm) in Dry Imbauba Leaves

Fig. 13: Detail of Sample Sites in the Vicinity of Two Garimpos (Area 'B', Fig. 7)– Gold and Mercury in Dried Leaves of Imbauba

Vassoura de Botão (*Borreria verticillata*)
As noted earlier, Vassoura appears to be capable of concentrating metals to higher levels than the Imbauba. Vassoura can grow in land devoid of any other species and can tolerate metal-rich sediments. Figure 14 shows that concentrations of gold and mercury are substantially higher than in Imbauba, yet relative enrichments of gold occur at both garimpos Joel and Mestre Antonio (there was no Vassoura present at garimpo JL). Similarly, mercury enrichment is present in Vassoura at the three garimpos where it was collected. Figure 15 shows details of the concentrations of these metals around garimpos Joel and Mestre Antonio (area 'B' on Fig. 7). Moderate levels of mercury enrichment around the abandoned operations at Joel appear to extend for about 300 m to the south. The northern and eastern limits are not defined because of lack of Vassoura. Other species from these surrounding areas are discussed in the next section. Gold enrichment >3 ppb (>four times background) extends for about 1 km to the south, implying that in this direction the natural enrichment of gold is more extensive than the anthropogenically-sourced mercury. Area 'A', shown on Fig. 7 (garimpo Jenipapo), had Vassoura growing at 4 of the 5 sample sites (sites 24 –28). Mercury concentrations were <10 ppb in the forest about 200 m north of the garimpo, increasing to 50 and 70 ppb near the abandoned site, to 120 ppb on the south side.

Figures 16 – 19 show the distributions in Vassoura of arsenic, antimony, cesium, molybdenum, cobalt, selenium, uranium and zinc. Each of these metals is enriched around garimpo Joel attesting to the natural metal associations with gold mineralization. Similarly, several of these metals are slightly enriched around the other two garimpos where Vassoura was collected. This information can be of use in mineral exploration, because by analyzing samples of Vassoura in areas of unknown mineral potential local metal enrichments in the plants can give focus for exploration efforts.



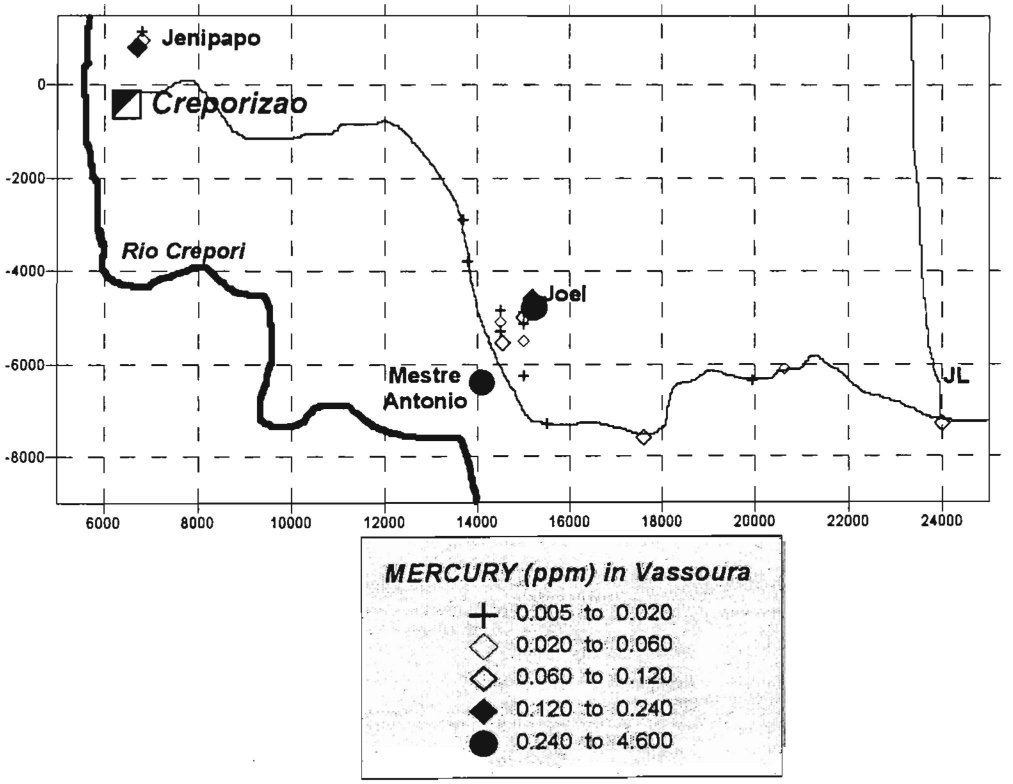
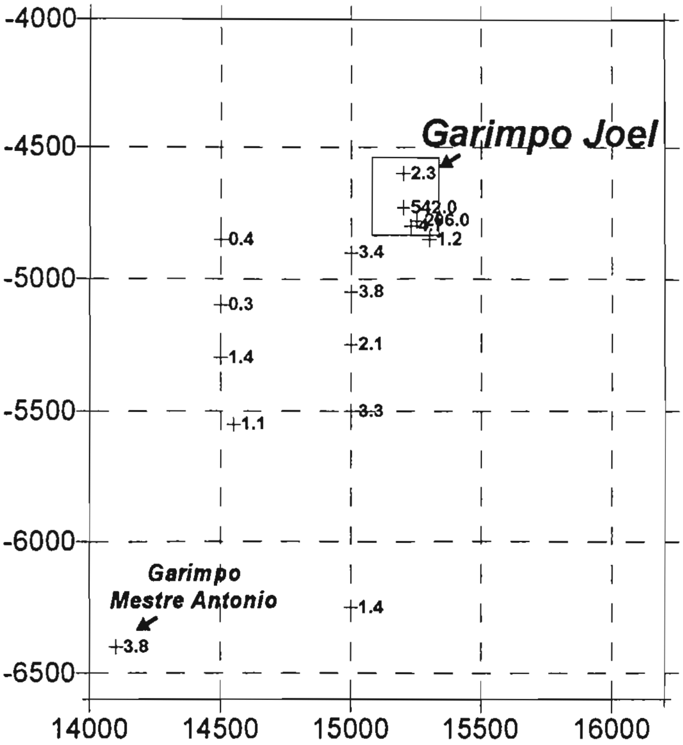
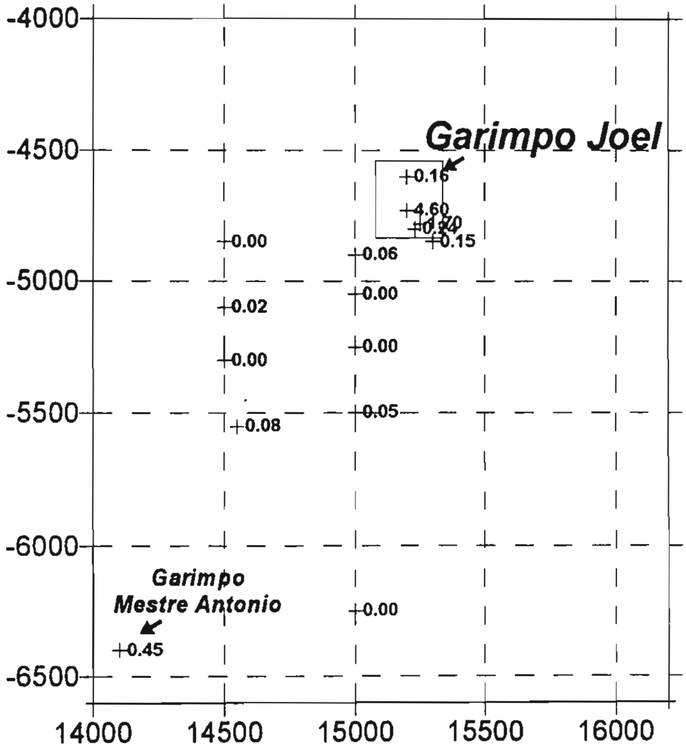


Fig. 14: Gold and Mercury in Dried Vassoura de Botão



Detail of Area 'B' (Fig. 7)
GOLD (ppb) in Dry Vassoura



Detail of Area 'B' (Fig. 7)
MERCURY (ppm) in Dry Vassoura

Fig. 15: Detail of Sample Sites in the Vicinity of Two Garimpos (Area 'B', Fig. 7)- Gold and Mercury in Dried Vassoura de Botão

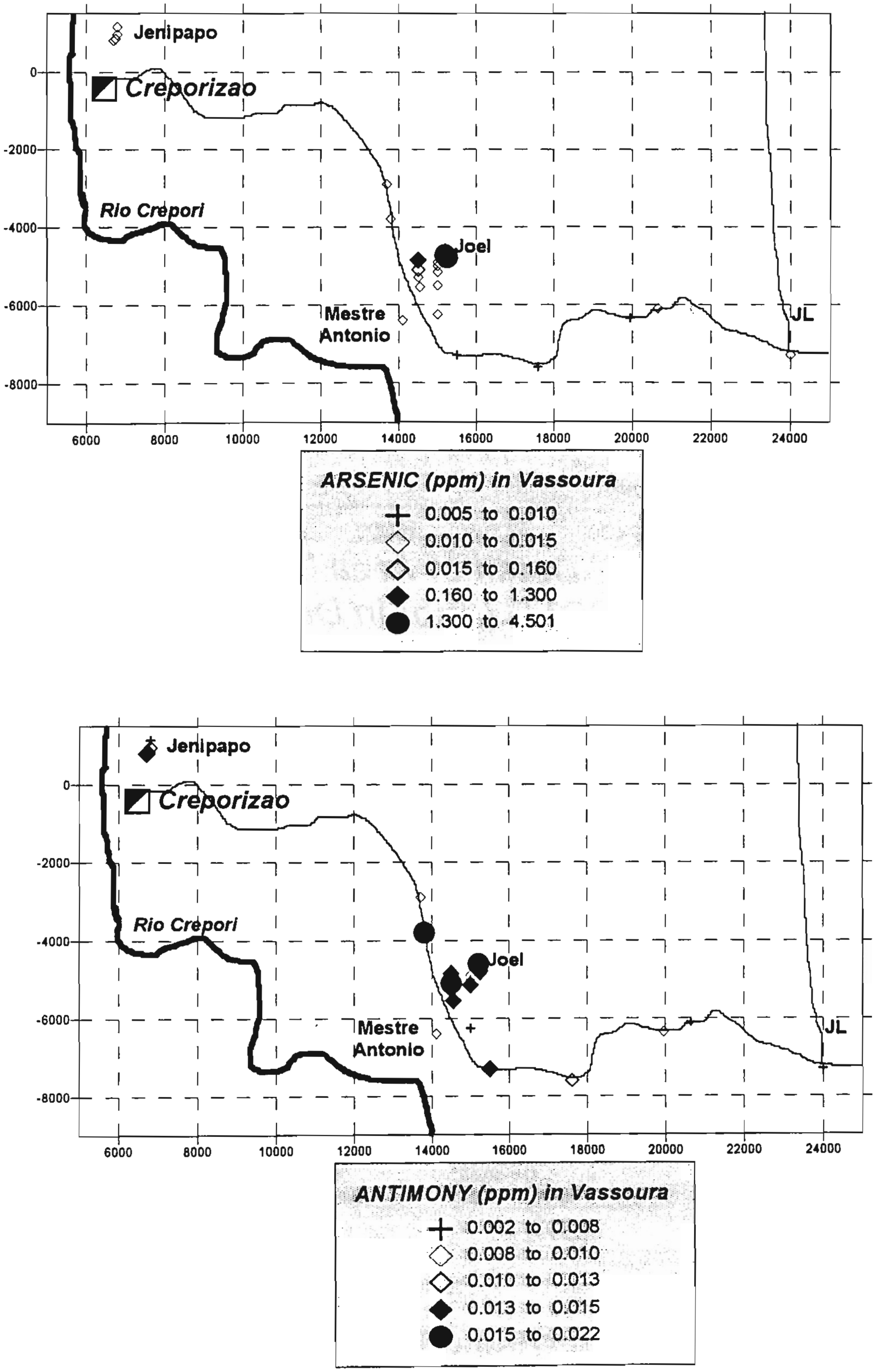
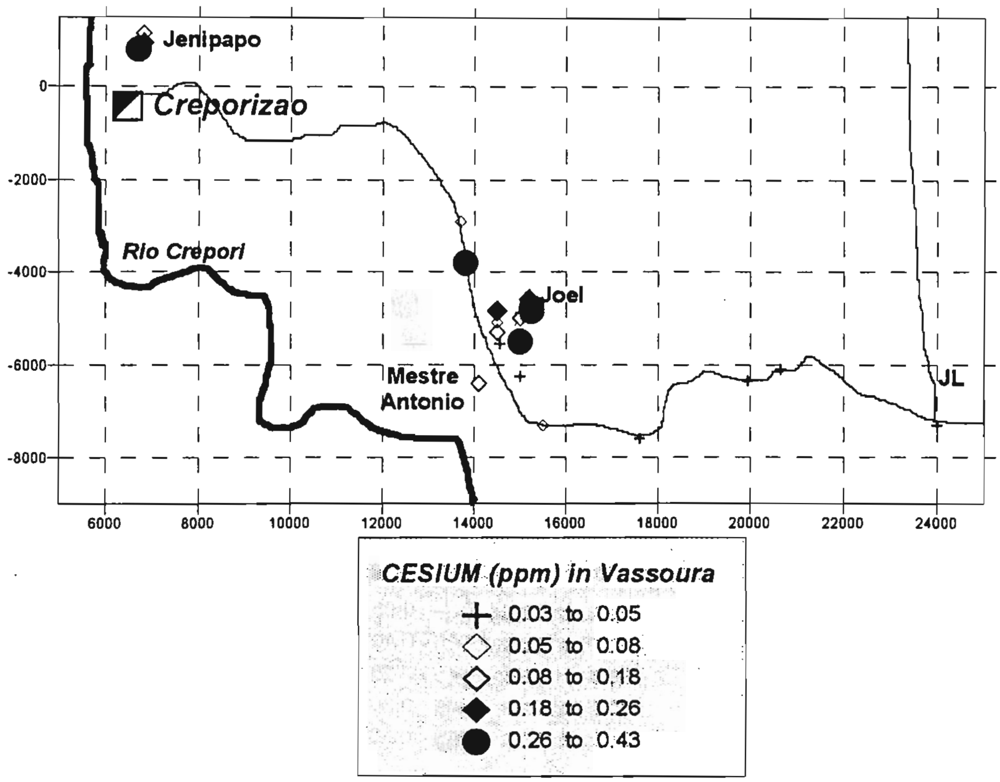


