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Amazonian flood impacts on managed Brazilnut stands along Brazil's Madeira River: A sustainable forest management system threatened by climate change

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ABSTRACT

Impact of flooding on tropical forest ecosystems and their management is a little-studied area that is expected to become increasingly important under projected climate change. A demonstration of this was provided by the record-breaking 2014 flood of the Madeira River in Brazil. We assessed factors affecting survival of Brazilnut trees (*Bertholletia excelsa* H.B.K.) under root asphyxia caused by flooding in the Lago do Capanã Grande Extractive Reserve in Manicoré municipality (county), Amazonas state, Brazil. Mortality was surveyed in three Brazilnut groves (*castanhais*) in 680 individual Brazilnut trees of which 357 had been exposed to flooding and 200 had been flooded for at least 83 days, which was the threshold for mortality effects. Trees were georeferenced and measured for DBH and the height above the ground of the flood-water mark. This information, together with topography from satellite data and water levels from hydrographic gauges, allowed calculation of the time each tree was flooded. None of the 323 unflooded trees died. The analysis indicates a relationship between mortality and duration of root asphyxia, killing 17% of the individuals exposed to flooding and 35% of the individuals that were flooded for periods greater than 109 days. Nevertheless, survival exceeded 50% for all flooding durations. The data suggest that larger trees have a greater probability of mortality for any given period of asphyxia. Expected increases in extreme flood events threaten a sustainable forest management system based on harvest of non-timber products.

Keywords: *Bertholletia excelsa*, root asphyxia, flood, mortality, Madeira River

1. Introduction

Increased flood levels in Amazonian rivers imply impacts on forests and on the human populations that manage them. Quantifying these impacts and identifying their causes are important for any adaptation efforts. In 2014 the Madeira River experienced its largest recorded flood, with the instantaneous streamflow at Porto Velho reaching 66,066 $m^3 s^{-1}$ on 31 March 2014 (Brazil, CPRM, 2014). The Madeira drains parts of Bolivia, Peru and Brazil and ranks among the World's largest rivers despite being a mere tributary of the Amazon River. The 2014 flood had multiple impacts on natural ecosystems and on the human population (Fearnside, 2014, 2015; Vauchel, 2014).

Extreme floods have occurred in the Amazon basin with greater frequency and intensity over the last two decades (Espinoza et al., 2012; Marengo and Espinoza, 2016; Marengo et al., 2011, 2013). These events are generally expected to increase in frequency due to climate change (Arnell and Gosling, 2016; Hirabayashi, et al., 2013; Marengo and Espinoza, 2016; Lehmann et al., 2015; Milly et al., 2002; Winsemius et al., 2016). Increased risks are especially high in the western Amazon (Guimberteau et al., 2012, 2013; Ronchail et al., 2006; Sorribas et al., 2016; Zulkafli et al., 2016). In addition to global climate change, ongoing deforestation also increases flood risk (Bradshaw et al., 2007; Coe et al., 2009).

The 2014 Madeira River flood was caused by abnormally high rainfall in the Madeira's Andean tributaries, especially the Beni, Madre de Dios and Mamoré Rivers, with precipitation in December 2013 and January 2014 up to 100% above average, and February 2014 precipitation up to 80% above average (Espinoza et al., 2014; Marengo and Espinoza, 2016). At Manicoré, Amazonas state, Brazil, the Madeira River was above the level of the last great flood (1997) for more than 70 days, and it was above the level of the second-largest previously registered flood (1993) for 97 days. The floodwaters in 2014 reached locations where flooding had never before been recorded, causing forest mortality and serious impacts on the local economy, loss of agricultural areas and forest extractivism, death of animals and the loss of houses, forcing the migration of families to higher settlements or to makeshift vessels.

Brazilnut (*Bertholletia excelsa* H.B.K.) is native to the Amazon and is found in all nine states in Brazil's Legal Amazonia region (Rondônia, Acre, Amazonas, Roraima, Pará, Amapá, Tocantins, Maranhão and Mato Grosso), as well as in the other Amazonian countries. The species has multiple uses and has long been widely exploited by traditional peoples, both for its edible seeds and for its excellent quality wood, which is used for building boats and houses despite cutting Brazilnut trees being banned (Decree 1282 of 19 October 1994) (Homma, 2014; Scoles, 2010, 2011; Scoles et al., 2014; Sousa et al., 2014). The nuts represent one of the main extractive export products of Amazonia (Salomão, 2009).

Brazilnut trees are long lived and may even remain productive at ages over 800 years (Salomão, 2009; Zuidema, 2003). Carbon 14 dating indicates an age of 440 ± 60 years for an individual with DBH of 233 cm (Camargo et al., 1994), implying an annual increment in DBH under mature forest conditions of 0.53 cm $year^{-1}$. Young individuals are defined as those with DBH ≤ 50 cm, after which the trees enter the reproductive stage (Sousa et al., 2014; Tonini et al., 2008; Wadt et al., 2005). Like most of the higher plants, Brazilnut trees show a relationship between the age and entry into production in which factors such as the light intensity directly influence reproductive maturity (Scoles, 2010; Guedes et al., 2014; Scoles et al., 2011, 2014).

Brazilnut is a species that is characteristic of the unflooded uplands (*terra firme*) and is typically not found in *várzea* (floodplain in rivers with "white" or muddy water) or in *igapó* (black-water floodplain) (Fernandes and Alencar, 1993; Scoles, 2010, 2011; Scoles and Gribel, 2015; Scoles et al., 2014; Tonini et al., 2014; Wadt and Kainer, 2009). Flooding stress interferes with photosynthesis in four of ten *terra firme* species that have been studied (dos Santos Júnior et al., 2013, 2015), but data are lacking on Brazilnut. There is a general lack of studies on responses of trees to anoxic stress under flooding.

The present study evaluates the survival of Brazilnut trees, relating mortality to duration of inundation and DBH. The study examines the impact of the 2014 Madeira River flood in an "extractive reserve," which is a type of federal conservation unit that allows extraction of non-timber forest products by local populations (e.g., Fearnside, 1989).

2. Materials and methods

2.1 Study area

The study was carried out in the Lago do Capanã Grande Extractive Reserve, which is located in the municipality (county) of Manicoré (Figure 1). This reserve is part of a mosaic of federal lands that also includes the Matupiri Agro-Extractive Settlement Project (PAE) and the Capanã Indigenous Land (Supplementary Material, Figure S-1).

[Figure 1 here]

The reserve was created by Decree on 3 June 2004 (IBAMA Process nº 02001001183/2003-57), covering an area of 304,146 ha. It is bounded to the north by the Amapá River, to the south by the Capanã stream, to the east by the Madeira River and on the west by Highway BR-319 (Figure S-1). The reserve is home to 127 families divided into seven communities: Ponto do Campo, Santa Civita, Nossa Senhora de Fátima, Jutaí, São Raimundo, São Sebastião and Bom que Dói (Miranda et al., 2004).

Brazilnuts are the main non-timber forest product (NTFP) extracted in the reserve, but other products include rubber (*Hevea brasiliensis* Willd.), açai (*Euterpe oleracea* Mart.) and various species of vines ("*cipós*") (Brazil, ICMBio, 2013). This extraction is complemented by small-scale agriculture based on annual crops like manioc (cassava) and watermelon (Miranda et al., 2004; Brazil, ICMBio, 2009a,b, 2013). NTFP extraction, in addition to being the mainstay of the local economy, has an important role in maintaining the culture of Lago do Capanã Grande communities (Figure S-2) (Miranda et al., 2004; Brazil, ICMBio, 2009a, 2013). Our survey of mortality was conducted in three Brazilnut groves (*castanhais*) in the reserve.

Miranda et al. (2004) conducted forest inventories in the reserve and found a high density of Brazilnut trees: up to 48 individuals per hectare, of which 26 were adults with diameter at breast height (DBH, measured 1.3 m above the ground) greater than 50 cm and 22 were young trees (DBH < 50 cm). These densities are higher than in other areas that have been surveyed in Acre, Pará and Rondônia (Miranda et al., 2004).

2.3 Determination of the duration of root asphyxia

To calculate the period of time (days) that each individual was under root asphyxia we used the height of the high-water mark on the trunk of the tree, together with river-stage data from the Hidroweb fluviometric system (Brazil, ANA, 2014). River-stage data were used from the station at Manicoré, Amazonas (station 15,700,000) for 2013 and 2014 as well as over the past 50 years. A total of 680 individual Brazilnut trees were surveyed, of which 357 had been exposed to flooding in the 2014 flood (Table S-1).

The daily record of the river level in centimeters defines the variable *"y."* The river level reached a maximum on 19 April 2014 (y_{max}). This variable was associated with the variable "*x*," also measured in centimeters: the mark of the maximum water depth, taking the ground at the base of the tree as the reference level. This permitted identifying the starting and ending day of root asphyxia conditions from the daily records in the Hidroweb system. The *"z"* value was identified using Equation 1

$$z = y_{max} - x \quad (1),$$

where

"*z*" is the elevation of the ground at the location of the tree (m above mean sea level),

"y" is the maximum level of the river (m above mean sea level), and

"x" is the maximum height of the water-level mark on the trunk of the tree (measured from the ground at the base of the tree (m above mean sea level).