Fig. 16: Arsenic and Antimony in Dried Vassoura de Botão



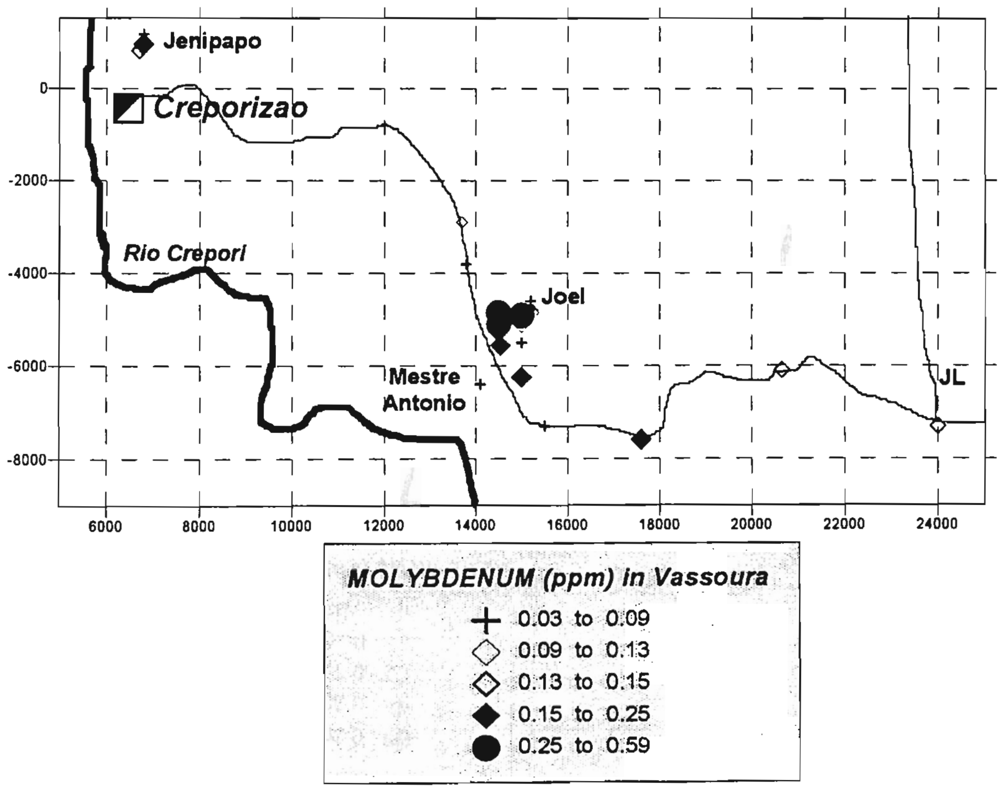


Fig. 17: Cesium and Molybdenum in Dried Vassoura de Botão

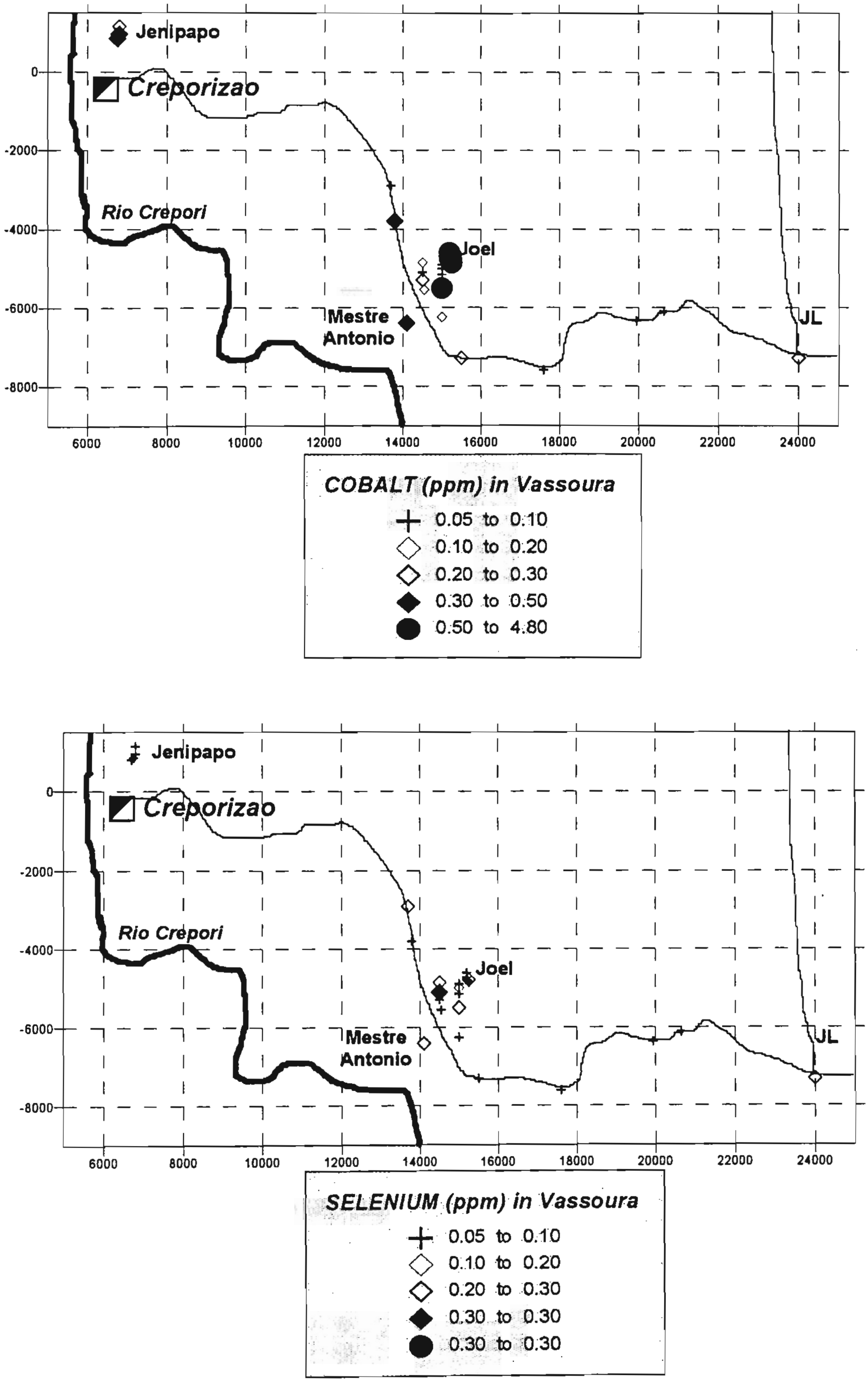
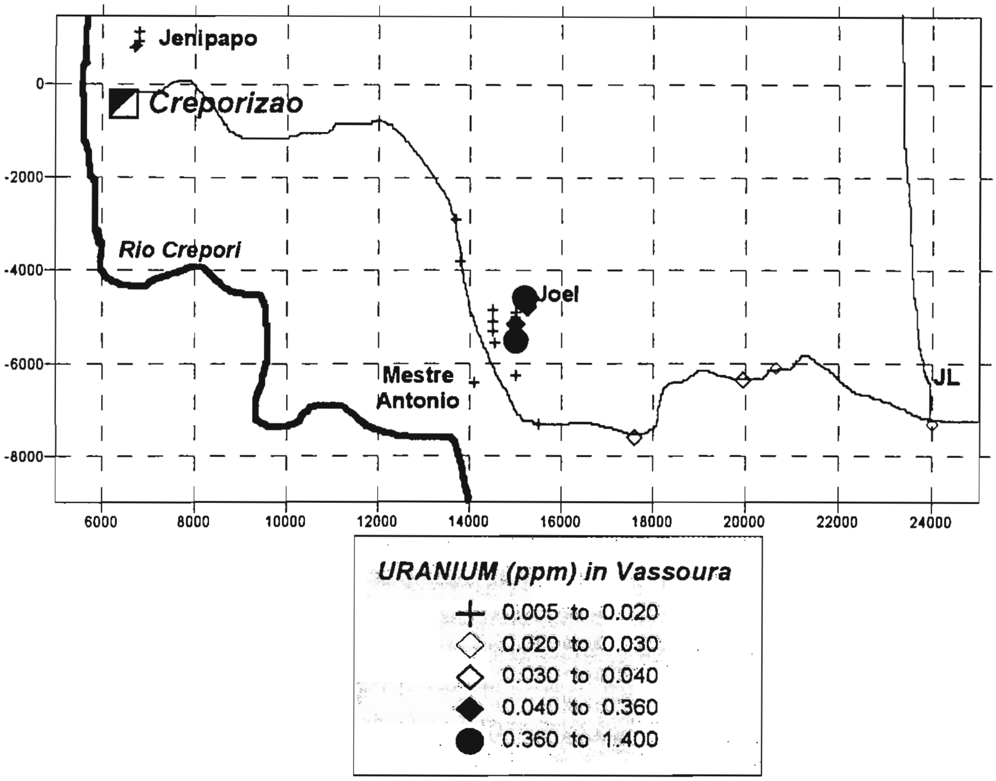


Fig. 18: Cobalt and Selenium in Dried Vassoura de Botão



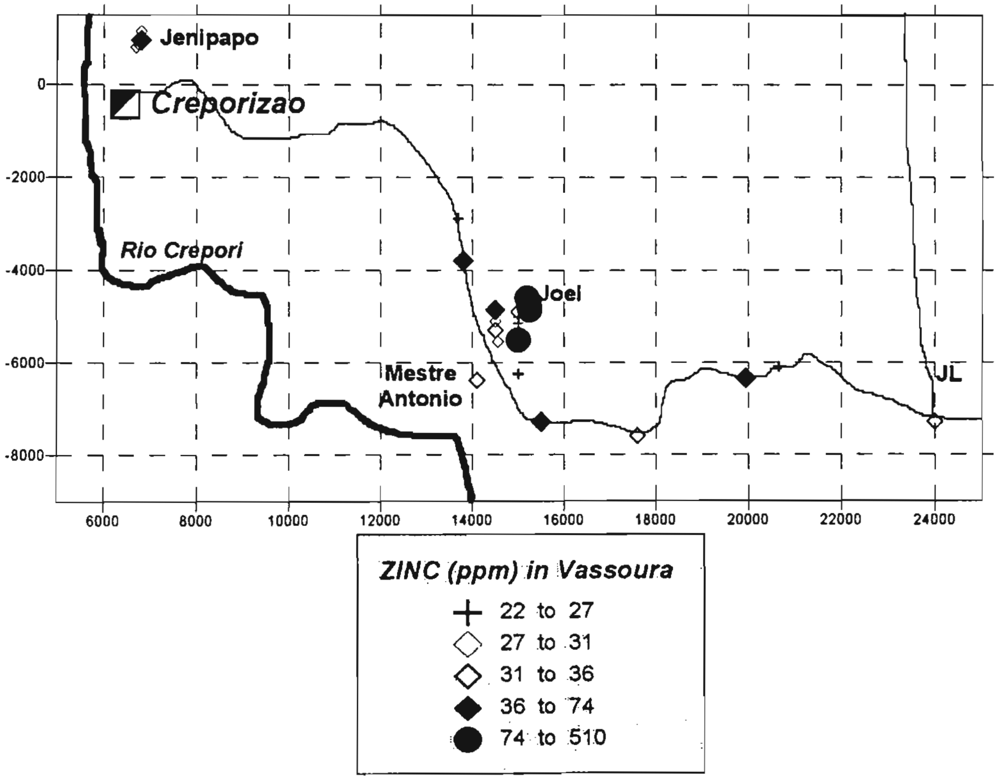


Fig. 19: Uranium and Zinc in Dried Vassoura de Botão

Regional Assessment of Mercury Contamination using All Species

As noted earlier, there is no single plant species present at all of the preferred sample sites, and there are differences in the metal content of the various species. However, major differences in metal uptake among species are mostly related to those metals present in the ground that are absorbed through the plants' roots. Each species has a different barrier mechanism to the uptake of metals through its roots. Where contamination is derived from airborne particulates there tends to be less differentiation among the species of the metal contaminant, because the particulates are fairly evenly distributed on plant surfaces (especially foliage) throughout the forest. With this principle in mind an assessment is made of the extent of mercury contamination from the garimpo operations. The procedure adopted is to consider the entire vegetation data set, and plot only those sites where mercury concentrations are above the median value of the population – i.e. only those sites with 50 ppb mercury or greater.

Figure 20 shows two maps. The lower is a repeat of Fig. 7, which simply shows the distribution of all sample sites. This is of relevance for comparison with the upper map that shows symbols representing mercury concentrations. Of note is the fact that by excluding data below the median value of 50 ppb mercury, there are very few sites remote from the garimpos: the main exception is a single sample of papaya leaves from a tree rooted in a garbage dump about 1 km east of Creporizão. It is apparent that there are metals in this dump.

The implication of the mercury distribution pattern is that there is airborne contamination of the forest for a distance of at least 500 m from garimpos Joel and Mestre Antonio. East of Joel, along L.16, 000, foliage samples contain between 130 and 240 ppb Hg. To determine the distance to background concentrations (i.e. < 50 ppb Hg) additional sampling would be required (e.g. along lines 17,000 and 18,000). There was insufficient sampling around the other garimpos to determine the extent of contamination from those operations.