From the estimate of "*z*" one can infer the number of days that the individual was under asphyxia. For example, if the maximum river level was 28.88 m above mean sea level and the high-water mark on the trunk of the tree was 4.00 m above the ground, this means that this individual went into a condition of asphyxia when the river had a level of 24.88 m (the "*z*" level). The dates of beginning and ending asphyxia can therefore be determined from the Hidroweb data. We established a relationship between river level (m) and the duration of root asphyxia.

2.4 Relation between mortality and the age of the individuals

The Brazilnut trees were classified into 10-cm DBH intervals. The relationship between mortality and age (indicated by DBH) of individuals was assessed by logistic regression. Determination of the status of individuals as live or dead was based on symptoms indicating lack of physiological activity: individuals without foliage and with necrotic stems, dry twigs and with evidence of attack by termites.

2.5 Topographic analysis of the Madeira River flood

The geographic locations of the Brazilnut trees (Figure S-3) were determined in the latitude/longitude coordinate system and *datum* WGS 84 using a GPS (global positioning system). For each tree, status as live or dead was recorded and the DBH and height of the water mark on the trunk were determined with a tape measure. The sample was composed of trees along the trails established by the Brazilnut gatherers for harvesting the nuts.

Geographical analysis was based on the information gathered in the field (georeferenced individuals) and from Shuttle Radar Topography Mission (SRTM) images. A geographical information system (ARCGIS software) was used to store the GPS data and to analyze the mortality in relation to local topography (altimetry), including the water depths and days of root asphyxia associated with different topographic positions.

2.6 Statistical analysis of the data

The effect of flooding duration on mortality of Brazilnut trees was tested by analysis of variance (ANOVA), with statistical significance determined by the Tukey test at the 5% probability level. Treatments were the four root-asphyxia durations (< 54, 54-83, 83-109 and > 109 days), and their associated water depths at the tree locations. The three Brazilnut groves served as repetitions. These analyses were performed using ASSISTAT 7.7 beta version software (Santos e Silva and de Azevedo, 2016).

To improve the normality of the data and/or reduce the heteroscedasticity in the analysis, which was based on percentage values, we applied the angular or arcsine transformation (Equation 2)

$$\text{Transformed value} = \text{arcsine}(v^{0.5}) \qquad (2),$$

where

"v" is the value as a proportion.

This transformation is used to homogenize the residual variance of values that are in the form of either proportions or percentages. It is especially recommended when the percentages cover a large range of values (Bianconi et al., 2008). The transformation was performed using Microsoft Excel software.

To separate the effects of DBH and water depth at the tree locations, a logistic regression was applied using the individual trees as the sampling unit. In the logistic linear regression analysis a value of "1" was assigned to dead trees and "0" to living trees. The null hypothesis (H_0) was tested in which neither of the factors measured (DBH and water depth at the tree location) influences mortality, with the alternative hypothesis (H_1) being that at least one of these factors influences mortality. Logistic regression was performed as a logit model in the binomial family of general linear models using R software (R Core Development Team, 2017).

R software reports the results of logarithmic regressions in terms of log odds (Equation 3):

$$\ln(\text{odds}) = \ln(p/(1-p)) \qquad (3),$$

where

p = the probability of mortality.

3. **Results**

3.1 Relationship between water depth at the tree location and duration of root asphyxia

River-stage data obtained from the Hidroweb system has a strong linear relationship ($R^2 = 0.99$) with the water depths at the tree locations (Figure S-4). With this information we were able to calculate the period under anoxic stress from the approximate beginning and ending dates of asphyxia for recent floods in the Madeira River, using as a reference the sampled tree with the greatest water depth in 2014 (4.6 m, or 150 days of flooding) (Table 1 and Figure S-4).

[Table 1 here]

3.2 Effect of the 2014 flood on mortality of Brazilnut trees

Mortality was classified according to the period of root asphyxia corresponding to a 1-m water depth at the location of each tree (Table 2). Grouping the trees into four classes (periods) of root asphyxia shows a significant increase in mortality with longer periods of asphyxia (Table 3).

[Tables 2 & 3 here]

Analyzing mortality as a function of the duration of root asphyxia during the 2014 flood, one can see that durations of less than 83 days (around 2 m of water depth at the tree location) did not cause mortality (Table 2). However, a period longer than 83 days proved to have negative impacts on survival, with mortality of individuals reaching values above 18%. For periods greater than 109 days (3-m water depth at the tree location), mortality reaches values around 35%. However, the fact that many trees survived flood durations greater than 109 days indicates that there is physiological plasticity among individuals or life stages (Table 2).

It should be emphasized that approximately 65% of the Brazilnut trees surveyed tolerated over 109 days of flooding. The analysis shows that the Brazilnut tree is capable of supporting a period longer than 140 days of root asphyxia, maintaining survival rates of over 50% (Table 2).

The effect of tree diameter can be seen by dividing the sample into DBH categories (Figure 2). Note that with DBH categories of only 10-cm width, several intervals have very few individuals. With the exception of the 0-10 cm DBH category, intervals between 10 and 150 cm have numbers of individuals ranging from 14 to 45, but for intervals above 150 cm the numbers of individuals are much smaller (Table S-2).

[Figure 2 here]

The effect of duration of root asphyxia can be seen for intervals of the number of days for intervals above the minimum number of days for an asphyxia effect (Figure 3 and Table S-3). The relationship between mortality and duration of root asphyxia was analyzed using a logistic regression model considering the 200 trees that were exposed to flooding for longer than the 83-day threshold for mortality from root asphyxia (Table 4).

[Tables 4 & Figure 3 here]

Many Brazilnut trees had been attacked by plant-eating pests (Figure S-6). Nevertheless, signs of physiological responses were observed that may signify a recovery of some of the individuals (Figure S-7).

The positions of georeferenced individuals with respect to topography based on SRTM imagery (Figure S-8) shows that mortality was associated with low areas. These areas would have experienced the longest periods of flooding and root asphyxia.

4. Discussion

Brazilnut trees have never been subjected to the stress conditions of 2014 in any of the historical floods recorded in the Madeira basin since 1967 in the Hidroweb system maintained by the National Water Agency (ANA) (Table 1). This study recorded depths of water at the tree locations of up to 460 cm, or 150 days of root asphyxia. Individuals such as the one with the longest period of inundation are in the lower areas and would also have been intensely affected by asphyxia in previous major floods. No individuals were found with water depth at the trunk in excess of 460 cm (or 150 days of flooding, Figure S-5). The period of flooding to which individuals were subjected can be considered to be the cause of mortality.

The number of days of root asphyxia during the 2014 flood (Table 1, Figure S-4) reinforces the hypothesis that the Brazilnut trees may have been affected by other major floods with asphyxia periods of over 100 days, as was the case in 2008. Events that resulted in mortality of Brazilnut trees had not been recorded on the Madeira River until 2014.

Mortality by flooding can occur long after an event of damage or stress. This has been shown in the case of mortality caused by fire, where death can occur one or more years after the event (Barlow et al., 2003). Long-term monitoring is needed to capture all mortality, and the values presented here are therefore conservative.

There are records of other species of woody plants in the family Lecythidaceae that are tolerant of flooded conditions both in *várzea* and *igapó* (Ferreira et al., 2013;

Reis, 2010). Lecythidaceae species such as *Allantoma lineata* (Mart. ex O. Berg) Miers are abundant in both in *várzeas* and in *igapós*, while *Gustavia hexapetala* (Aubl.) Sm and *Parinari excelsa* Sabine only occur in *várzea* (Ferreira et al., 2013). Reis (2010) identified Lecythidaceae in floodplains on the Jaci-Paraná River (a tributary of the Madeira), highlighting *Eschweilera tenuifolia* (O. Berg) Miers, *Cariniana decandra* Ducke, *Corythophora alta* R. Knuth, *Eschweilera atropetiolata* S.A. Mori, *Eschweilera bracteosa* (Poepp. ex O. Berg) Miers, *Eschweilera collina* Eyma, *Gustavia augusta* L. and *Gustavia cf. hexapetala* (Aubl.) Sm. Many other species of Lecythidaceae also occur in Amazonian floodplains.

The duration of root asphyxia has a strong influence on the number of individuals killed by the flood. Statistically, the analysis made with four treatments (water depths at the tree location) and three repetitions indicated that there are significant differences ($p < 0.05$) between the different durations of asphyxia (treatments), showing that, as the duration of asphyxia (or water depth at the tree location) increases, the number of individuals killed also increases ($F = 6697$, $p = 0.03$, $df = 2$) (Table 3).

Results for the different treatments in Table 3 indicate that periods of asphyxia up to 83 days have no effect on the survival of individuals. Above this threshold, flooding periods begin to cause mortality, and this worsens substantially beginning at 109 days of root asphyxia; in the case of the 2014 Madeira River flood, this limit corresponds to a 300-cm water depth at the tree location.

The distribution of the diameter classes in the Brazilnut groves we studied was typical of "young" groves, with high numbers of individuals in the first diameter classes (up to 120 cm) (Table 4). This corroborates the description by Scoles (2010, 2011) for the same area. This diameter distribution can be explained by human interference in the Brazilnut groves favoring light conditions that result in greater recruitment of seedlings (Scoles, 2010, 2011; Guedes et al., 2014).

Brazilnut trees with DBH less than 10 cm are very rare, with only two trees in this size range having been observed (Table S-2). Seedlings were not observed in the Brazilnut groves we visited. New Brazilnut groves are established in the forest as a result of the opening of clearings that increase light penetration and attract agoutis (*Dasyprocta* sp.) and other wild animals that facilitate seed dispersal and thus increase the rate of recruitment (Scoles, 2010, 2011; Shepard Jr. and Ramirez, 2011). Human populations have inhabited Amazonian forest since the Pleistocene, and the occurrence of Brazilnut trees is believed to have been influenced by humans over thousands of years (Levis et al., 2017; Scoles and Gribel, 2015; Shepard Jr. and Ramirez, 2011). One can assume the prior existence of seedlings of Brazilnut trees in areas affected by flooding. The conditions of asphyxia in 2014 may have prevented the survival of seedlings, abruptly interrupting the natural renewal rate of this species over recent years.

The logistic regression analysis for the 200 trees flooded for at least 83 days (Table 4) shows that duration of asphyxia is significant as a predictor of mortality ($p < 0.05$). Logistic regressions that also include DBH as an explanatory variable are suggestive that larger trees are more susceptible to mortality from flooding, but fail to meet the 5% standard for significance: $p = 0.11$ considering the 200 trees flooded for at least 83 days, while $p = 0.056$ if all 357 trees exposed to flooding are considered. The mortality percentages by diameter class (Figure 2) indicate a clear increase in mortality up to 60 cm DBH, after which there is no trend with further increase in diameter.

Considering the 200-tree sample and only asphyxia, each 1-day increment in the duration of asphyxia adds 0.38% to the probability of a tree dying. If DBH is considered, each 1-cm increment adds 0.10% to the probability of a tree dying in the flood event.

Brazilnut trees can recover from physiological stresses such as fires or severe wounds on the stem (Salomão, 2014; Scoles et al., 2014). Biological responses of survival as the leaf regrowth were recorded in many Brazilnut trees affected by the flood (Figure S-7). Even so, these trees will be unproductive for several years and they will be weakened even after recovering their productive cycles. This makes the trees easy targets for forest pests (Figure S-6) that may seriously compromise their physical support structure. These individuals should be monitored to both detect delayed mortality and to understand possible physiological and productive recovery.

The location of individual Brazilnut trees on the topography of the site (altitude from SRTM images) has a close relationship with mortality. On higher ground, such as that at the control Brazilnut grove, individuals did not suffer mortality (Figure S-8a). Individuals in lower areas (Figures S-8a and S-8b) suffered longer root asphyxia conditions and were more likely to die. The spatial distribution of mortality shows a close relation to the proximity of water bodies (Figure S-8b).

The 2014 flood serves as a warning of the changing climate and of expected future increases in the frequency and severity of extreme flood events. The 2014 event caused Brazil's official estimate of the recurrence time for a flood of this magnitude on the Madeira River to be revised from 300 years to 113 years (Pante and Albuquerque, 2014), and ongoing climate change would increase this risk. The Brazilnut mortality observed in the present study implies that more extreme floods would threaten the sustainable forest management system for non-timber forest products practiced by traditional extractivist populations along the Madeira River.

5. Conclusions

There is a close relationship between mortality in Brazilnut trees, the time they were flooded, with longer periods of asphyxia leading to significant increase in mortality. Results are suggestive that greater diameter at breast height (DBH), which is a proxy for age, further increases the risk of mortality from flooding. Research is needed on additional species and under other flooding regimes in order to predict and minimize impacts of increased flooding throughout the Amazon region.

Tree mortality from the 2014 flood will affect the extractive economy based on forest management for Brazilnut harvesting, and this effect will extend over the long term. Long-term monitoring is needed to detect delayed mortality and to understand how the surviving trees can respond and perhaps recover their productivity.

Projected climate change implies substantially higher extreme flood events in Amazonian rivers, including the Madeira. These extreme events threaten forest resources on which the livelihoods of traditional populations depend.

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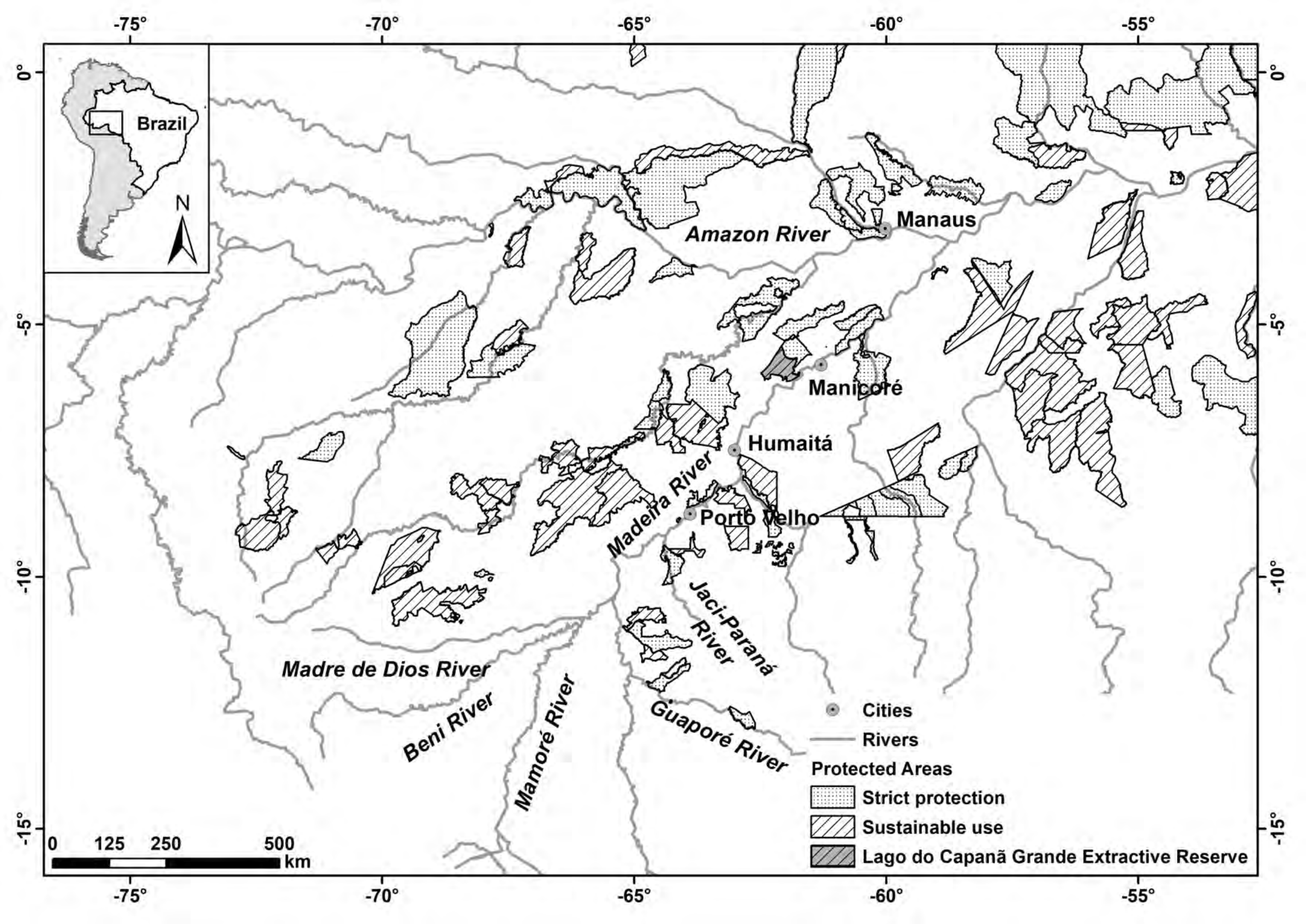
Figure legends

Figure 1. Locations mentioned in the text.