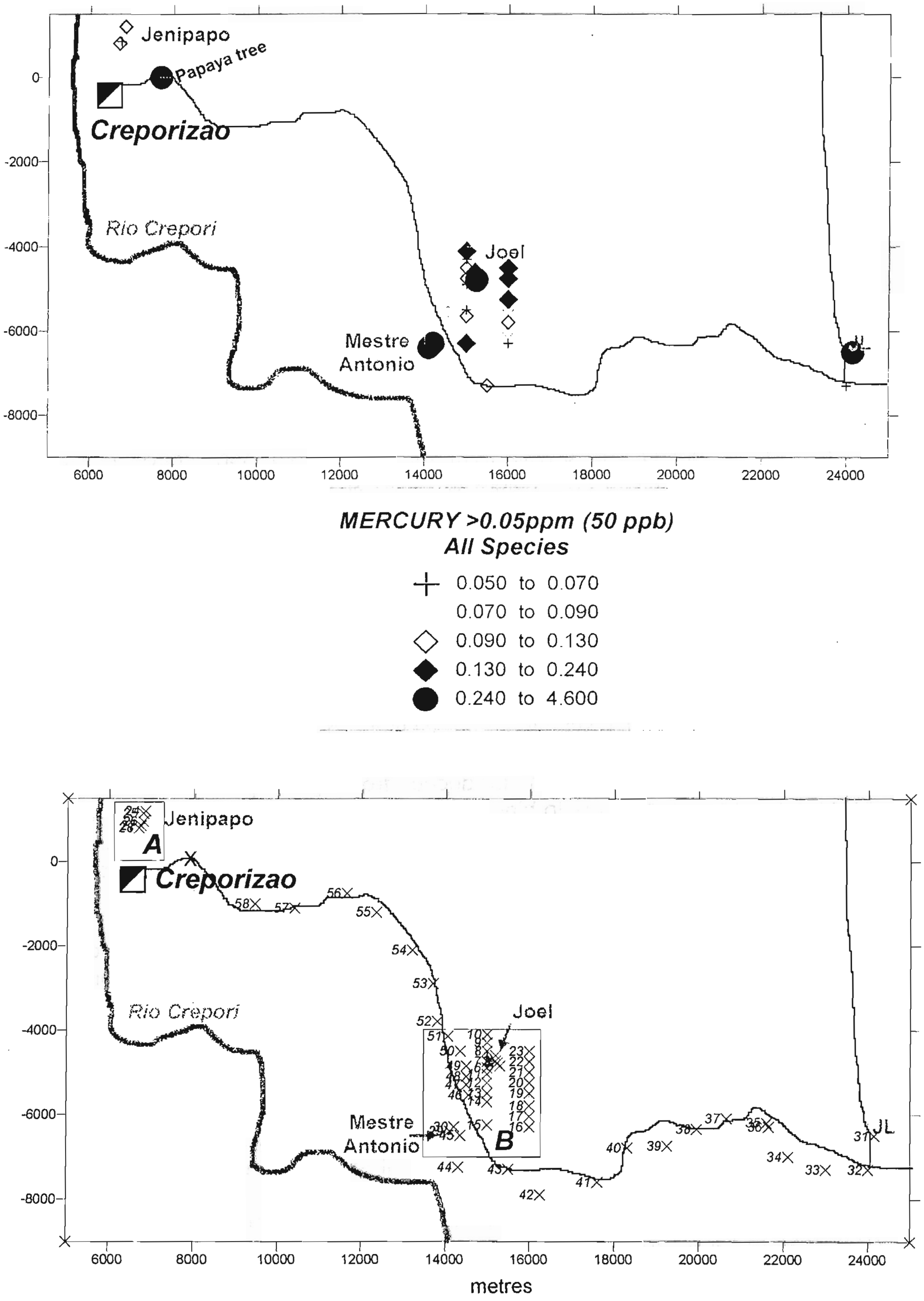


Fig. 20: Upper Map Shows Mercury Concentrations >50 ppb in All Species.
Lower Map is Repeat of Fig.7 to Show All Sample Sites.

SUMMARY AND CONCLUSIONS

From the collection and analysis of 180 plant samples in the Creporizão area, with focus around four garimpos, it has been possible to establish a first set of baseline data on the trace element composition of 23 plants common to many areas of the Amazon. No previous studies of this nature in the Amazon are known. Results show that in general the outer bark of mature trees contains higher concentrations of many metals than leaves, because trees sequester most heavy and potentially toxic metals in dead tissue (i.e. outer bark). A notable exception is mercury, which tends to be relatively enriched in leaves. These findings are in accord with studies undertaken in North America and Russia.

This orientation survey, designed primarily to assess the levels in plants of mercury contamination derived from the burning by garimpeiros of gold amalgam, has provided a first insight to those species of Amazonia that can concentrate metals. The most common tree of the survey area, Imbauba, does not accumulate high levels of metals, but reveals *relative* enrichments around the garimpos. However, the most common shrub of the area, Vassoura de botão, grows vigorously in disturbed areas and is found to accumulate high levels of both gold and mercury. Furthermore, determinations of other trace elements can provide an indication of metal assemblages that may be related to mineralization, and can therefore provide focus to exploration activities.

Of note is the indiscriminate enrichment of mercury among several different species around garimpo Joel. It is concluded that this enrichment is derived from mercury vapours produced from gold processing by the garimpeiros: mercury appears to blanket all components of the forest regardless of plant species. Where metal accumulations in plants are from natural sources there are usually significant differences in metal uptake because of the barriers established at the soil/water/plant interfaces.

More detailed and more extensive sampling of vegetation around the garimpos should define the full extent of the mercury contamination. Scanning electron microscope studies of plant tissues, such as the highly enriched specimen of Vassoura at Joel, may cast light on the nature of the mercury and confirm whether it is wholly on the plant surfaces or is also within the plant structure.

Future studies could be undertaken to add valuable baseline data on the trace element chemistry of other common plant species of the Amazon. Such information would be of value as a base against which to measure long-term trends in metal variations, and would be of particular value in that the Amazon is considered to be a 'sink' for worldwide atmospheric pollutants. Thus any data collected in the short term would be a 'snapshot' of metal levels at the beginning of the millennium.

ACKNOWLEDGEMENTS

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Many people contributed help and information to this study. In the planning stages whilst in Belém, the assistance of botanist Raimundo Bahia of Museu Emilio Goeldi was of great value in providing basic information needed to get started. Whilst in the field two local guides provided invaluable information on local names of the flora and had keen eyes, and sometimes noses, for identifying subtle differences in plant species. We are deeply grateful to Silvana Rodrigues, and Yvon Maurice for their field assistance, and to Yvon for his logistical support and advice throughout this project.

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APPENDIX
Data Listings

Site #	Species	Tissue	Grid Coordinates Easting	Grid Coordinates Northing	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	K %	MO PPM	NA PPM	NI PPM	RB PPM	SB PPM
1	Imbauba	Leaf	15200	-4600	1.7	-0.3	-0.05	25	63	0.62	0.1	-0.3	0.12	0.007	-0.05	0.03	-0.1	1.91	3.1	39.1	-2	71	-0.005
5	Imbauba	Leaf	15300	-4850	0.9	-0.3	-0.04	16	43	0.69	-0.1	0.3	0.12	0.007	-0.05	0.03	-0.1	1.63	0.18	29.4	-2	90	-0.005
6	Imbauba	Leaf	15000	-4900	2.1	-0.3	0.01	14	28	0.63	-0.1	0.3	-0.05	0.007	-0.05	0.04	-0.1	2.02	0.43	41	-2	60	-0.005
7	Imbauba	Leaf	15000	-4750	5	-0.3	-0.02	5	11	0.31	-0.1	0.3	0.1	0.007	-0.05	0.1	-0.1	1.44	-0.05	88.5	-2	88	0.01
8	Imbauba	Leaf	15000	-4500	1.2	-0.3	-0.02	22	10	0.47	-0.1	-0.3	0.26	0.005	-0.05	-0.01	-0.1	1.46	-0.05	36.7	-2	110	0.009
9	Imbauba	Leaf	15000	-4300	1.1	-0.3	0.06	10	8.2	0.62	-0.1	0.3	0.06	0.005	-0.05	0.02	-0.1	1.59	0.09	45.5	-2	58	-0.005
13	Imbauba	Leaf	15000	-5500	1.2	-0.3	-0.02	34	26	0.76	0.3	-0.3	-0.05	-0.005	-0.05	-0.01	-0.1	1.2	0.68	38.7	-2	24	-0.005
14	Imbauba2	Leaf	15000	-5700	1.1	-0.3	0.02	9	1.7	0.43	-0.1	-0.3	0.1	-0.005	-0.05	-0.01	-0.1	2.05	0.26	42.6	-2	150	-0.005
15	Imbauba	Leaf	15000	-6250	1.6	-0.3	0.04	28	21	0.63	-0.1	-0.3	-0.05	-0.005	-0.05	-0.01	-0.1	1.27	-0.05	43.3	-2	33	-0.005
16	Imbauba	Leaf	16000	-6300	0.9	-0.3	-0.02	54	33	0.63	-0.1	-0.3	0.05	0.005	-0.05	0.02	-0.1	1.76	0.12	42.8	-2	87	-0.005
17	Imbauba	Leaf	16000	-6050	0.8	-0.3	-0.02	34	24	0.75	-0.1	-0.3	0.06	-0.005	-0.05	0.03	-0.1	1.32	0.28	36.9	-2	52	-0.005
26	Imbauba2	Leaf	6800	950	0.6	-0.3	0.02	150	5.1	1.07	-0.1	-0.3	0.08	-0.005	-0.05	0.04	-0.1	1.54	0.17	40.9	-2	52	-0.005
27	Imbauba2	Leaf	6750	850	0.5	-0.3	-0.01	120	12	1.14	-0.1	-0.3	0.08	0.011	-0.05	0.04	-0.1	1.97	0.55	41.6	-2	40	-0.005
28	Imbauba2	Leaf	6700	800	0.2	-0.3	0.03	23	20	0.88	-0.1	-0.3	0.15	-0.005	-0.05	0.09	-0.1	1.7	0.22	45.5	-2	54	-0.005
29	Imbauba2	Leaf	14100	-6400	1.2	-0.3	-0.02	92	81	0.78	-0.1	-0.3	-0.05	0.005	-0.05	0.51	-0.1	1.67	0.12	55.8	-2	30	0.015
30	Imbauba2	Leaf	14200	-6300	0.8	-0.3	-0.02	80	44	0.92	-0.1	-0.3	-0.05	0.006	-0.05	0.24	-0.1	1.67	-0.05	66.6	-2	25	0.011
31	Imbauba2	Leaf	24150	-6500	0.5	-0.3	0.04	-5	6.1	0.28	-0.1	-0.3	-0.05	-0.005	-0.05	0.15	-0.1	1.42	-0.05	45.1	-2	83	-0.005
32	Imbauba2	Leaf	24000	-7300	1.5	-0.3	-0.02	7	16	0.42	-0.1	0.5	-0.05	0.009	-0.05	0.04	-0.1	2.38	0.17	56.9	-2	79	-0.005
33	Imbauba	Leaf	23000	-7300	2.1	-0.3	-0.01	15	31	0.63	-0.1	-0.3	-0.05	0.009	-0.05	0.02	-0.1	2.02	0.14	87.2	-2	69	-0.005
34	Imbauba	Leaf	22100	-7000	0.6	-0.3	-0.03	23	44	0.65	-0.1	-0.3	0.07	0.006	-0.05	-0.01	-0.1	1.91	1.8	60.2	-2	71	-0.005
35	Imbauba	Leaf	21600	-6200	1	-0.3	-0.03	32	68	0.8	-0.1	-0.3	0.09	0.006	-0.05	0.01	-0.1	1.31	0.29	69.1	-2	50	-0.005
36	Imbauba	Leaf	21650	-6300	0.7	-0.3	0.06	38	18	0.87	-0.1	-0.3	0.05	0.007	-0.05	0.03	-0.1	1.8	1.4	56.2	-2	41	-0.005
37	Imbauba	Leaf	20650	-6100	0.5	-0.3	-0.02	67	14	0.81	-0.1	-0.3	0.06	0.007	-0.05	-0.01	-0.1	1.7	1.8	57.4	-2	36	-0.005
38	Imbauba	Leaf	19950	-6350	0.6	-0.3	0.05	73	5.1	0.73	-0.1	-0.3	-0.05	0.01	-0.05	0.03	-0.1	1.45	0.68	54.5	-2	26	-0.005
39	Imbauba	Leaf	19250	-6750	1.1	-0.3	0.05	25	59	0.88	-0.1	-0.3	-0.05	0.01	-0.05	-0.01	-0.1	1.35	2.8	63.8	-2	39	-0.005
40	Imbauba	Leaf	18300	-6800	0.6	-0.3	-0.02	44	36	0.75	-0.1	0.3	-0.05	0.013	-0.05	0.03	-0.1	1.25	-0.05	61.8	-2	67	0.006
41	Imbauba	Leaf	17600	-7600	0.5	-0.3	0.1	41	39	0.82	-0.1	0.3	-0.05	0.014	-0.05	0.04	-0.1	1.22	0.51	44.4	-2	37	-0.005
42	Imbauba	Leaf	16250	-7900	0.8	-0.3	-0.02	-5	37	0.5	-0.1	-0.3	-0.05	0.007	-0.05	0.04	-0.1	1.05	-0.05	57.2	-2	24	-0.005
43	Imbauba	Leaf	15500	-7300	0.9	-0.3	-0.02	22	11	0.53	-0.1	-0.3	-0.05	0.01	-0.05	0.01	-0.1	1.7	0.08	51.5	-2	39	-0.005
44	Imbauba	Leaf	14300	-7250	3.3	-0.3	0.05	8	4.6	0.62	-0.1	0.3	-0.05	0.021	-0.05	-0.01	-0.1	1.68	0.2	78	-2	31	-0.005
45	Imbauba2	Leaf	14350	-6500	0.6	-0.3	0.03	78	1	0.83	-0.1	-0.3	-0.05	0.01	-0.05	0.04	-0.1	1.26	0.3	36.2	-2	58	-0.005
45	Imbauba	Leaf	14350	-6500	1.9	-0.3	-0.02	130	19	1.06	-0.1	-0.3	-0.05	0.018	-0.05	0.03	-0.1	1.79	0.36	86.3	-2	34	-0.005
46	Imbauba	Leaf	14550	-5550	1	-0.3	-0.02	40	25	1.01	-0.1	-0.3	-0.05	0.022	-0.05	0.04	-0.1	1.96	0.96	43.5	-2	55	-0.005
47	Imbauba	Leaf	14500	-5300	0.6	-0.3	-0.02	24	19	0.73	-0.1	-0.3	0.08	0.007	-0.05	-0.01	-0.1	2.44	0.84	59.1	-2	130	-0.005
49	Imbauba	Leaf	14500	-4850	0.3	-0.3	-0.02	45	24	1.15	-0.1	-0.3	-0.05	0.012	-0.05	-0.01	-0.1	2.07	0.9	44.2	-2	62	-0.005
50	Imbauba	Leaf	14350	-4500	0.9	-0.3	0.05	14	13	0.85	-0.1	-0.3	0.1	0.005	-0.05	-0.01	-0.1	1.61	0.12	50.2	-2	62	0.006
50	Imbauba3	Leaf	14350	-4500	0.5	-0.3	-0.02	7	17	0.24	-0.1	-0.3	0.05	-0.005	-0.05	0.03	-0.1	1.14	-0.05	41.7	-2	88	-0.005
51	Imbauba	Leaf	14050	-4150	1	-0.3	-0.02	11	150	0.5	-0.1	0.5	0.08	0.022	-0.05	0.03	-0.1	0.122	0.28	52.7	-2	39	-0.005
52	Imbauba	Leaf	13800	-3800	0.3	-0.3	-0.02	18	35	0.76	-0.1	-0.3	-0.05	0.007	-0.05	-0.01	-0.1	1.59	0.76	43.3	-2	49	-0.005
52	Imbauba2	Leaf	13800	-3800	-0.1	-0.3	-0.02	44	29	1.04	-0.1	-0.3	0.09	0.008	-0.05	0.04	-0.1	1.74	0.4	48.7	-2	82	-0.005
53	Imbauba	Leaf	13700	-2900	0.3	-0.3	0.07	40	25	0.79	-0.1	-0.3	0.06	0.009	-0.05	0.03	-0.1	1.55	1	41.1	-2	56	-0.005
54	Imbauba2	Leaf	13200	-2100	0.4	-0.3	-0.01	24	1.6	0.55	-0.1	0.3	-0.05	0.007	-0.05	-0.01	-0.1	1.45	0.85	44.2	-2	69	-0.005
55	Imbauba	Leaf	12350	-1200	0.7	-0.3	-0.02	16	14	0.78	-0.1	-0.3	-0.05	0.011	-0.05	0.03	-0.1	1.32	0.98	45.9	-2	25	-0.005
56	Imbauba	Leaf	11650	-750	1.5	-0.3	-0.02	34	48	0.9	-0.1	-0.3	0.08	0.007	-0.05	-0.01	-0.1	1.33	0.3	51.5	-2	53	-0.005
57	Imbauba	Leaf	10400	-1100	0.7	-0.3	-0.02	28	41	0.99	-0.1	-0.3	0.11	0.013	-0.05	-0.01	-0.1	1.03	0.38	58.6	-2	31	-0.005
58	Imbauba2	Leaf	9450	-1000	1.4	-0.3	-0.02	28	16	0.53	-0.1	-0.3	-0.05	0.011	-0.05	0.04	-0.1	1.69	0.15	51.2	-2	75	-0.005
59	Imbauba2	Leaf	West of Itaituba		0.9	-0.3	0.03	9	1.7	0.66	-0.1	0.4	-0.05	0.013	-0.05	-0.01	-0.1	0.74	0.06	188	-2	7	-0.005
60	Imbauba	Leaf	West of Itaituba		0.6	-0.3	-0.02	8	100	1.37	-0.1	-0.3	0.29	0.013	-0.05	0.03	-0.1	1.49	0.71	50.9	-2	35	-0.005
16	Banana braba	Leaf	16000	-6300	0.7	-0.3	0.08	18	29	0.21	-0.1	0.4	0.09	0.006	-0.05	0.01	-0.1	2.13	0.06	42.6	-2	80	0.006
20	Banana braba	Leaf	16000	-5250	0.5	-0.3	-0.02	24	26	0.3	-0.1	0.4	0.09	-0.005	-0.05	0.04	-0.1	2.67	0.16	55.8	-2	95	-0.005
21	Banana braba	Leaf	16000	-5000	0.8	-0.3	-0.02	23	29	0.29	-0.1	0.4	0.2	0.005	-0.05	0.01	-0.1	2.74	-0.05	64.2	-2	170	0.014
22	Banana braba	Leaf	16000	-4750	0.6	-0.3	-0.02	13	34	0.32	-0.1	0.7	0.12	0.006	-0.05	0.04	-0.1	2.85	-0.05	55.4	-2	160	-0.005
23	Banana braba	Leaf	16000	-4500	0.4	-0.3	-0.01	26	21	0.34	0.1	0.6	0.05	0.005	-0.05	0.02	-0.1	2.9	0.2	69	-2	64	-0.005
24	Banana braba	Leaf	6850	1200	0.8	-0.3	-0.02	16	46	0.25	-0.1	0.4	0.6	0.006	-0.05	0.05	-0.1	2.65	-0.05	51.9	-2	130	0.007
25	Banana braba	Leaf	6800	1150	0.8	-0.3	0.05	6	68	0.27	-0.1	0.6	0.96	-0.005	-0.05	0.02	-0.1	2.13	-0.05	41.7	-2	88	0.021
30	Banana braba	Leaf	14200	-6300	0.8	-0.3	-0.02	24	43	0.22	-0.1	0.6	-0.05	0.005	-0.05	0.1	-0.1	3.54	0.26	119	-2	100	0.013
31	Banana braba	Leaf	24150	-6500	0.7	-0.3	-0.02	-5	42	0.12	0.1	-0.3	-0.05	0.008	-0.05	0.15	-0.1	0.813	-0.05	47.1	-2	37	-0.005
34	Banana braba	Leaf	22100	-7000	0.5	-0.3	-0.02	25	49	0.38	-0.1	0.7	0.06	0.01	-0.05	0.04	-0.1	2.43	0.1	60.3	-2	59	-0.005
43	Banana braba	Leaf	15500	-7300	1	-0.3	-0.02	44	39	0.22	0.2	0.6	0.11	0.012	-0.05	0.02	-0.1	2.7	-0.05	84.7	-2	73	-0.005
44	Banana braba	Leaf	14300	-7250	1.5	-0.3	-0.02	-5	41	0.3	-0.1	0.8	1.1	0.016	-0.05	0.03	-0.1	1.74	-0.05	960	-2	51	0.017
10	Anjiroba	Leaf	15000	-4100	0.6	-0.3	-0.02	-5	23	0.35	-0.1	-0.3	-0.05	-0.005	-0.05	0.02	-0.1	0.736	-0.05	37.8	-2	38	-0.005
17	Anjiroba	Leaf	16000	-6050	0.5	-0.3	0.09	29	16	0.69	-0.1	-0.3	0.3	-0.005	-0.05	0.02	-0.1	1.47	0.09	39.7	-2	88	0.006
21	Anjiroba	Leaf	16000	-5000	0.3	-0.3	0.11	11	22	0.71	-0.1	-0.3	0.05	-0.005	-0.05	0.04	-0.1	0.905	-0.05	43.9	-2	38	-0.005
22	Anjiroba	Leaf	16000	-4750	0.8	-0.3	0.01	51	30	0.83	-0.1	-0.3	-0.05	-0.005	-0.05	0.1	-0.1	0.733	-0.05	39.4	-2	41	-0.005
24	Anjiroba	Leaf	6850	1200	0.7	-0.3	0.02	7	25	0.45	-0.1	-0.3	0.25	-0.005	-0.05	0.11	-0.1	0.748	-0.05	44.2	-2	41	-0.005
31	Anjiroba	Leaf	24150	-6500	0.9	-0.3	-0.02	13	60	0.55	-0.1	-0.3	-0.05	-0.005	-0.05	0.3	-0.1	1.02	-0.05	45.7	-2	23	-0.005
7	Boa macaca	Leaf	15000	-4750	1.1	-0.3	0.03	6	9.5	0.6	-0.1	-0.3	0.08	-0.005	-0.05	0.09	-0.1	0.863	-0.05	60.1	-2	48	-0.005