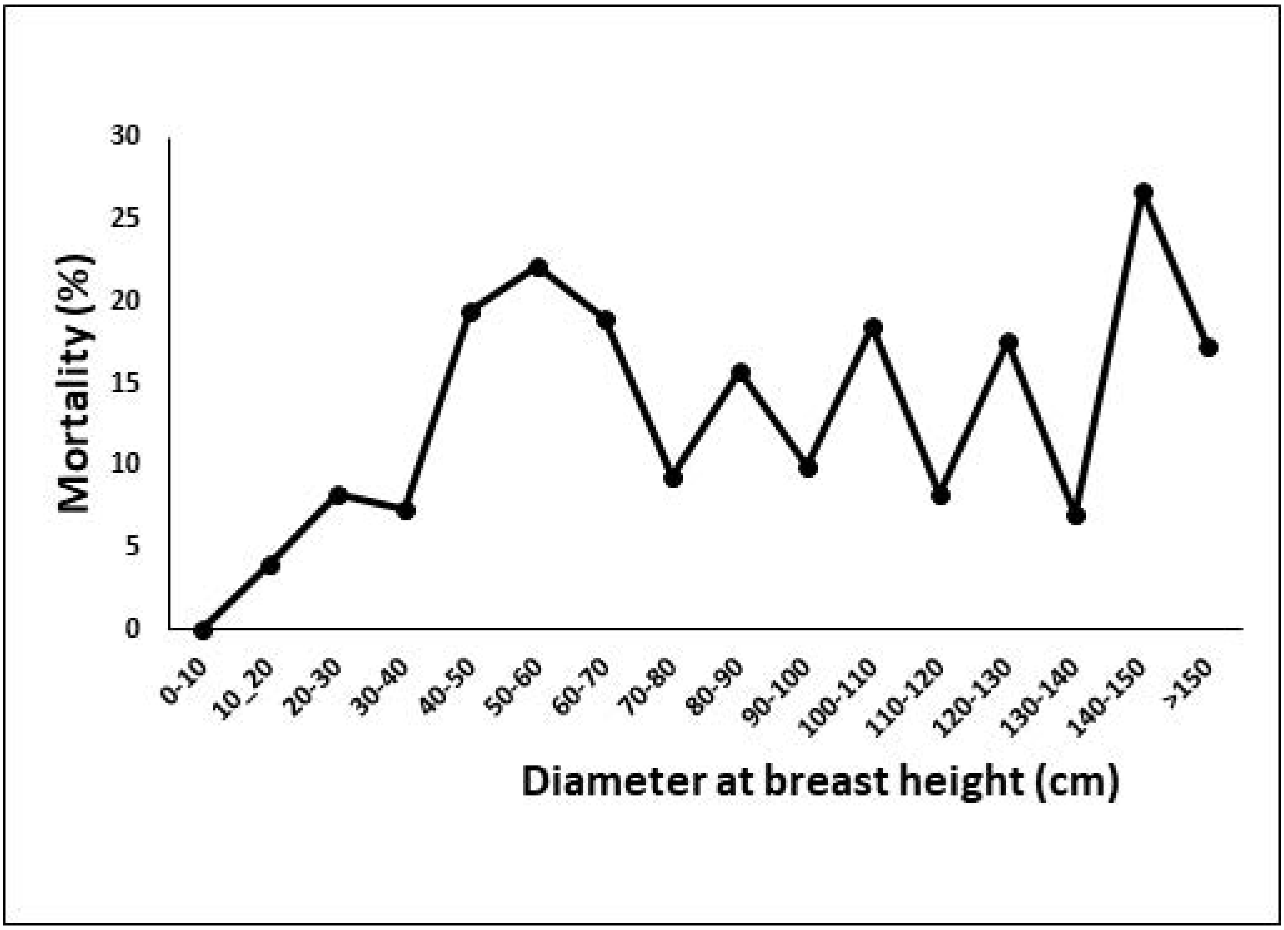
Figure 2. Mortality percentages by diameter class.

Figure 3. Mortality percentages by asphyxia-duration class.



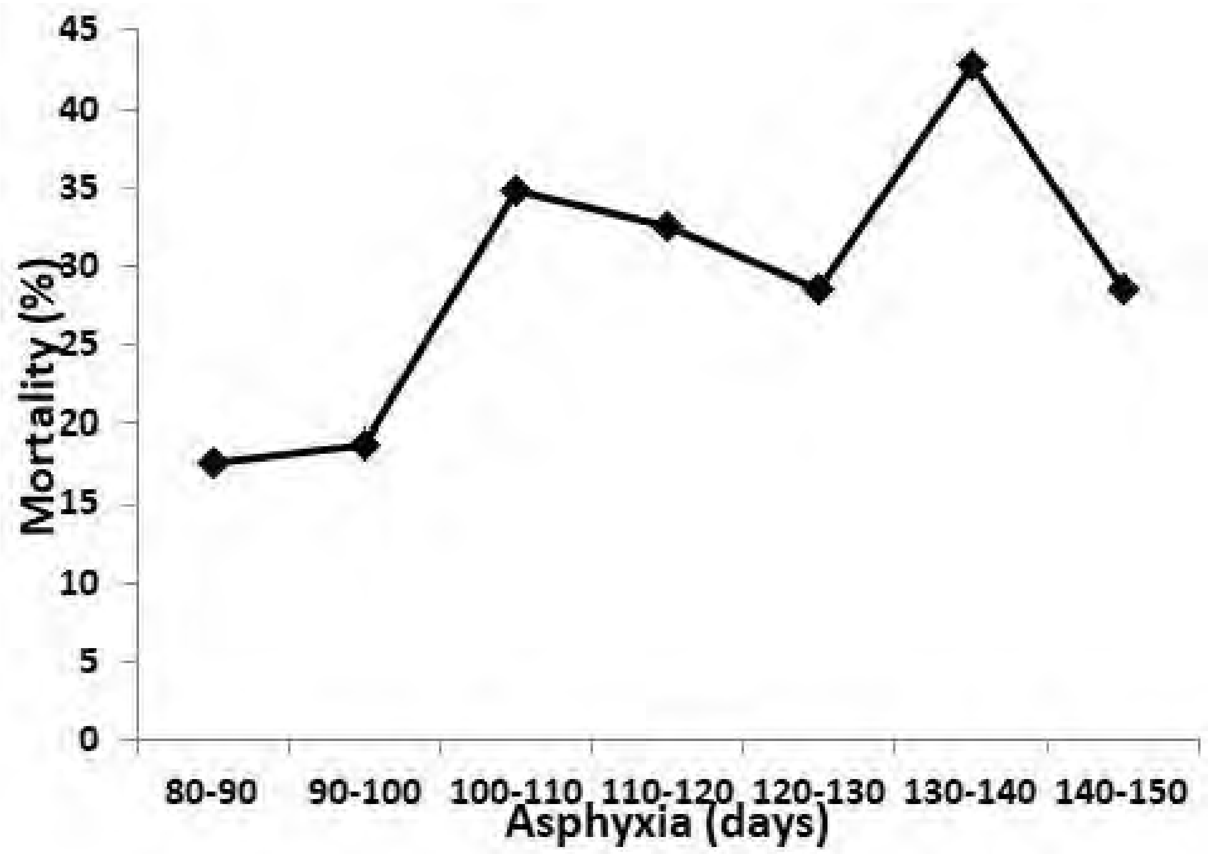
-75°
-70°
-65°
-60°
-55°
0°
-5°
-10°
-15°
Brazil
N
Amazon River
Manaus
Manicoré
Humaitá
Porto Velho
Madeira River
Jaci-Paraná River
Madre de Dios River
Beni River
Mamoré River
Guaporé River
Cities
Rivers
Protected Areas
Strict protection
Sustainable use
Lago do Capanã Grande Extractive Reserve
0 125 250 500
km

Figure 2



30
25
20
15
10
5
0
Mortality (%)
0-10
10_20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
100-110
110-120
120-130
130-140
140-150
>150
Diameter at breast height (cm)

Figure 3



45
40
35
30
25
20
15
10
5
0
Mortality (%)
80-90
90-100
100-110
110-120
120-130
130-140
140-150
Asphyxia (days)

Table 1. Periods of root asphyxia in Madeira River floods in Manicoré municipality, Amazonas state, Brazil, for a reference water depth at the tree location of 4.6 m.

Year	Stress time (days)	Maximum elevation (m)	Date of maximum water level	Asphyxia beginning date	Asphyxia ending date
1993	98	26.35	29/04/1993	21/02/1993	29/05/1993
1997	91	27.26	20/04/1997	05/03/1997	03/06/1997
2006	88	26.10	20/04/2006	21/02/2006	19/05/2006
2008	107	26.32	19/04/2008	14/02/2008	31/05/2008
2013	71	25.80	25/04/2013	04/03/2013	13/05/2013
2014	148	28.88	19/04/2014	06/02/2014	03/07/2014
Reference elevation		24.28 m			

Table 2. Mortality observed in 2015 in Brazilnut trees (*B. excelsa* H. & B.) that had been exposed to root asphyxia in 2014, Lago de Campanã Grande Extractive Reserve, Manicoré municipality, Amazonas state, Brazil.

Duration of asphyxia (Days)	Water depth (cm)	Numbers and percentages of Brazilnut trees				
		Live (No.)	Dead (No.)	Total (No.)	Live (%)	Dead (%)
≤ 54	0-100	117	3	120	97.5	2.5
55-83	100-200	91	0	91	100	0
84-108	200-300	70	16	86	81.4	18.6
≥ 109	> 300	95	46	141	67.4	32.6
	Total	373	65	438	85.2	14.8

Table 3. Mean percentages of dead Brazilnut trees in relation to the water level in four treatments (water levels and corresponding durations of asphyxia) with three repetitions (Brazilnut groves) in the Lago de Campanã Grande Extractive Reserve, Manicoré municipality, Amazonas state, Brazil.

N	Water level (cm)	Duration of asphyxia (days)	Mean (%)	Transformed mean[1] (%)[3]	SD	CV
1	0-100	≤ 54	3.84 (n = 1)[2]	-	-	-
2	100-200	54-83	0.56 (n = 3)	0.066 a	0.075	1.732
3	200-300	83-109	20.06 (n = 3)	0.440 ab	0.225	0.512
4	> 300	> 109	42.10 (n = 3)	0.702 b	0.303	0.431

1-Means followed by the same letter do not differ significantly ($p < 0.05$) by the Tukey test.

2- Single value: this water-level range has insufficient trees to obtain a mean (n = 1).

3- Arcsine transformation

SD = Standard deviation; CV = coefficient of variation.

SUPPLEMENTARY MATERIAL

Amazonian flood impacts on managed Brazilnut stands along Brazil's Madeira River: A sustainable forest management system threatened by climate change

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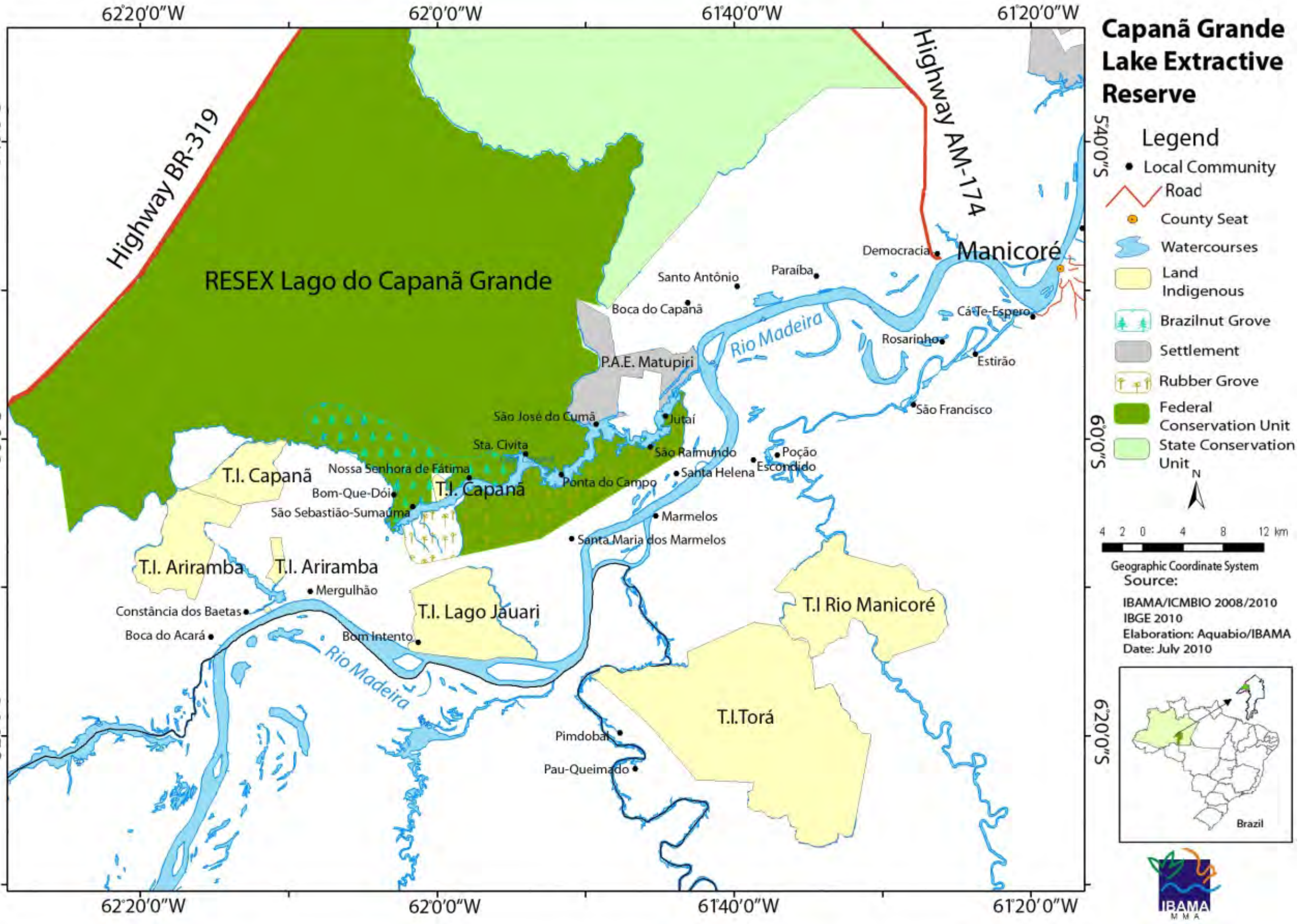

Figure S-1. Map of the Lago do Capanã Grande Extractive Reserve and surrounding area. Source: Brazil, ICMBio (2009).

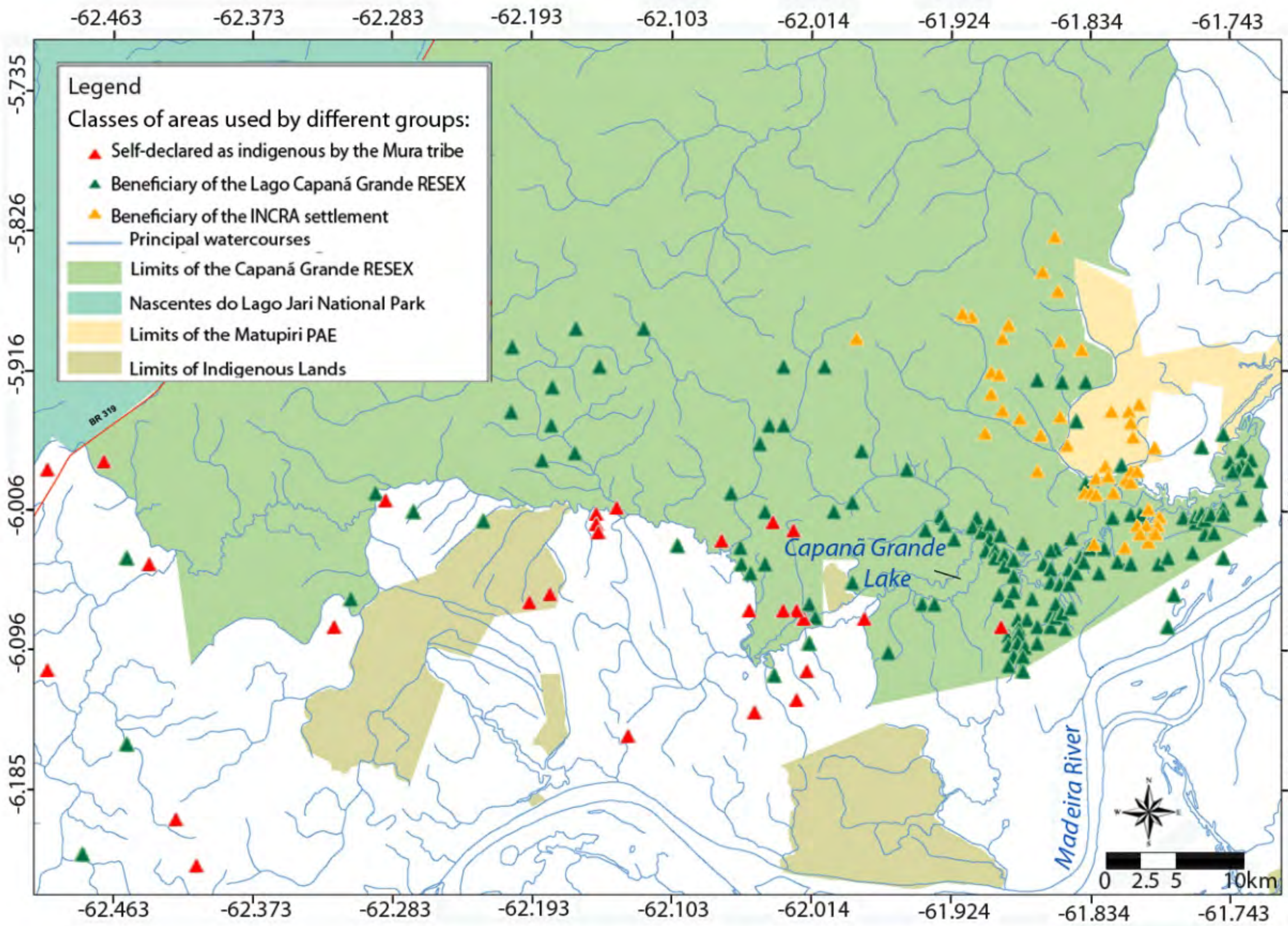

Figure S-2. Map of Brazilnut and rubber stands managed by local communities. Source: Brazil, ICMBio (2009).