Table Vegetation 1

Analytical Data for All Vegetation Samples: Determinations by INAA

Site #	Species	Tissue	Grid Coordinates Easting	Northing	SC PPM	SE PPM	SR PPM	TA PPM	TH PPM	U PPM	W PPM	ZN PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM	YB PPM	LU PPM	Mass g
1	Imbauba	Leaf	15200	-4600	-0.01	-0.1	17	-0.05	-0.1	-0.01	-0.05	9	0.11	-0.1	-0.3	0.008	-0.05	-0.1	-0.005	-0.001	8.32
5	Imbauba	Leaf	15300	-4850	-0.01	-0.1	49	-0.05	-0.1	-0.01	-0.05	20	0.02	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.97
6	Imbauba	Leaf	15000	-4900	-0.01	-0.1	94	-0.05	-0.1	-0.01	-0.05	10	0.03	-0.1	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	7.9
7	Imbauba	Leaf	15000	-4750	0.01	-0.1	35	-0.05	-0.1	-0.01	-0.05	17	0.07	0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	5.37
8	Imbauba	Leaf	15000	-4500	-0.01	-0.1	100	-0.05	-0.1	-0.01	-0.05	12	0.02	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.36
9	Imbauba	Leaf	15000	-4300	-0.01	-0.1	69	-0.05	-0.1	-0.01	-0.05	13	0.02	-0.1	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.5
13	Imbauba	Leaf	15000	-5500	-0.01	-0.1	100	-0.05	-0.1	-0.01	-0.05	11	0.45	1.1	-0.3	0.025	-0.05	-0.1	-0.005	-0.001	8.67
14	Imbauba2	Leaf	15000	-5700	-0.01	-0.1	42	-0.05	-0.1	-0.01	-0.05	15	0.01	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.64
15	Imbauba	Leaf	15000	-6250	-0.01	-0.1	110	-0.05	-0.1	-0.01	-0.05	8	0.03	-0.1	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.5
16	Imbauba	Leaf	16000	-6300	-0.01	-0.1	110	-0.05	-0.1	-0.01	-0.05	12	-0.01	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.32
17	Imbauba	Leaf	16000	-6050	-0.01	-0.1	78	-0.05	-0.1	-0.01	-0.05	10	0.03	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.28
26	Imbauba2	Leaf	6800	950	-0.01	-0.1	100	-0.05	-0.1	-0.01	-0.05	15	0.4	0.6	-0.3	0.013	-0.05	-0.1	0.009	0.001	8.13
27	Imbauba2	Leaf	6750	850	-0.01	-0.1	96	-0.05	-0.1	-0.01	-0.05	19	0.03	0.1	-0.3	0.001	-0.05	-0.1	-0.005	-0.001	8.57
28	Imbauba2	Leaf	6700	800	-0.01	-0.1	79	-0.05	-0.1	-0.01	-0.05	14	0.03	-0.1	-0.3	0.001	-0.05	-0.1	-0.005	-0.001	8.16
29	Imbauba2	Leaf	14100	-6400	-0.01	-0.1	65	-0.05	-0.1	-0.01	-0.05	12	0.85	1	-0.3	0.09	-0.05	-0.1	0.037	0.006	7.01
30	Imbauba2	Leaf	14200	-6300	-0.01	-0.1	150	-0.05	-0.1	-0.01	-0.05	11	0.05	0.2	-0.3	0.004	-0.05	-0.1	0.013	-0.001	8.86
31	Imbauba2	Leaf	24150	-6500	-0.01	-0.1	38	-0.05	-0.1	-0.01	-0.05	11	-0.01	-0.1	0.4	-0.001	-0.05	-0.1	-0.005	-0.001	8.33
32	Imbauba2	Leaf	24000	-7300	-0.01	-0.1	58	-0.05	-0.1	-0.01	-0.05	10	0.03	0.1	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.36
33	Imbauba	Leaf	23000	-7300	-0.01	0.2	73	-0.05	-0.1	-0.01	-0.05	17	0.06	0.2	-0.3	0.004	-0.05	-0.1	-0.005	-0.001	8.96
34	Imbauba	Leaf	22100	-7000	-0.01	-0.1	96	-0.05	-0.1	-0.01	-0.05	15	0.16	0.1	-0.3	0.029	-0.05	-0.1	-0.005	-0.001	8.3
35	Imbauba	Leaf	21600	-6200	-0.01	0.1	81	-0.05	-0.1	-0.01	-0.05	12	0.08	0.2	-0.3	0.004	-0.05	-0.1	-0.005	-0.001	8.27
36	Imbauba	Leaf	21650	-6300	-0.01	-0.1	85	-0.05	-0.1	-0.01	-0.05	15	0.08	0.3	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.5
37	Imbauba	Leaf	20650	-6100	-0.01	-0.1	110	-0.05	-0.1	-0.01	-0.05	12	0.11	0.2	-0.3	0.005	-0.05	-0.1	0.007	0.001	8.83
38	Imbauba	Leaf	19950	-6350	0.01	-0.1	96	-0.05	-0.1	-0.01	-0.05	12	0.17	0.3	0.4	0.007	-0.05	-0.1	-0.005	-0.001	8.56
39	Imbauba	Leaf	19250	-6750	0.01	-0.1	110	-0.05	-0.1	-0.01	-0.05	9	0.08	-0.1	-0.3	0.006	-0.05	-0.1	-0.005	-0.001	7.61
40	Imbauba	Leaf	18300	-6800	0.02	0.1	120	-0.05	-0.1	-0.01	-0.05	12	0.09	0.2	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	8.62
41	Imbauba	Leaf	17600	-7600	0.02	-0.1	98	-0.05	-0.1	-0.01	-0.05	11	0.08	0.1	-0.3	0.006	-0.05	-0.1	0.014	0.002	8.54
42	Imbauba	Leaf	16250	-7900	-0.01	-0.1	66	-0.05	-0.1	-0.01	-0.05	14	0.04	0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.27
43	Imbauba	Leaf	15500	-7300	0.01	-0.1	96	-0.05	-0.1	0.02	-0.05	12	0.07	0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	8.28
44	Imbauba	Leaf	14300	-7250	0.05	-0.1	62	-0.05	0.2	0.02	-0.05	14	0.24	0.9	-0.3	0.018	-0.05	-0.1	0.017	0.004	8.45
45	Imbauba2	Leaf	14350	-6500	0.03	-0.1	86	-0.05	-0.1	-0.01	-0.05	8	0.11	0.2	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	8.71
45	Imbauba	Leaf	14350	-6500	0.05	-0.1	120	-0.05	0.1	-0.01	-0.05	12	0.25	0.5	-0.3	0.013	-0.05	-0.1	-0.005	-0.001	8.85
46	Imbauba	Leaf	14550	-5550	0.07	-0.1	88	-0.05	0.2	-0.01	-0.05	20	0.26	0.6	-0.3	0.017	-0.05	-0.1	0.023	0.002	8.32
47	Imbauba	Leaf	14500	-5300	-0.01	-0.1	71	-0.05	-0.1	-0.01	-0.05	21	0.04	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.52
49	Imbauba	Leaf	14500	-4850	0.02	-0.1	63	-0.05	-0.1	-0.01	-0.05	19	0.16	0.5	-0.3	0.009	-0.05	-0.1	0.012	-0.001	8.34
50	Imbauba	Leaf	14350	-4500	-0.01	-0.1	100	-0.05	-0.1	-0.01	-0.05	14	0.03	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.74
50	Imbauba3	Leaf	14350	-4500	-0.01	-0.1	25	-0.05	-0.1	-0.01	-0.05	12	0.03	-0.1	-0.3	0.001	-0.05	-0.1	-0.005	-0.001	8.65
51	Imbauba	Leaf	14050	-4150	0.04	-0.1	50	-0.05	0.2	-0.01	-0.05	11	0.19	0.3	-0.3	0.008	-0.05	-0.1	-0.005	-0.001	8.66
52	Imbauba	Leaf	13800	-3800	0.01	-0.1	55	-0.05	-0.1	0.03	-0.05	12	0.07	0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.94
52	Imbauba2	Leaf	13800	-3800	0.01	-0.1	79	-0.05	-0.1	-0.01	-0.05	21	0.1	0.1	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.52
53	Imbauba	Leaf	13700	-2900	0.02	-0.1	67	-0.05	-0.1	-0.01	-0.05	15	0.1	0.2	-0.3	0.006	-0.05	-0.1	-0.005	-0.001	8.83
54	Imbauba2	Leaf	13200	-2100	0.01	-0.1	46	-0.05	-0.1	-0.01	-0.05	14	0.06	-0.1	-0.3	0.004	-0.05	-0.1	-0.005	-0.001	8.76
55	Imbauba	Leaf	12350	-1200	0.01	-0.1	100	-0.05	-0.1	-0.01	-0.05	13	0.11	0.2	-0.3	0.006	-0.05	-0.1	-0.005	-0.001	8.6
56	Imbauba	Leaf	11650	-750	0.01	-0.1	59	-0.05	-0.1	-0.01	-0.05	13	0.09	0.4	-0.3	0.004	-0.05	-0.1	-0.005	-0.001	8.64
57	Imbauba	Leaf	10400	-1100	0.03	-0.1	57	-0.05	0.2	-0.01	-0.05	11	0.43	1.8	-0.3	0.021	-0.05	-0.1	-0.005	-0.001	8.62
58	Imbauba2	Leaf	9450	-1000	-0.01	-0.1	56	-0.05	0.1	-0.01	-0.05	25	0.13	0.6	-0.3	0.009	-0.05	-0.1	-0.005	-0.001	8.81
59	Imbauba2	Leaf	West of Itaituba		0.04	-0.1	22	-0.05	-0.1	0.03	-0.05	8	0.25	0.3	-0.3	0.018	-0.05	-0.1	0.009	0.002	8.64
60	Imbauba	Leaf	West of Itaituba		-0.01	-0.1	69	-0.05	-0.1	-0.01	-0.05	29	0.09	0.1	-0.3	0.004	-0.05	-0.1	0.02	0.003	8.43
16	Banana braba	Leaf	16000	-6300	-0.01	0.3	32	-0.05	-0.1	-0.01	-0.05	9	0.03	-0.1	-0.3	0.001	-0.05	-0.1	0.011	0.002	8.39
20	Banana braba	Leaf	16000	-5250	-0.01	0.2	33	-0.05	-0.1	-0.01	-0.05	9	0.03	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	7.05
21	Banana braba	Leaf	16000	-5000	-0.01	-0.1	30	-0.05	-0.1	-0.01	-0.05	12	0.04	0.2	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	6.55
22	Banana braba	Leaf	16000	-4750	-0.01	0.2	27	-0.05	-0.1	-0.01	-0.05	15	0.27	0.2	-0.3	0.022	-0.05	-0.1	0.009	0.002	8.32
23	Banana braba	Leaf	16000	-4500	-0.01	0.2	38	-0.05	-0.1	-0.01	-0.05	12	0.05	-0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	5
24	Banana braba	Leaf	6850	1200	-0.01	0.1	28	-0.05	-0.1	-0.01	-0.05	12	0.03	-0.1	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.6
25	Banana braba	Leaf	6800	1150	-0.01	-0.1	19	-0.05	-0.1	-0.01	-0.05	9	0.04	0.2	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	8.32
30	Banana braba	Leaf	14200	-6300	-0.01	0.1	26	-0.05	-0.1	-0.01	-0.05	19	0.05	0.2	-0.3	0.005	-0.05	-0.1	0.008	0.001	5.16
31	Banana braba	Leaf	24150	-6500	0.02	0.3	12	-0.05	-0.1	-0.01	-0.05	12	0.1	0.1	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	8.32
34	Banana braba	Leaf	22100	-7000	0.02	0.3	39	-0.05	-0.1	-0.01	-0.05	8	0.08	0.3	-0.3	0.008	-0.05	-0.1	-0.005	-0.001	7.42
43	Banana braba	Leaf	15500	-7300	0.02	-0.1	34	-0.05	-0.1	-0.01	-0.05	11	0.09	0.2	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	6.08
44	Banana braba	Leaf	14300	-7250	0.04	-0.1	11	-0.05	-0.1	-0.01	-0.05	14	0.2	0.3	-0.3	0.017	-0.05	-0.1	0.014	0.002	7.62
10	Anjiroba	Leaf	15000	-4100	-0.01	-0.1	41	-0.05	-0.1	-0.01	-0.05	12	0.01	-0.1	-0.3	0.001	-0.05	-0.1	-0.005	-0.001	8.33
17	Anjiroba	Leaf	16000	-6050	-0.01	-0.1	86	-0.05	-0.1	-0.01	-0.05	12	0.01	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.31
21	Anjiroba	Leaf	16000	-5000	-0.01	-0.1	70	-0.05	-0.1	-0.01	-0.05	10	0.02	-0.1	-0.3	0.001	-0.05	-0.1	-0.005	-0.001	8.48
22	Anjiroba	Leaf	16000	-4750	-0.01	0.1	120	-0.05	-0.1	-0.01	-0.05	11	0.16	-0.1	-0.3	0.008	-0.05	-0.1	0.007	0.001	8.54
24	Anjiroba	Leaf	6850	1200	-0.01	-0.1	45	-0.05	-0.1	0.03	-0.05	11	0.02	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.4
31	Anjiroba	Leaf	24150	-6500	-0.01	0.1	90	-0.05	-0.1	-0.01	-0.05	12	0.02	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.02
7	Boa macaca	Leaf	15000	-4750	-0.01	-0.1	88	-0.05	-0.1	-0.01	-0.05	7	0.03	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	6.97