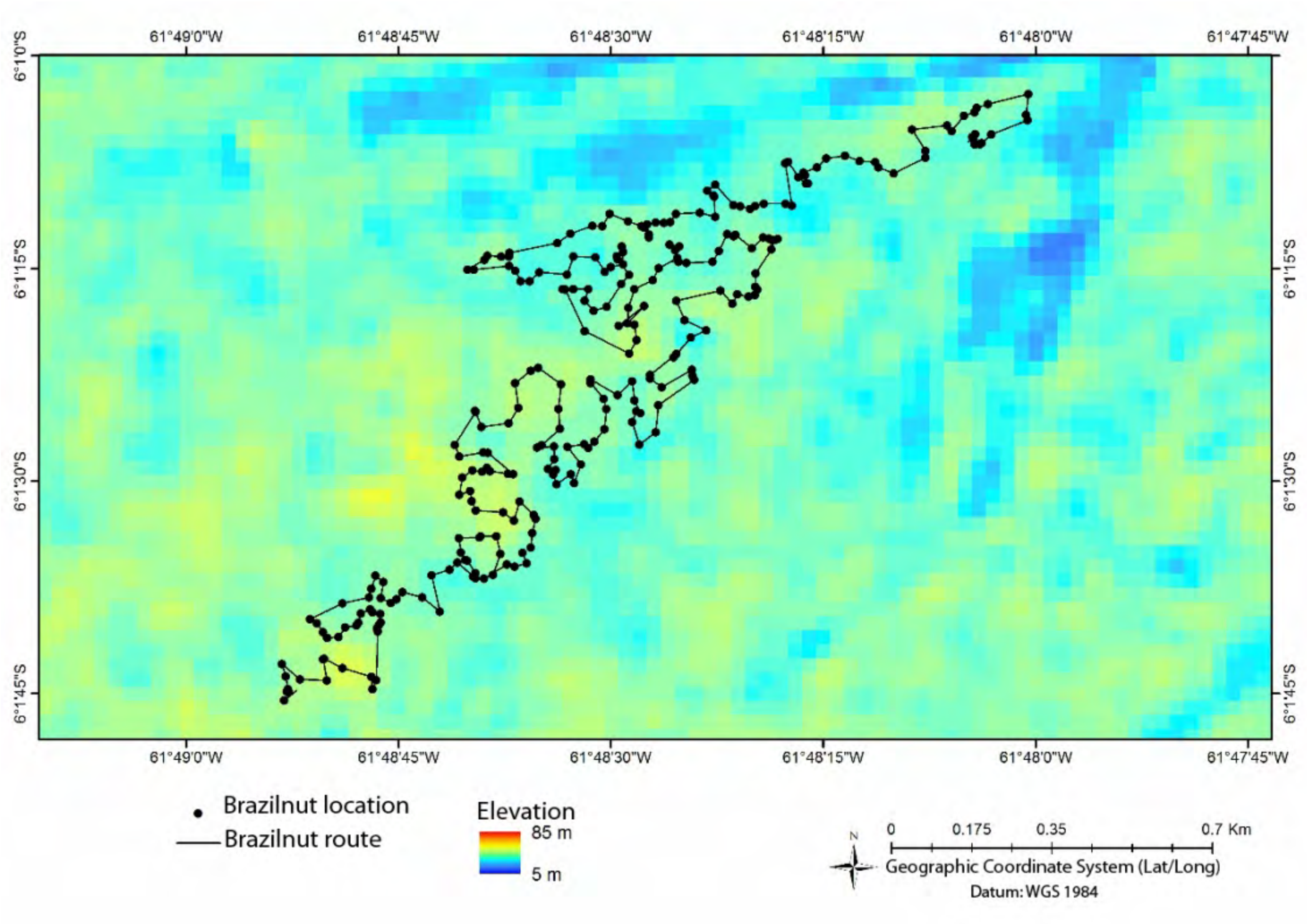

Figure S-3. SRTM (Shuttle Radar Topography Mission) image with Brazilnut groves studied in the Lago do Campana Grande Extractive Reserve, Manicoré municipality, Amazonas state, Brazil, 2015.

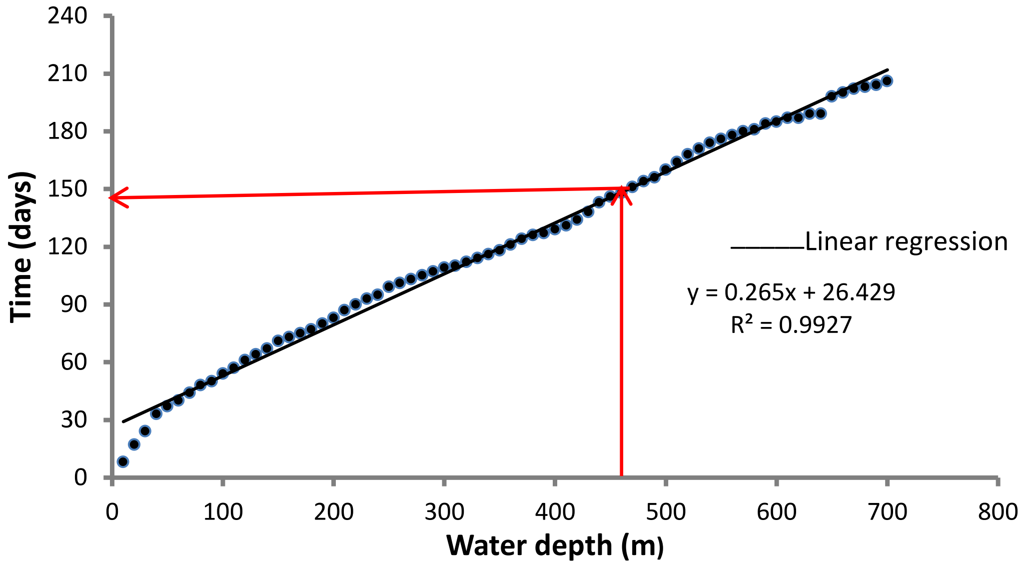

Figure S-4. Relationship between water depth and duration of root asphyxia in the 2014 Madeira River flood.

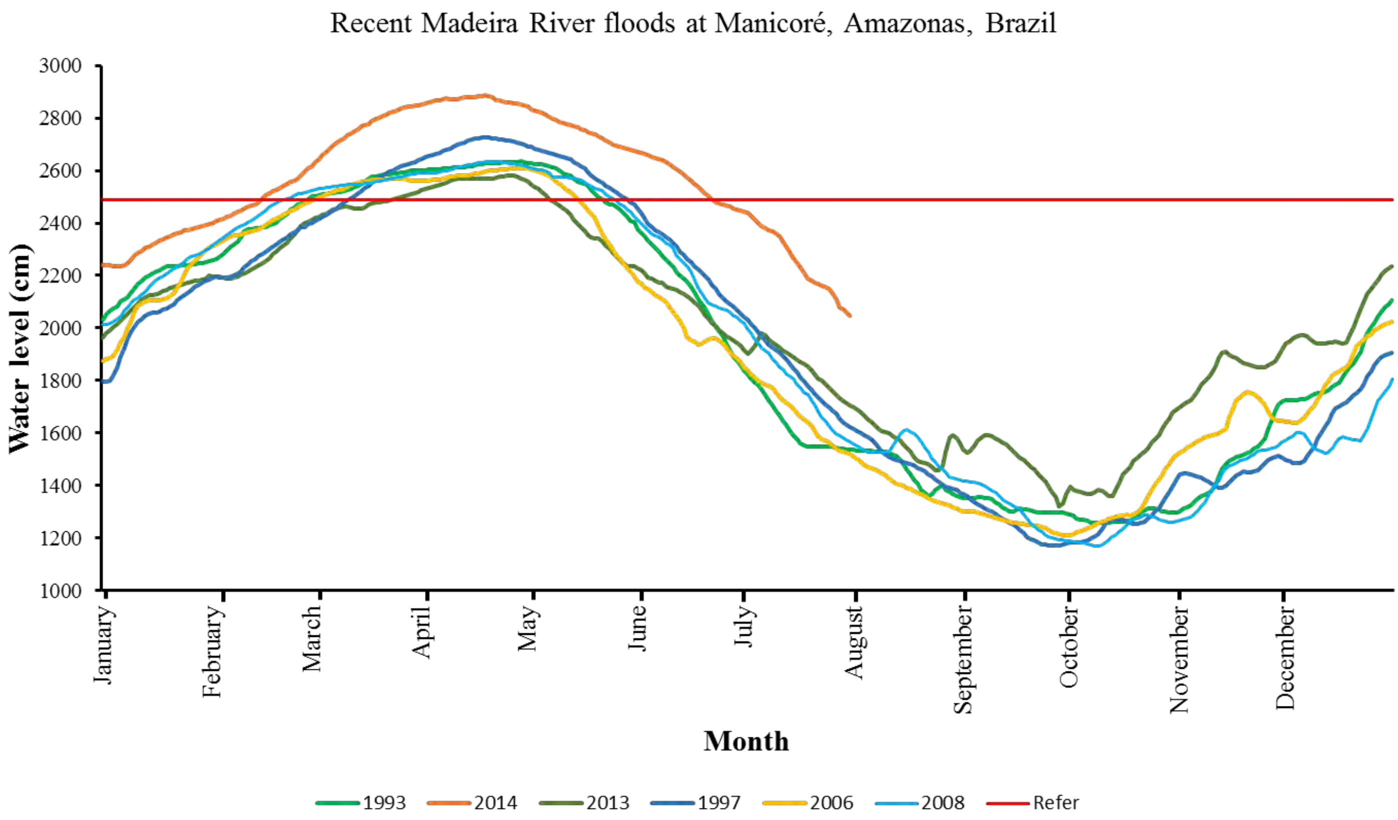

Figure S-5. Comparison of historical Madeira River floods in Manicoré municipality. The reference water level is indicated by the horizontal red line at 2487 cm above mean sea level or a height of 4.6 m above the ground at the location of the lowest Brazilnut tree (the highest floodwater depth observed at the tree). Source: Brazil, ANA (2014).

Figure S-6. Brazilnut trunks affected by pests. Photograph by A.D. Herraiz (2015)

Figure S-7. Brazilnut tree regrowth response after root asphyxia stress for a prolonged period. Photograph by A.D. Herraiz (2015).

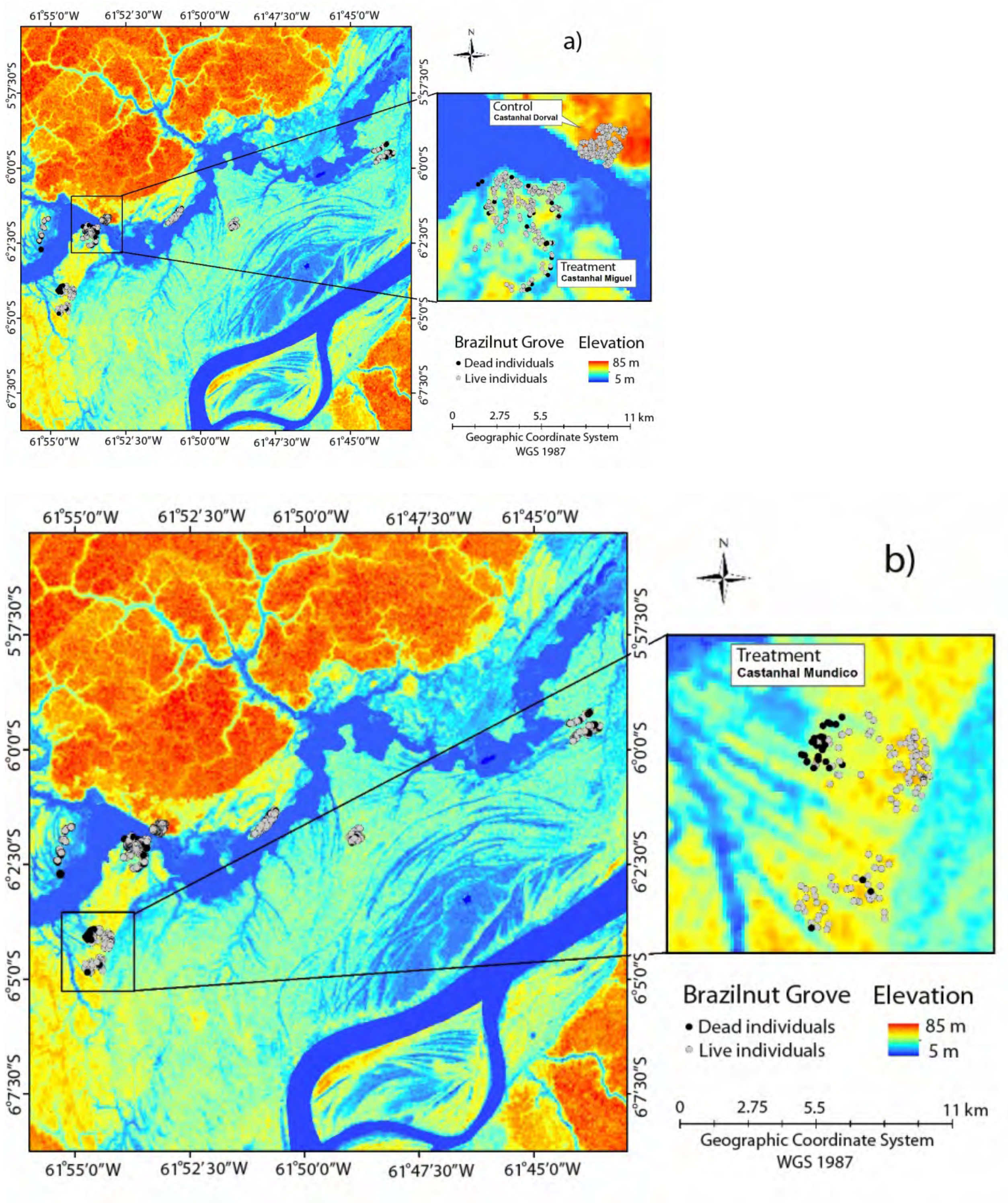

Figure S-8. Locations of trees affected by the 2014 Madeira River flood in the Lago do Capanã Grande Extractive Reserve, Manicoré municipality, Amazonas state, Brazil. Elevation data were derived from a 2015 SRTM image. (**a**): Control Brazilnut grove (Castanhal Dorval) and first treatment grove (Castanhal Miguel); (**b**): Second treatment grove (Castanhal Mundico). Higher mortality in low areas is apparent.

Table S1: Brazilnut trees sampled in Lago do Capanã Grande Extractive Reserve

Brazilnut grove	Tree No.	Date	UTM Coordinates	Status	DBH (cm)	Water depth at tree (cm)	Asphyxia duration (days)
Dorval	427	6 Aug. 2015	20 M 623448 9333475	Live	127.39	0	0
Dorval	430	6 Aug. 2015	20 M 623468 9333491	Live	122.29	0	0
Dorval	431	6 Aug. 2015	20 M 623474 9333497	Live	89.17	0	0
Dorval	432	6 Aug. 2015	20 M 623465 9333509	Live	28.66	0	0
Dorval	433	6 Aug. 2015	20 M 623464 9333511	Live	50.96	0	0
Dorval	434	6 Aug. 2015	20 M 623464 9333507	Live	50.96	0	0
Dorval	436	6 Aug. 2015	20 M 623447 9333510	Live	53.50	0	0
Dorval	437	6 Aug. 2015	20 M 623442 9333509	Live	54.14	0	0
Dorval	438	6 Aug. 2015	20 M 623444 9333514	Live	47.77	0	0
Dorval	439	6 Aug. 2015	20 M 623438 9333518	Live	49.68	0	0
Dorval	440	6 Aug. 2015	20 M 623439 9333515	Live	49.04	0	0
Dorval	441	6 Aug. 2015	20 M 623428 9333507	Live	57.32	0	0
Dorval	442	6 Aug. 2015	20 M 623403 9333502	Live	85.99	0	0
Dorval	443	6 Aug. 2015	20 M 623414 9333542	Live	82.80	0	0
Dorval	444	6 Aug. 2015	20 M 623422 9333558	Live	57.32	0	0
Dorval	445	6 Aug. 2015	20 M 623457 9333512	Live	93.95	0	0
Dorval	446	6 Aug. 2015	20 M 623446 9333534	Live	52.87	0	0
Dorval	447	6 Aug. 2015	20 M 623451 9333539	Live	73.89	0	0
Dorval	448	6 Aug. 2015	20 M 623432 9333550	Live	60.51	0	0
Dorval	449	6 Aug. 2015	20 M 623422 9333562	Live	136.94	0	0
Dorval	450	6 Aug. 2015	20 M 623417 9333565	Live	63.69	0	0
Dorval	451	6 Aug. 2015	20 M 623415 9333578	Live	89.17	0	0
Dorval	452	6 Aug. 2015	20 M 623415 9333578	Live	87.90	0	0
Dorval	453	6 Aug. 2015	20 M 623393 9333568	Live	70.06	0	0
Dorval	454	6 Aug. 2015	20 M 623393 9333571	Live	63.69	0	0
Dorval	455	6 Aug. 2015	20 M 623396 9333576	Live	65.92	0	0
Dorval	456	6 Aug. 2015	20 M 623376 9333582	Live	42.04	0	0
Dorval	457	6 Aug. 2015	20 M 623396 9333594	Live	75.16	0	0
Dorval	458	6 Aug. 2015	20 M 623494 9333616	Live	77.39	0	0
Dorval	459	6 Aug. 2015	20 M 623499 9333638	Live	76.43	0	0
Dorval	460	6 Aug. 2015	20 M 623495 9333647	Live	69.43	0	0
Dorval	461	6 Aug. 2015	20 M 623526 9333663	Live	226.11	0	0
Dorval	462	6 Aug. 2015	20 M 623516 9333686	Live	54.14	0	0
Dorval	463	6 Aug. 2015	20 M 623510 9333695	Live	63.69	0	0
Dorval	464	6 Aug. 2015	20 M 623513 9333709	Live	84.08	0	0
Dorval	465	6 Aug. 2015	20 M 623514 9333713	Live	57.96	0	0
Dorval	466	6 Aug. 2015	20 M 623504 9333702	Live	41.40	0	0
Dorval	467	6 Aug. 2015	20 M 623500 9333696	Live	73.25	0	0
Dorval	468	6 Aug. 2015	20 M 623504 9333691	Live	57.32	0	0
Dorval	469	6 Aug. 2015	20 M 623475 9333686	Live	89.17	0	0
Dorval	470	6 Aug. 2015	20 M 623462 9333687	Live	38.22	0	0