Table Vegetation 1

Analytical Data for All Vegetation Samples: Determinations by INAA

Site #	Species	Tissue	Grid Coordinates Easting	Northing	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	K %	MO PPM	NA PPM	NI PPM	RB PPM	SB PPM
9	Boa macaca	Leaf	15000	-4300	0.8	-0.3	0.04	-5	22	0.55	-0.1	-0.3	0.08	-0.005	-0.05	0.06	-0.1	1.41	-0.05	39.3	-2	85	-0.005
10	Boa macaca	Leaf	15000	-4100	0.8	-0.3	0.05	-5	18	0.96	-0.1	-0.3	0.18	-0.005	-0.05	0.14	-0.1	1.17	-0.05	53	-2	69	-0.005
14	Boa macaca	Leaf	15000	-5650	1.3	-0.3	0.06	-5	77	0.84	-0.1	-0.3	0.05	-0.005	-0.05	0.09	-0.1	1.35	-0.05	64.6	-2	98	-0.005
15	Boa macaca	Leaf	15000	-6300	2.3	-0.3	0.04	40	25	0.56	0.2	-0.3	-0.05	0.006	-0.05	0.14	-0.1	1.04	-0.05	85	-2	48	0.007
17	Boa macaca	Leaf	16000	-6050	0.3	-0.3	0.05	-5	17	1.55	-0.1	-0.3	0.26	-0.005	-0.05	0.07	-0.1	0.87	-0.05	37.7	-2	50	-0.005
22	Boa macaca	Leaf	16000	-4750	0.3	-0.3	-0.01	-5	31	0.82	-0.1	-0.3	-0.05	0.005	-0.05	0.13	-0.1	1.2	-0.05	37.5	-2	72	-0.005
23	Boa macaca	Leaf	16000	-4500	0.2	-0.3	0.02	9	13	1.69	0.2	-0.3	0.06	0.005	-0.05	0.14	-0.1	0.759	-0.05	35.1	-2	28	-0.005
31	Boa macaca	Leaf	24150	-6500	0.4	-0.3	0.02	40	3.4	1.24	-0.1	-0.3	-0.05	-0.005	-0.05	0.21	0.1	0.547	-0.05	68.4	-2	17	-0.005
43	Boa macaca	Leaf	15500	-7300	0.4	-0.3	0.02	26	6.3	0.99	0.1	-0.3	-0.05	0.01	-0.05	0.1	-0.1	0.618	-0.05	44.4	-2	26	-0.005
59	Boa macaca	Leaf	West of Itaituba		0.6	-0.3	0.04	-5	18	0.33	-0.1	0.4	0.3	0.018	-0.05	0.07	-0.1	0.411	-0.05	253	-2	10	-0.005
10	Costela de vaca	Leaf	15000	-4100	0.5	-0.3	-0.01	-5	0.58	0.08	-0.1	-0.3	0.05	-0.005	-0.05	0.04	-0.1	0.508	0.06	49	-2	41	-0.005
16	Costela de vaca	Leaf	16000	-6300	0.4	-0.3	-0.01	-5	0.91	0.12	-0.1	-0.3	-0.05	-0.005	-0.05	0.05	-0.1	0.445	0.06	42.4	-2	19	-0.005
20	Costela de vaca	Leaf	16000	-5250	0.4	-0.3	0.02	6	0.7	0.13	-0.1	0.4	-0.05	-0.005	-0.05	0.07	-0.1	0.386	0.11	43.9	-2	13	-0.005
30	Costela de vaca	Leaf	14200	-6300	0.5	-0.3	-0.01	10	0.44	0.18	-0.1	-0.3	-0.05	-0.005	-0.05	0.05	-0.1	0.361	-0.05	49.2	-2	12	-0.005
59	Costela de vaca	Leaf	West of Itaituba		0.5	-0.3	0.02	-5	0.86	0.14	-0.1	0.5	0.15	0.016	0.07	0.01	-0.1	0.446	0.14	79.7	-2	8	0.005
61	Costela de vaca	Leaf	West of Itaituba		0.9	-0.3	0.01	-5	2	0.25	-0.1	-0.3	0.34	0.006	-0.05	0.04	-0.1	0.334	0.12	115	-2	9	0.008
6	Caapeba	Leaf	15000	-4900	1.1	-0.3	-0.01	38	21	1	-0.1	-0.3	-0.05	0.008	-0.05	0.02	-0.1	3.78	0.29	43.4	-2	110	-0.005
15	Caapeba	Leaf	15000	-6300	1.6	-0.3	-0.02	240	62	1.02	-0.1	-0.3	0.07	0.009	-0.05	0.02	-0.1	5.41	0.18	72.1	-2	170	-0.005
1	Jurubeba	Leaf	15200	-4600	0.3	-0.3	0.03	28	30	1.1	1.4	0.8	0.17	0.006	-0.05	0.09	-0.1	2.23	0.66	38	-2	120	-0.005
7	Peruana	Leaf	15000	-4750	1.8	-0.3	0.03	-5	2.3	0.27	-0.1	-0.3	0.05	-0.005	-0.05	0.05	-0.1	0.507	-0.05	43	-2	29	-0.005
8	Peruana	Leaf	15000	-4500	0.3	-0.3	-0.02	8	33	0.22	0.1	-0.3	0.28	-0.005	-0.05	0.09	-0.1	2.03	-0.05	40.4	-2	110	0.008
10	Peruana	Leaf	15000	-4100	1.8	-0.3	0.02	7	11	0.88	-0.1	0.5	0.09	0.005	-0.05	0.11	-0.1	1.68	-0.05	65.6	-2	99	0.008
31	Peruana	Leaf	24150	-6500	-0.1	-0.3	-0.02	29	120	0.31	-0.1	-0.3	-0.05	-0.005	-0.05	0.18	-0.1	1.71	-0.05	52.1	-2	40	-0.005
31	Peruana2	Leaf	24150	-6500	0.9	-0.3	-0.01	17	44	0.85	-0.1	-0.3	-0.05	-0.005	-0.05	0.34	-0.1	1.57	-0.05	75.9	-2	36	0.007
16	Acacia	Tw + Leaf	16000	-6300	0.1	-0.3	-0.01	17	18	0.53	-0.1	-0.3	0.05	0.006	-0.05	0.05	-0.1	1.16	-0.05	35.4	-2	48	-0.005
24	Acacia	Leaf	6850	1200	1	-0.3	-0.05	-5	200	0.35	-0.1	-0.3	0.21	0.007	-0.05	0.09	-0.1	1.2	-0.05	35.5	-2	81	-0.005
24	Acacia	Twig	6850	1200	0.6	-0.3	-0.05	-5	170	0.35	-0.1	-0.3	0.16	0.005	-0.05	-0.01	-0.1	1.3	-0.05	35.9	-2	80	-0.005
	Manioc	Leaf	8000	700	4.3	-0.3	0.02	-5	14	1.1	-0.1	-0.3	-0.05	0.008	-0.05	0.04	-0.1	1.84	0.68	87	-2	45	-0.005
6	Jurubeba	Leaf	15000	-4900	-0.1	-0.3	-0.02	79	140	0.72	-0.1	0.5	0.11	0.008	-0.05	0.05	-0.1	2.28	0.26	57.4	-2	73	-0.005
40	Fern	All	18300	-6800	0.3	-0.3	-0.02	110	1.2	-0.02	-0.1	0.7	-0.05	0.007	-0.05	-0.01	-0.1	1.05	-0.05	100	-2	28	-0.005
25	Castanha do Para	Leaf	6800	1150	0.4	-0.3	-0.02	150	130	0.56	2.3	-0.3	0.51	0.005	-0.05	0.03	-0.1	0.903	-0.05	39.1	-2	61	-0.005
14	Negramina	Leaf	15000	-5700	2.4	-0.3	-0.02	26	99	1.26	-0.1	-0.3	-0.05	-0.005	-0.05	0.08	-0.1	1.35	-0.05	75.3	-2	57	-0.005
15	Negramina	Leaf	15000	-6250	0.6	-0.3	-0.02	130	130	1.2	-0.1	-0.3	-0.05	0.006	-0.05	0.07	-0.1	1.03	0.18	54.6	-2	32	-0.005
23	Negramina	Leaf	16000	-4500	0.6	-0.3	-0.02	42	67	1.06	-0.1	-0.3	0.07	-0.005	-0.05	0.11	-0.1	1.66	0.1	44.6	-2	100	-0.005
8	Café brabo	Leaf	15000	-4500	1.2	-0.3	-0.02	10	11	1.62	-0.1	0.4	0.13	0.007	-0.05	0.12	-0.1	1.06	-0.05	55.6	-2	59	0.011
9	Café brabo	Leaf	15000	-5700	1.8	-0.3	0.02	14	13	1.27	-0.1	1.8	0.07	0.007	-0.05	0.07	-0.1	1.69	-0.05	59.4	-2	79	0.013
10	Café brabo	Leaf	15000	-4100	1.6	-0.3	-0.01	7	9.3	1.22	-0.1	0.8	0.08	0.005	-0.05	0.13	-0.1	1.31	-0.05	52.7	-2	84	0.014
17	Café brabo	Leaf	16000	-6050	1.4	-0.3	-0.01	11	3.2	1.29	-0.1	0.7	0.14	0.006	-0.05	0.06	-0.1	1.25	-0.05	56.7	2	70	0.009
18	Café brabo	Leaf	16000	-5800	0.8	-0.3	-0.01	9	4.4	1.08	-0.1	0.4	-0.05	0.005	-0.05	0.09	-0.1	1.43	-0.05	51.6	-2	55	0.014
19	Café brabo	Leaf	16000	-5500	1.3	-0.3	-0.01	11	4.3	1.13	-0.1	-0.3	0.05	-0.005	-0.05	0.08	-0.1	1.01	-0.05	53.5	-2	49	0.006
24	Café brabo	Leaf	6850	1200	0.7	-0.3	-0.01	-5	7.4	0.89	-0.1	-0.3	0.15	-0.005	-0.05	0.07	-0.1	1.09	-0.05	40.8	-2	52	0.009
31	Muirapiranga	Leaf	24150	-6500	0.9	-0.3	-0.02	-5	17	0.26	-0.1	-0.3	-0.05	-0.005	-0.05	0.15	-0.1	0.5	-0.05	53	-2	12	0.012
	Papaya	Leaf	7700	0	63.4	-0.3	0.28	19	6.7	3.41	-0.1	0.4	0.07	0.067	0.13	0.37	-0.1	2.8	0.25	292	2	61	0.017
1	Vassoura de Botao	All	15200	-4600	2.3	-0.3	-0.03	15	38	0.52	1.5	0.5	0.22	-0.005	-0.05	0.16	-0.1	1.19	-0.05	170	-2	60	0.015
2	Vassoura de Botao	All	15200	-4730	542	-0.3	4.5	15	65	0.31	0.9	0.7	0.17	0.106	0.06	4.6	-0.1	0.943	-0.05	173	-2	46	0.01
3	Vassoura de Botao	All	15250	-4780	206	-0.3	1.3	18	68	0.28	1.2	0.9	0.43	0.083	0.27	1.7	-0.1	1.49	-0.05	170	-2	39	0.014
4	Vassoura de Botao	All	15230	-4800	4.7	-0.3	0.29	20	36	0.59	0.3	-0.3	0.11	0.006	-0.05	0.24	-0.1	1.39	0.1	216	2	38	0.008
5	Vassoura de Botao	All	15300	-4850	1.2	-0.3	-0.02	13	29	0.44	0.5	0.4	0.33	0.005	-0.05	0.15	-0.1	1.67	0.1	254	-2	52	0.012
6	Vassoura de Botao	All	15000	-4900	3.4	-0.3	-0.02	6	250	0.45	-0.1	-0.3	0.08	-0.005	-0.05	0.06	-0.1	0.995	-0.05	96	-2	70	-0.005
11	Vassoura de Botao	All	15000	-5050	3.8	-0.3	-0.02	-5	56	0.54	-0.1	-0.3	0.07	-0.005	-0.05	-0.01	-0.1	1.21	0.32	80.7	-2	45	0.009
12	Vassoura de Botao	All	15000	-5250	2.1	-0.3	-0.02	11	80	0.73	-0.1	-0.3	0.07	0.006	-0.05	-0.01	-0.1	1.15	0.1	81.1	-2	33	0.013
13	Vassoura de Botao	All	15000	-5500	3.3	-0.3	-0.02	26	44	0.54	4.8	-0.3	0.26	-0.005	-0.05	0.05	-0.1	0.958	-0.05	57.1	-2	71	0.022
15	Vassoura de Botao	All	15000	-6250	1.4	-0.3	-0.02	490	95	1.04	0.1	-0.3	-0.05	0.006	-0.05	-0.01	-0.1	1.55	0.16	172	-2	43	-0.005
25	Vassoura de Botao	All	6800	1150	0.5	-0.3	-0.02	18	1400	0.52	0.2	0.3	0.17	0.029	0.11	-0.01	-0.1	2.2	-0.05	202	-2	34	-0.005
26	Vassoura de Botao	All	6800	950	0.8	-0.3	-0.02	180	6.2	0.76	0.4	-0.3	0.23	0.01	-0.05	0.07	-0.1	1.03	0.15	763	-2	56	0.01
27	Vassoura de Botao	All	6750	850	0.6	-0.3	-0.02	64	13	0.61	0.3	-0.3	0.23	-0.005	-0.05	0.05	-0.1	1.1	0.09	409	-2	34	0.01
28	Vassoura de Botao	All	6700	800	0.6	-0.3	-0.02	15	40	0.5	-0.1	-0.3	0.29	0.006	-0.05	0.12	-0.1	1.6	0.14	748	-2	38	0.013
29	Vassoura de Botao	All	14100	-6400	3.8	-0.3	-0.02	40	95	0.51	0.4	-0.3	0.11	0.01	-0.05	0.45	-0.1	1.28	-0.05	534	-2	51	0.009
32	Vassoura de Botao	All	24000	-7300	1	-0.3	-0.02	28	46	0.62	0.2	-0.3	-0.05	0.013	-0.05	0.06	-0.1	0.929	0.13	193	-2	15	-0.005
37	Vassoura de Botao	All	20650	-6100	0.7	-0.3	-0.02	49	7.7	0.65	-0.1	-0.3	-0.05	0.016	-0.05	0.03	-0.1	1.14	0.13	59.6	-2	25	0.007
38	Vassoura de Botao	All	19950	-6350	0.8	-0.3	-0.01	18	7.2	0.88	-0.1	0.6	-0.05	0.035	0.05	-0.01	-0.1	1.52	0.59	130	-2	35	0.009
41	Vassoura de Botao	All	17600	-7600	1.1	-0.3	-0.01	16	14	0.74	-0.1	0.9	-0.05	0.05	0.06	0.08	-0.1	1.44	0.16	49.2	-2	30	0.011
43	Vassoura de Botao	All	15500	-7300	0.7	-0.3	-0.01	36	29	0.54	0.2	0.4	0.05	0.036	0.05	-0.01	-0.1	1.26	-0.05	102	-2	45	0.013
46	Vassoura de Botao	All	14550	-5550	1.1	-0.3	-0.02	7	67	0.74	0.1	-0.3	-0.05	0.015	-0.05	0.08	-0.1	1.35	0.2	72.9	-2	47	0.014
47	Vassoura de Botao	All	14500	-5300	1.4	-0.3	-0.02	15	29	0.51	0.2	-0.3	0.11	0.015	-0.05	-0.01	-0.1	1.15	0.13	109	-2	33	0.012

Table Vegetation 1

Analytical Data for All Vegetation Samples: Determinations by INAA

Site #	Species	Tissue	Grid Coordinates Easting	Northing	SC PPM	SE PPM	SR PPM	TA PPM	TH PPM	U PPM	W PPM	ZN PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM	YB PPM	LU PPM	Mass g
9	Boa macaca	Leaf	15000	-4300	-0.01	-0.1	56	-0.05	-0.1	-0.01	-0.05	10	0.02	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	7.96
10	Boa macaca	Leaf	15000	-4100	-0.01	0.1	100	-0.05	-0.1	-0.01	-0.05	9	0.04	-0.1	-0.3	0.004	-0.05	-0.1	-0.005	-0.001	8.75
14	Boa macaca	Leaf	15000	-5650	-0.01	-0.1	53	-0.05	-0.1	0.03	-0.05	15	0.02	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.44
15	Boa macaca	Leaf	15000	-6300	0.01	0.2	76	-0.05	-0.1	-0.01	-0.05	14	0.06	-0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	8.37
17	Boa macaca	Leaf	16000	-6050	-0.01	-0.1	78	-0.05	-0.1	-0.01	-0.05	9	0.03	-0.1	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.62
22	Boa macaca	Leaf	16000	-4750	-0.01	0.2	37	-0.05	-0.1	-0.01	-0.05	12	0.06	0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	8.49
23	Boa macaca	Leaf	16000	-4500	0.01	-0.1	90	-0.05	-0.1	-0.01	-0.05	7	0.05	-0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	8.58
31	Boa macaca	Leaf	24150	-6500	-0.01	-0.1	190	-0.05	-0.1	-0.01	-0.05	9	0.05	-0.1	-0.3	0.005	-0.05	-0.1	0.005	-0.001	8.06
43	Boa macaca	Leaf	15500	-7300	0.03	-0.1	180	-0.05	-0.1	-0.01	-0.05	6	0.08	0.1	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	8.35
59	Boa macaca	Leaf	West of Itaituba		0.05	0.3	14	-0.05	-0.1	-0.01	-0.05	7	0.25	0.3	-0.3	0.023	-0.05	-0.1	0.012	0.002	8.79
10	Costela de vaca	Leaf	15000	-4100	-0.01	0.3	-10	-0.05	-0.1	-0.01	-0.05	5	0.02	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.48
16	Costela de vaca	Leaf	16000	-6300	-0.01	0.3	11	-0.05	-0.1	-0.01	-0.05	6	0.02	-0.1	-0.3	0.001	-0.05	-0.1	-0.005	-0.001	8.43
20	Costela de vaca	Leaf	16000	-5250	-0.01	0.3	16	-0.05	-0.1	-0.01	-0.05	5	0.02	-0.1	-0.3	0.001	-0.05	-0.1	-0.005	-0.001	8.37
30	Costela de vaca	Leaf	14200	-6300	-0.01	0.1	23	-0.05	-0.1	-0.01	-0.05	4	0.04	0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.5
59	Costela de vaca	Leaf	West of Itaituba		0.06	0.1	-10	-0.05	0.1	0.02	-0.05	7	0.33	0.4	-0.3	0.03	-0.05	-0.1	0.016	0.002	5.12
61	Costela de vaca	Leaf	West of Itaituba		0.01	0.2	-10	-0.05	-0.1	0.01	-0.05	7	0.06	-0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	6.94
6	Caapeba	Leaf	15000	-4900	-0.01	-0.1	110	-0.05	-0.1	-0.01	-0.05	31	0.09	-0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	6.96
15	Caapeba	Leaf	15000	-6300	-0.01	0.1	190	-0.05	-0.1	-0.01	-0.05	34	0.59	1.9	-0.3	0.019	-0.05	-0.1	0.01	0.001	8.2
1	Jurubeba	Leaf	15200	-4600	-0.01	0.1	56	-0.05	-0.1	-0.01	-0.05	230	1.6	0.7	-0.3	0.11	-0.05	-0.1	0.028	0.004	8.37
7	Peruana	Leaf	15000	-4750	0.02	-0.1	38	-0.05	-0.1	-0.01	-0.05	7	0.02	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.75
8	Peruana	Leaf	15000	-4500	-0.01	0.1	33	-0.05	-0.1	-0.01	-0.05	12	0.02	-0.1	-0.3	0.002	-0.05	-0.1	0.007	0.001	8.49
10	Peruana	Leaf	15000	-4100	0.11	0.2	280	-0.05	-0.1	-0.01	-0.05	10	0.04	0.3	-0.3	0.009	-0.05	-0.1	0.012	0.002	6.31
31	Peruana	Leaf	24150	-6500	-0.01	0.1	88	-0.05	-0.1	0.02	-0.05	10	0.03	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.64
31	Peruana2	Leaf	24150	-6500	-0.01	-0.1	210	-0.05	-0.1	-0.01	-0.05	14	0.04	0.2	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.53
16	Acacia	Tw + Leaf	16000	-6300	-0.01	-0.1	79	-0.05	-0.1	-0.01	-0.05	13	0.02	-0.1	-0.3	-0.001	-0.05	-0.1	-0.005	-0.001	8.26
24	Acacia	Leaf	6850	1200	-0.01	-0.1	27	-0.05	-0.1	-0.01	-0.05	21	-0.01	0.2	-0.3	-0.001	-0.05	-0.1	-0.007	0.006	7.99
24	Acacia	Twig	6850	1200	-0.01	-0.1	35	-0.05	-0.1	-0.01	-0.05	14	0.03	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.49
	Manioc	Leaf	8000	700	-0.01	0.6	59	-0.05	-0.1	0.02	-0.05	51	0.17	0.5	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	8.48
6	Jurubeba	Leaf	15000	-4900	-0.01	0.2	81	-0.05	-0.1	-0.01	-0.05	23	0.3	0.5	-0.3	0.019	-0.05	-0.1	-0.005	-0.001	5.96
40	Fern	All	18300	-6800	0.06	-0.1	10	-0.05	-0.1	-0.01	-0.05	9	37	97	24	3.4	0.19	0.1	0.201	0.034	8.17
25	Castanha do Para	Leaf	6800	1150	-0.01	-0.1	140	-0.05	-0.1	-0.01	-0.05	15	0.05	0.2	-0.3	0.006	-0.05	-0.1	0.026	0.003	8.44
14	Negramina	Leaf	15000	-5700	-0.01	-0.1	160	-0.05	0.2	-0.01	-0.05	15	0.07	0.2	-0.3	0.013	-0.05	-0.1	-0.005	0.003	8.38
15	Negramina	Leaf	15000	-6250	0.02	-0.1	190	-0.05	-0.1	-0.01	-0.05	9	0.13	0.4	-0.3	0.017	-0.05	-0.1	0.019	-0.001	8.67
23	Negramina	Leaf	16000	-4500	-0.01	-0.1	140	-0.05	-0.1	-0.01	-0.05	10	0.04	-0.1	-0.3	0.006	-0.05	-0.1	-0.005	-0.001	8.02
8	Café brabo	Leaf	15000	-4500	0.12	0.3	420	-0.05	-0.1	-0.01	-0.05	14	0.1	0.4	-0.3	0.013	-0.05	-0.1	0.018	0.002	8.74
9	Café brabo	Leaf	15000	-5700	0.04	0.1	270	-0.05	-0.1	-0.01	0.09	13	0.14	0.4	-0.3	0.015	-0.05	-0.1	0.019	0.003	8.21
10	Café brabo	Leaf	15000	-4100	0.13	0.3	290	-0.05	0.1	-0.01	-0.05	11	0.06	0.5	-0.3	0.009	-0.05	-0.1	0.02	0.003	8.5
17	Café brabo	Leaf	16000	-6050	0.13	0.3	250	-0.05	-0.1	-0.01	-0.05	15	0.13	0.5	-0.3	0.015	-0.05	-0.1	0.014	0.002	8.39
18	Café brabo	Leaf	16000	-5800	0.04	0.3	260	-0.05	0.1	0.02	-0.05	14	0.09	0.4	-0.3	0.01	-0.05	-0.1	0.015	0.002	8.24
19	Café brabo	Leaf	16000	-5500	0.02	0.2	230	-0.05	-0.1	-0.01	-0.05	14	0.09	0.3	-0.3	0.01	-0.05	-0.1	0.006	-0.001	8.26
24	Café brabo	Leaf	6850	1200	0.17	0.1	150	-0.05	-0.1	-0.01	-0.05	11	0.04	0.2	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.61
31	Muirapiranga	Leaf	24150	-6500	-0.01	0.2	21	-0.05	-0.1	-0.01	-0.05	13	0.02	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.19
	Papaya	Leaf	7700	0	0.21	-0.1	130	-0.05	0.7	0.11	0.14	23	1.5	4.3	0.6	0.075	-0.05	-0.1	0.027	0.004	8.04
1	Vassoura de Botao	All	15200	-4600	0.05	-0.1	-10	-0.05	-0.1	0.41	-0.05	330	8.1	5.3	6	0.83	0.08	-0.1	0.213	0.031	8.01
2	Vassoura de Botao	All	15200	-4730	0.19	-0.1	-10	-0.05	0.2	1.4	-0.05	45	8.8	3	6.5	1.1	0.09	0.1	0.388	0.065	8.4
3	Vassoura de Botao	All	15250	-4780	0.28	0.2	21	0.12	0.7	0.35	-0.05	74	3.4	6.2	1.9	0.28	-0.05	-0.1	0.257	0.04	8.14
4	Vassoura de Botao	All	15230	-4800	0.02	-0.1	43	-0.05	-0.1	-0.01	-0.05	89	1	1.3	0.5	0.07	-0.05	-0.1	0.03	0.004	8.46
5	Vassoura de Botao	All	15300	-4850	0.05	-0.1	36	-0.05	-0.1	-0.01	-0.05	110	1.5	3.2	0.6	0.091	-0.05	-0.1	-0.005	-0.001	8.15
6	Vassoura de Botao	All	15000	-4900	-0.01	0.1	71	-0.05	-0.1	-0.01	0.22	24	0.84	0.9	0.6	0.026	-0.05	-0.1	-0.005	-0.001	8.26
11	Vassoura de Botao	All	15000	-5050	-0.01	-0.1	47	-0.05	-0.1	-0.01	-0.05	31	0.49	1.6	-0.3	0.028	-0.05	-0.1	-0.005	-0.001	8.21
12	Vassoura de Botao	All	15000	-5250	0.02	-0.1	71	-0.05	-0.1	0.04	-0.05	23	1.5	4.1	0.6	0.048	-0.05	-0.1	-0.005	-0.001	8.16
13	Vassoura de Botao	All	15000	-5500	0.06	0.2	-10	-0.05	-0.1	0.36	-0.05	510	8.2	6.3	2.7	0.34	-0.05	-0.1	0.094	0.014	8.36
15	Vassoura de Botao	All	15000	-6250	0.11	-0.1	200	-0.05	-0.1	-0.01	-0.05	25	4.7	10	1.9	0.27	-0.05	-0.1	0.06	0.008	8.43
25	Vassoura de Botao	All	6800	1150	0.12	-0.1	65	-0.05	0.2	-0.01	-0.05	29	1.7	5.7	0.8	0.005	-0.05	-0.1	-0.005	-0.001	8.53
26	Vassoura de Botao	All	6800	950	0.04	-0.1	78	-0.05	-0.1	-0.01	-0.05	50	5.9	10	2.1	0.21	-0.05	-0.1	0.056	0.01	8.24
27	Vassoura de Botao	All	6750	850	0.04	-0.1	61	-0.05	-0.1	-0.01	-0.05	30	5.8	7.4	2.1	0.25	-0.05	-0.1	0.1	0.015	8.33
28	Vassoura de Botao	All	6700	800	0.04	-0.1	44	-0.05	-0.1	-0.01	-0.05	28	0.71	1.8	0.4	0.025	-0.05	-0.1	0.012	0.002	8.37
29	Vassoura de Botao	All	14100	-6400	0.07	0.2	42	-0.05	-0.1	-0.01	-0.05	34	4.4	11	2.6	0.29	-0.05	-0.1	0.061	0.01	8.2
32	Vassoura de Botao	All	24000	-7300	0.04	0.2	62	-0.05	0.1	0.02	-0.05	34	0.91	4	0.4	0.04	-0.05	-0.1	-0.005	-0.001	8.17
37	Vassoura de Botao	All	20650	-6100	0.05	-0.1	80	-0.05	0.3	0.02	-0.05	24	1.7	8.8	0.5	0.062	-0.05	-0.1	0.012	0.002	8.06
38	Vassoura de Botao	All	19950	-6350	0.07	-0.1	47	-0.05	0.3	0.03	-0.05	50	3.7	7	1.1	0.15	-0.05	-0.1	0.021	0.003	8.07
41	Vassoura de Botao	All	17600	-7600	0.1	-0.1	50	-0.05	0.3	0.03	-0.05	31	1.5	5.6	0.6	0.083	-0.05	-0.1	0.023	0.004	8.2
43	Vassoura de Botao	All	15500	-7300	0.09	-0.1	60	-0.05	0.2	-0.01	-0.05	48	5	7.9	1.9	0.21	-0.05	-0.1	0.04	0.006	8.26
46	Vassoura de Botao	All	14550	-5550	0.08	-0.1	66	-0.05	0.1	-0.01	-0.05	30	2.4	8.2	1.3	0.18	-0.05	-0.1	0.035	0.005	8.06
47	Vassoura de Botao	All	14500	-5300	0.08	-0.1	38	-0.05	0.2	-0.01	-0.05	32	2.2	4.8	1.1	0.15	-0.05	-0.1	0.034	0.005	8.47

Table Vegetation 1

Analytical Data for All Vegetation Samples: Determinations by INAA

Site #	Species	Tissue	Grid Coordinates Easting	Northing	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	K %	MO PPM	NA PPM	NI PPM	RB PPM	SB PPM
48	Vassoura de Botao	All	14500	-5100	0.3	-0.3	0.05	8	60	0.57	-0.1	-0.3	0.06	0.01	-0.05	0.02	-0.1	1.39	0.25	206	-2	54	0.017
49	Vassoura de Botao	All	14500	-4850	0.4	-0.3	0.16	34	53	0.77	0.1	-0.3	0.18	0.009	-0.05	-0.01	-0.1	1.17	0.28	108	-2	52	0.014
52	Vassoura de Botao	All	13800	-3800	-0.1	-0.3	-0.02	26	480	0.52	0.3	0.3	0.37	0.045	0.07	-0.01	-0.1	1.45	-0.05	400	-2	57	0.015
53	Vassoura de Botao	All	13700	-2900	-0.1	-0.3	-0.02	340	100	0.46	-0.1	-0.3	0.06	0.006	-0.05	-0.01	-0.1	1.12	0.1	71.8	-2	71	0.008
59	Vassoura de Botao	All	West of Itaituba		0.6	-0.3	-0.02	17	130	0.44	0.1	1.7	0.35	0.065	0.28	0.04	-0.1	1.03	0.1	495	-2	23	0.024
24	Tauari	Bark	6850	1200	0.4	-0.3	-0.02	28	7.5	0.77	-0.1	-0.3	-0.05	0.036	0.13	0.08	-0.1	0.121	0.09	47.8	-2	5	0.008
31	Atameju	Bark	24150	-6500	-0.1	-0.3	-0.02	10	17	0.58	-0.1	-0.3	-0.05	0.006	-0.05	0.1	-0.1	0.119	-0.05	38.8	-2	4	0.008
31	Tauari	Bark	24150	-6500	0.3	-0.3	-0.02	280	36	2.37	-0.1	-0.3	-0.05	0.013	0.1	0.1	-0.1	0.17	0.06	46.5	-2	5	0.007
31	Muirapiranga	Bark	24150	-6500	22.1	-0.3	0.12	9	20	0.1	0.1	1	-0.05	0.063	0.24	0.07	-0.1	0.057	0.08	56.2	-2	3	0.01
31	Macaranduba	Bark(back)	24150	-6500	2.1	-0.3	0.15	60	22	0.98	0.2	0.9	0.1	0.153	0.91	0.13	-0.1	0.139	-0.05	49.4	-2	7	0.022
31	Macaranduba	Bark(front	24150	-6500	0.5	-0.3	0.14	32	20	0.75	-0.1	0.5	-0.05	0.023	0.15	0.17	-0.1	0.092	0.13	40.6	-2	3	0.012
31	Cachimbeira	Bark	24150	-6500	0.7	-0.3	0.15	26	19	0.91	-0.1	0.8	-0.05	0.05	0.26	0.24	-0.1	0.055	0.09	38.1	-2	2	0.015
31	Castanha do Para	Bark	24150	-6500	5	-0.3	0.25	960	16	0.41	1.1	1.9	0.1	0.204	0.92	0.21	-0.1	0.123	-0.05	45	-2	5	0.013
31	Envireira	Bark	24150	-6500	2.1	-0.3	-0.02	11	15	0.02	-0.1	0.3	-0.05	0.014	0.07	0.23	-0.1	0.075	-0.05	48	-2	1	0.009
20	Macaranduba	Bark	16000	-5250	0.2	-0.3	-0.02	16	32	0.31	0.2	1	0.26	0.121	0.44	0.15	-0.1	0.074	-0.05	44.2	-2	5	0.015
59	Macaranduba	Bark	West of Itaituba		0.3	-0.3	0.28	22	52	0.25	0.2	6	0.25	0.144	1.7	0.02	-0.1	0.051	-0.05	44	-2	1	0.057
59	Atameju	Bark	West of Itaituba		0.3	-0.3	-0.02	-5	8.8	0.4	-0.1	0.5	-0.05	0.017	-0.05	0.05	-0.1	0.069	-0.05	34.3	-2	2	0.014
61	Castanha do Para	Barl	West of Itaituba		0.3	-0.3	-0.01	66	3.3	0.48	-0.1	0.9	0.18	0.031	0.35	-0.01	-0.1	0.04	-0.05	49.6	-2	2	0.013
61	Cachimbeira	Bark	West of Itaituba		0.8	-0.3	-0.02	8	17	3.13	-0.1	1.1	0.14	0.048	0.46	0.11	-0.1	0.061	-0.05	98.8	-2	2	0.015

<u>Table Vegetation 1</u>
Analytical Data for All Vegetation Samples:
Determinations by INAA

Site #	Species	Tissue	Grid Coordinates Easting	Grid Coordinates Northing	SC PPM	SE PPM	SR PPM	TA PPM	TH PPM	U PPM	W PPM	ZN PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM	YB PPM	LU PPM	Mass g
48	Vassoura de Botao	All	14500	-5100	0.03	0.3	41	-0.05	0.2	-0.01	-0.05	27	3.4	4.3	1.4	0.18	-0.05	-0.1	0.031	0.004	8.1
49	Vassoura de Botao	All	14500	-4850	0.03	0.2	50	-0.05	-0.1	-0.01	-0.05	37	1.6	8	-0.3	0.057	-0.05	-0.1	0.01	0.002	8.02
52	Vassoura de Botao	All	13800	-3800	0.13	-0.1	44	-0.05	0.3	-0.01	-0.05	36	2.1	3.6	0.7	0.075	-0.05	-0.1	-0.005	-0.001	8.15
53	Vassoura de Botao	All	13700	-2900	0.02	0.2	55	-0.05	-0.1	-0.01	-0.05	22	0.49	1.6	-0.3	0.033	-0.05	-0.1	-0.005	-0.001	8.36
59	Vassoura de Botao	All	West of Itaituba		0.17	-0.1	16	-0.05	0.3	-0.01	-0.05	23	1.5	1.7	0.6	0.086	-0.05	-0.1	0.055	0.008	8.13
24	Tauari	Bark	6850	1200	0.12	0.1	68	-0.05	0.2	0.04	-0.05	4	0.53	0.6	-0.3	0.041	-0.05	-0.1	0.015	0.002	8.71
31	Atameju	Bark	24150	-6500	0.02	0.3	99	-0.05	-0.1	-0.01	-0.05	3	0.09	0.3	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	8.13
31	Tauari	Bark	24150	-6500	0.04	0.2	160	-0.05	0.2	0.02	-0.05	6	0.34	0.9	-0.3	0.017	-0.05	-0.1	0.013	0.002	8.37
31	Muirapiranga	Bark	24150	-6500	0.17	0.4	19	-0.05	0.9	0.08	-0.05	6	1.1	2.5	-0.3	0.064	-0.05	-0.1	0.031	0.006	8.12
31	Macaranduba	Bark(back)	24150	-6500	0.41	0.3	140	0.11	2.1	0.22	-0.05	8	3.3	4.4	1.1	0.18	-0.05	-0.1	0.093	0.017	8.15
31	Macaranduba	Bark(front	24150	-6500	0.06	0.2	140	-0.05	0.2	-0.01	-0.05	3	0.38	0.9	-0.3	0.023	-0.05	-0.1	0.013	0.002	8.19
31	Cachimbeira	Bark	24150	-6500	0.18	0.4	59	-0.05	0.6	-0.01	-0.05	6	0.9	1.4	0.3	0.055	-0.05	-0.1	0.047	0.007	8.21
31	Castanha do Para	Bark	24150	-6500	0.58	0.2	58	0.08	3.9	0.27	-0.05	22	3.6	11	1.5	0.21	-0.05	-0.1	0.11	0.017	8.2
31	Envireira	Bark	24150	-6500	0.04	0.2	-10	-0.05	0.2	-0.01	-0.05	3	0.24	0.5	-0.3	0.016	-0.05	-0.1	0.012	0.002	8.27
20	Macaranduba	Bark	16000	-5250	0.44	0.3	35	0.14	2	0.44	-0.05	6	1.7	2.9	0.6	0.12	-0.05	-0.1	0.194	0.036	8.03
59	Macaranduba	Bark	West of Itaituba		0.75	0.3	22	0.19	1.7	0.29	-0.05	7	5.3	5.9	2.2	0.41	0.08	-0.1	0.389	0.068	8.55
59	Atameju	Bark	West of Itaituba		0.03	0.1	-10	-0.05	-0.1	-0.01	-0.05	2	0.2	0.3	-0.3	0.015	-0.05	-0.1	0.012	0.002	8.1
61	Castanha do Para	Barl	West of Itaituba		0.11	-0.1	21	-0.05	0.2	0.06	-0.05	2	0.73	0.9	0.4	0.062	-0.05	-0.1	0.06	0.011	8.38
61	Cachimbeira	Bark	West of Itaituba		0.15	0.5	15	-0.05	0.3	0.07	-0.05	4	0.94	1.2	0.4	0.081	-0.05	-0.1	0.077	0.012	8.1

Table Vegetation 1
Analytical Data for All Vegetation Samples: Determinations by INAA

Standard V6

"Element"	AU	AG	AS	BA	BR	CA	CO	CR	CS	FE	HF	HG	IR	K	MO	NA	NI	RB	SB	SC	SE
"Units"	PPB	PPM	PPM	PPM	PPM	%	PPM	PPM	PPM	%	PPM	PPM	PPB	%	PPM	PPM	PPM	PPM	PPM	PPM	PPM
CD98/D8	0.9	-0.3	0.36	18	2.2	0.64	0.3	3	-0.05	0.073	0.2	0.04	-0.1	0.131	0.13	401	-2	2	0.039	0.18	-0.1
CD98/D26	0.8	-0.3	0.39	19	2.5	0.67	0.4	3.4	-0.05	0.08	0.23	0.03	-0.1	0.132	0.16	438	-2	2	0.043	0.2	0.1
CD98/D48	0.5	-0.3	0.44	19	2.5	0.7	0.3	3.2	-0.05	0.08	0.22	0.04	-0.1	0.127	0.14	432	-2	2	0.041	0.2	-0.1
CD98/D70	0.6	-0.3	0.35	20	2.3	0.68	0.4	3.2	-0.05	0.076	0.22	0.04	-0.1	0.131	0.15	426	-2	2	0.042	0.2	-0.1
CD98/D93	0.5	-0.3	0.35	19	2.2	0.65	0.3	3.1	-0.05	0.073	0.21	0.04	-0.1	0.136	0.19	402	-2	2	0.043	0.18	0.2
CD98/112	0.6	-0.3	0.38	20	2.5	0.7	0.4	3.3	-0.05	0.08	0.21	0.05	-0.1	0.139	0.17	439	2	2	0.044	0.21	-0.1
CD98/124	1	-0.3	0.34	18	2	0.58	0.3	2.7	-0.05	0.072	0.18	0.11	-0.1	0.109	0.21	387	-2	2	0.044	0.17	-0.1
CD98/145	1	-0.3	0.36	18	2.2	0.64	0.3	2.9	-0.05	0.073	0.2	0.05	-0.1	0.126	0.18	413	3	2	0.047	0.18	0.1
CD98/169	0.6	-0.3	0.15	20	2	0.64	0.3	3	-0.05	0.075	0.18	0.04	-0.1	0.118	0.1	407	3	2	0.047	0.18	-0.1

	SR	TA	TH	U	W	ZN	LA	CE	ND	SM	EU	TB	YB	LU	Weight
	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	g
CD98/D8	39	-0.05	0.1	0.05	-0.05	26	1.2	1.6	0.8	0.13	-0.05	-0.1	0.064	0.01	8.19
CD98/D26	41	-0.05	0.1	0.05	-0.05	27	1.2	1.6	0.8	0.14	-0.05	-0.1	0.07	0.011	8
CD98/D48	44	-0.05	-0.1	0.05	-0.05	28	1.1	1.7	0.8	0.14	-0.05	-0.1	0.071	0.011	8.13
CD98/D70	42	-0.05	0.1	0.07	-0.05	29	1.2	1.5	0.8	0.15	-0.05	-0.1	0.068	0.011	7.93
CD98/D93	39	-0.05	0.1	0.05	-0.05	27	1	1.5	0.6	0.14	-0.05	-0.1	0.063	0.01	8.12
CD98/112	40	-0.05	0.2	0.06	-0.05	28	1.2	1.6	0.8	0.15	-0.05	-0.1	0.067	0.011	8.53
CD98/124	37	-0.05	0.1	0.05	-0.05	24	0.95	1.3	0.5	0.11	-0.05	-0.1	0.062	0.01	8.07
CD98/145	34	-0.05	0.2	0.05	-0.05	26	1.1	1.6	0.9	0.13	-0.05	-0.1	0.072	0.012	8.04
CD98/169	35	-0.05	0.1	0.04	-0.05	25	1	1.4	0.6	0.12	-0.05	-0.1	0.056	0.012	8.04

Laboratory Duplicates of Vegetation Samples

Element Units	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	K %	MO PPM	NA PPM	NI PPM	RB PPM	SB PPM	SC PPM	SE PPM
CD98/D6	1.1	-0.3	0.06	10	8.2	0.62	-0.1	0.3	0.06	0.005	-0.05	0.02	-0.1	1.59	0.09	45.5	-2	58	-0.005	-0.01	-0.1
CD98/D7	1.3	-0.3	0.02	10	8.1	0.6	-0.1	-0.3	0.05	0.006	-0.05	-0.01	-0.1	1.53	-0.05	43.8	-2	57	-0.005	-0.01	-0.1
CD98/D25	0.5	-0.3	-0.02	67	14	0.81	-0.1	-0.3	0.06	0.007	-0.05	-0.01	-0.1	1.7	1.8	57.4	-2	36	-0.005	-0.01	-0.1
CD98/D27	1	-0.3	0.05	64	13	0.79	-0.1	-0.3	0.06	0.006	-0.05	0.04	-0.1	1.71	1.7	58	-2	36	-0.005	-0.01	-0.1
CD98/D46	0.4	-0.3	-0.01	24	1.6	0.55	-0.1	0.3	-0.05	0.007	-0.05	-0.01	-0.1	1.45	0.85	44.2	-2	69	-0.005	0.01	-0.1
CD98/D47	0.5	-0.3	-0.01	22	1.5	0.58	-0.1	0.3	-0.05	0.007	-0.05	0.02	-0.1	1.51	0.93	45.6	-2	70	-0.005	0.01	-0.1
CD98/D58	0.6	-0.3	-0.02	13	34	0.32	-0.1	0.7	0.12	0.006	-0.05	0.04	-0.1	2.85	-0.05	55.4	-2	160	-0.005	-0.01	0.2
CD98/D59	3.3	-0.3	-0.01	12	33	0.35	-0.1	0.6	0.11	0.005	-0.05	0.03	-0.1	2.82	-0.05	50	-2	160	0.006	-0.01	0.2
CD98/D68	0.6	-0.3	-0.02	-5	23	0.35	-0.1	-0.3	-0.05	-0.005	-0.05	0.02	-0.1	0.736	-0.05	37.8	-2	38	-0.005	-0.01	-0.1
CD98/D69	0.5	-0.3	-0.02	-5	22	0.31	-0.1	-0.3	-0.05	-0.005	-0.05	0.01	-0.1	0.708	-0.05	36	-2	39	-0.005	-0.01	-0.1
CD98/D85	0.4	-0.3	0.02	26	6.3	0.99	0.1	-0.3	-0.05	0.01	-0.05	0.1	-0.1	0.618	-0.05	44.4	-2	26	-0.005	0.03	-0.1
CD98/D86	0.4	-0.3	0.02	26	6.3	0.98	0.1	-0.3	-0.05	0.01	-0.05	0.08	-0.1	0.598	-0.05	46.1	-2	25	-0.005	0.02	-0.1
CD98/D91	0.5	-0.3	-0.01	10	0.44	0.18	-0.1	-0.3	-0.05	-0.005	-0.05	0.05	-0.1	0.361	-0.05	49.2	-2	12	-0.005	-0.01	0.1
CD98/D92	0.5	-0.3	-0.01	7	0.45	0.17	-0.1	-0.3	-0.05	-0.005	-0.05	0.05	-0.1	0.363	0.05	43.8	-2	11	-0.005	-0.01	0.1
CD98/D109	0.3	-0.3	-0.02	110	1.2	-0.02	-0.1	0.7	-0.05	0.007	-0.05	-0.01	-0.1	1.05	-0.05	100	-2	28	-0.005	0.06	-0.1
CD98/D110	0.4	-0.3	-0.02	110	1.4	-0.02	-0.1	0.7	-0.05	0.008	-0.05	-0.01	-0.1	1	-0.05	103	-2	28	-0.005	0.06	-0.1
CD98/122	0.7	-0.3	-0.01	-5	7.4	0.89	-0.1	-0.3	0.15	-0.005	-0.05	0.07	-0.1	1.09	-0.05	40.8	-2	52	0.009	0.17	0.1
CD98/123	0.6	-0.3	-0.01	-5	7.4	0.95	-0.1	-0.3	0.15	-0.005	-0.05	0.06	-0.1	1.2	-0.05	44.3	2	53	0.01	0.17	0.1
CD98/143	0.7	-0.3	-0.02	49	7.7	0.65	-0.1	-0.3	-0.05	0.016	-0.05	0.03	-0.1	1.14	0.13	59.6	-2	25	0.007	0.05	-0.1
CD98/144	0.8	-0.3	-0.02	53	7.7	0.6	-0.1	0.3	-0.05	0.021	-0.05	0.03	-0.1	1.15	0.13	59.5	-2	26	0.009	0.05	-0.1
CD98/167	0.3	-0.3	-0.02	-5	8.8	0.4	-0.1	0.5	-0.05	0.017	-0.05	0.05	-0.1	0.069	-0.05	34.3	-2	2	0.014	0.03	0.1
CD98/168	0.2	-0.3	0.05	-5	8.7	0.39	-0.1	0.3	-0.05	0.017	-0.05	0.03	-0.1	0.061	0.05	35.8	-2	3	0.013	0.03	-0.1

Analytical Precision
(Duplicates by INAA)

Laboratory Duplicates of Vegetation Samples

Element Units	SR PPM	TA PPM	TH PPM	U PPM	W PPM	ZN PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM	YB PPM	LU PPM	Mass g
CD98/D6	69	-0.05	-0.1	-0.01	-0.05	13	0.02	-0.1	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.5
CD98/D7	65	-0.05	-0.1	-0.01	-0.05	12	0.02	-0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.79
CD98/D25	110	-0.05	-0.1	-0.01	-0.05	12	0.11	0.2	-0.3	0.005	-0.05	-0.1	0.007	0.001	8.83
CD98/D27	110	-0.05	-0.1	-0.01	-0.05	12	0.09	0.1	-0.3	0.004	-0.05	-0.1	-0.005	-0.001	8.73
CD98/D46	46	-0.05	-0.1	-0.01	-0.05	14	0.06	-0.1	-0.3	0.004	-0.05	-0.1	-0.005	-0.001	8.76
CD98/D47	56	-0.05	-0.1	-0.01	-0.05	13	0.06	0.1	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	8.54
CD98/D58	27	-0.05	-0.1	-0.01	-0.05	15	0.27	0.2	-0.3	0.022	-0.05	-0.1	0.009	0.002	8.32
CD98/D59	29	-0.05	-0.1	0.01	-0.05	16	0.28	0.2	-0.3	0.024	-0.05	-0.1	0.01	0.001	8.47
CD98/D68	41	-0.05	-0.1	-0.01	-0.05	12	0.01	-0.1	-0.3	0.001	-0.05	-0.1	-0.005	-0.001	8.33
CD98/D69	43	-0.05	-0.1	-0.01	-0.05	12	0.03	-0.1	-0.3	0.001	-0.05	-0.1	0.006	0.001	8.65
CD98/D85	180	-0.05	-0.1	-0.01	-0.05	6	0.08	0.1	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	8.35
CD98/D86	170	-0.05	-0.1	-0.01	-0.05	7	0.08	0.1	-0.3	0.007	-0.05	-0.1	-0.005	-0.001	8.47
CD98/D91	23	-0.05	-0.1	-0.01	-0.05	4	0.04	0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.5
CD98/D92	23	-0.05	-0.1	-0.01	-0.05	4	0.04	0.1	-0.3	0.002	-0.05	-0.1	-0.005	-0.001	8.66
CD98/D109	10	-0.05	-0.1	-0.01	-0.05	9	37	97	24	3.4	0.19	0.1	0.201	0.034	8.17
CD98/D110	10	-0.05	-0.1	-0.01	-0.05	9	37	95	24	3.4	0.19	0.1	0.203	0.036	8.1
CD98/122	150	-0.05	-0.1	-0.01	-0.05	11	0.04	0.2	-0.3	0.003	-0.05	-0.1	-0.005	-0.001	8.61
CD98/123	160	-0.05	-0.1	-0.01	-0.05	12	0.05	0.2	-0.3	0.005	-0.05	-0.1	-0.005	-0.001	8.04
CD98/143	80	-0.05	0.3	0.02	-0.05	24	1.7	8.8	0.5	0.062	-0.05	-0.1	0.012	0.002	8.06
CD98/144	78	-0.05	0.3	0.02	-0.05	25	1.7	8.8	0.5	0.06	-0.05	-0.1	0.013	0.002	8.4
CD98/167	-10	-0.05	-0.1	-0.01	-0.05	2	0.2	0.3	-0.3	0.015	-0.05	-0.1	0.012	0.002	8.1
CD98/168	12	-0.05	-0.1	0.02	0.06	-2	0.21	0.2	-0.3	0.015	-0.05	-0.1	0.015	0.002	8.08