Dorval	471	6 Aug. 2015	20 M 623451 9333677	Live	61.15	0	0
Dorval	472	6 Aug. 2015	20 M 623454 9333667	Live	35.67	0	0
Dorval	473	6 Aug. 2015	20 M 623447 9333662	Live	28.66	0	0
Dorval	474	6 Aug. 2015	20 M 623436 9333683	Live	31.85	0	0
Dorval	475	6 Aug. 2015	20 M 623430 9333688	Live	28.66	0	0
Dorval	476	6 Aug. 2015	20 M 623426 9333687	Live	79.62	0	0
Dorval	477	6 Aug. 2015	20 M 623424 9333687	Live	12.74	0	0
Dorval	478	6 Aug. 2015	20 M 623422 9333696	Live	101.91	0	0
Dorval	263	6 Aug. 2015	20 M 623012 9333474	Live	21.02	0	0
Dorval	265	6 Aug. 2015	20 M 623004 9333468	Live	87.90	0	0
Dorval	284	6 Aug. 2015	20 M 622999 9333482	Live	49.36	0	0
Dorval	286	6 Aug. 2015	20 M 623011 9333496	Live	79.62	0	0
Dorval	287	6 Aug. 2015	20 M 623028 9333533	Live	105.10	0	0
Dorval	288	6 Aug. 2015	20 M 623036 9333541	Live	35.03	0	0
Dorval	289	6 Aug. 2015	20 M 623047 9333542	Live	60.51	0	0
Dorval	290	6 Aug. 2015	20 M 623026 9333547	Live	152.87	0	0
Dorval	291	6 Aug. 2015	20 M 623026 9333551	Live	79.62	0	0
Dorval	292	6 Aug. 2015	20 M 623045 9333555	Live	82.80	0	0
Dorval	293	6 Aug. 2015	20 M 623064 9333558	Live	31.85	0	0
Dorval	294	6 Aug. 2015	20 M 623089 9333549	Live	109.87	0	0
Dorval	296	6 Aug. 2015	20 M 623126 9333536	Live	39.81	0	0
Dorval	297	6 Aug. 2015	20 M 623133 9333541	Live	79.62	0	0
Dorval	303	6 Aug. 2015	20 M 623139 9333571	Live	156.05	0	0
Dorval	304	6 Aug. 2015	20 M 623138 9333570	Live	60.51	0	0
Dorval	305	6 Aug. 2015	20 M 623137 9333555	Live	79.62	0	0
Dorval	306	6 Aug. 2015	20 M 623138 9333555	Live	54.14	0	0
Dorval	311	6 Aug. 2015	20 M 623165 9333545	Live	11.15	0	0
Dorval	312	6 Aug. 2015	20 M 623157 9333525	Live	50.96	0	0
Dorval	315	6 Aug. 2015	20 M 623196 9333563	Live	55.73	0	0
Dorval	316	6 Aug. 2015	20 M 623204 9333558	Live	66.88	0	0
Dorval	317	6 Aug. 2015	20 M 623206 9333567	Live	61.15	0	0
Dorval	319	6 Aug. 2015	20 M 623237 9333570	Live	100.64	0	0
Dorval	320	6 Aug. 2015	20 M 623225 9333586	Live	78.03	0	0
Dorval	321	6 Aug. 2015	20 M 623231 9333607	Live	69.43	0	0
Dorval	322	6 Aug. 2015	20 M 623273 9333564	Live	65.92	0	0
Dorval	323	6 Aug. 2015	20 M 623284 9333574	Live	71.02	0	0
Dorval	324	6 Aug. 2015	20 M 623309 9333592	Live	114.65	0	0
Dorval	325	6 Aug. 2015	20 M 623324 9333598	Live	114.65	0	0
Dorval	326	6 Aug. 2015	20 M 623303 9333614	Live	99.36	0	0
Dorval	327	6 Aug. 2015	20 M 623301 9333639	Live	97.13	0	0
Dorval	328	6 Aug. 2015	20 M 623284 9333643	Live	105.10	0	0
Dorval	329	6 Aug. 2015	20 M 623277 9333628	Live	84.39	0	0
Dorval	330	6 Aug. 2015	20 M 623269 9333607	Live	84.39	0	0
Dorval	331	6 Aug. 2015	20 M 623274 9333669	Live	54.14	0	0
Dorval	332	6 Aug. 2015	20 M 623279 9333677	Live	52.23	0	0
Dorval	333	6 Aug. 2015	20 M 623261 9333663	Live	89.17	0	0

Dorval	334	6 Aug. 2015	20 M 623210 9333680	Live	71.34	0	0
Dorval	335	6 Aug. 2015	20 M 623231 9333695	Live	65.29	0	0
Dorval	336	6 Aug. 2015	20 M 623225 9333711	Live	79.62	0	0
Dorval	337	6 Aug. 2015	20 M 623258 9333724	Live	15.92	0	0
Dorval	338	6 Aug. 2015	20 M 623252 9333735	Live	44.59	0	0
Dorval	339	6 Aug. 2015	20 M 623260 9333735	Live	25.48	0	0
Dorval	340	6 Aug. 2015	20 M 623257 9333714	Live	57.32	0	0
Dorval	341	6 Aug. 2015	20 M 623272 9333727	Live	79.62	0	0
Dorval	342	6 Aug. 2015	20 M 623288 9333733	Live	82.80	0	0
Dorval	343	6 Aug. 2015	20 M 623300 9333712	Live	27.39	0	0
Dorval	344	6 Aug. 2015	20 M 623306 9333703	Live	81.53	0	0
Dorval	345	6 Aug. 2015	20 M 623310 9333689	Live	98.73	0	0
Dorval	346	6 Aug. 2015	20 M 623309 9333728	Live	138.54	0	0
Dorval	347	6 Aug. 2015	20 M 623330 9333719	Live	77.07	0	0
Dorval	348	6 Aug. 2015	20 M 623319 9333729	Live	24.20	0	0
Dorval	349	6 Aug. 2015	20 M 623349 9333744	Live	88.22	0	0
Dorval	350	6 Aug. 2015	20 M 623352 9333715	Live	79.62	0	0
Dorval	351	6 Aug. 2015	20 M 623352 9333700	Live	101.91	0	0
Dorval	352	6 Aug. 2015	20 M 623368 9333690	Live	50.96	0	0
Dorval	353	6 Aug. 2015	20 M 623361 9333681	Live	96.50	0	0
Dorval	355	6 Aug. 2015	20 M 623339 9333640	Live	41.40	0	0
Dorval	358	6 Aug. 2015	20 M 623389 9333702	Live	81.85	0	0
Dorval	359	6 Aug. 2015	20 M 623340 9333625	Live	13.38	0	0
Dorval	361	6 Aug. 2015	20 M 623301 9333511	Live	82.80	0	0
Dorval	362	6 Aug. 2015	20 M 623294 9333503	Live	77.39	0	0
Dorval	363	6 Aug. 2015	20 M 623291 9333479	Live	101.91	0	0
Dorval	365	6 Aug. 2015	20 M 623361 9333483	Live	102.87	0	0
Dorval	368	6 Aug. 2015	20 M 623355 9333466	Live	76.43	0	0
Dorval	376	6 Aug. 2015	20 M 623335 9333438	Live	35.99	0	0
Dorval	377	6 Aug. 2015	20 M 623301 9333450	Live	222.93	0	0
Dorval	378	6 Aug. 2015	20 M 623273 9333418	Live	87.26	0	0
Dorval	379	6 Aug. 2015	20 M 623334 9333416	Live	66.88	0	0
Dorval	380	6 Aug. 2015	20 M 623342 9333423	Live	63.69	0	0
Dorval	381	6 Aug. 2015	20 M 623333 9333405	Live	92.36	0	0
Dorval	382	6 Aug. 2015	20 M 623336 9333393	Live	77.71	0	0
Dorval	383	6 Aug. 2015	20 M 623301 9333365	Live	103.50	0	0
Dorval	384	6 Aug. 2015	20 M 623302 9333360	Live	79.62	0	0
Dorval	385	6 Aug. 2015	20 M 623302 9333359	Live	100.00	0	0
Dorval	386	6 Aug. 2015	20 M 623323 9333347	Live	98.73	0	0
Dorval	387	6 Aug. 2015	20 M 623331 9333350	Live	93.63	0	0
Dorval	388	6 Aug. 2015	20 M 623318 9333339	Live	65.61	0	0
Dorval	389	6 Aug. 2015	20 M 623322 9333335	Live	78.03	0	0
Dorval	390	6 Aug. 2015	20 M 623323 9333333	Live	87.58	0	0
Dorval	391	6 Aug. 2015	20 M 623286 9333305	Live	62.42	0	0
Dorval	392	6 Aug. 2015	20 M 623298 9333286	Live	101.91	0	0
Dorval	393	6 Aug. 2015	20 M 623320 9333281	Live	107.64	0	0

Dorval	394	6 Aug. 2015	20 M 623348 9333296	Live	96.18	0	0
Dorval	395	6 Aug. 2015	20 M 623329 9333317	Live	125.48	0	0
Dorval	396	6 Aug. 2015	20 M 623339 9333323	Live	85.99	0	0
Dorval	398	6 Aug. 2015	20 M 623336 9333335	Live	79.62	0	0
Dorval	400	6 Aug. 2015	20 M 623360 9333347	Live	66.88	0	0
Dorval	402	6 Aug. 2015	20 M 623363 9333342	Live	22.29	0	0
Dorval	403	6 Aug. 2015	20 M 623367 9333366	Live	149.68	0	0
Dorval	405	6 Aug. 2015	20 M 623378 9333388	Live	36.62	0	0
Dorval	406	6 Aug. 2015	20 M 623385 9333401	Live	79.62	0	0
Dorval	407	6 Aug. 2015	20 M 623393 9333395	Live	63.69	0	0
Dorval	408	6 Aug. 2015	20 M 623402 9333393	Live	16.88	0	0
Dorval	409	6 Aug. 2015	20 M 623392 9333399	Live	89.17	0	0
Dorval	410	6 Aug. 2015	20 M 623391 9333400	Live	70.06	0	0
Dorval	411	6 Aug. 2015	20 M 623381 9333416	Live	55.73	0	0
Dorval	412	6 Aug. 2015	20 M 623365 9333441	Live	89.17	0	0
Dorval	413	6 Aug. 2015	20 M 623383 9333448	Live	89.17	0	0
Dorval	415	6 Aug. 2015	20 M 623382 9333452	Live	49.68	0	0
Dorval	416	6 Aug. 2015	20 M 623399 9333446	Live	70.06	0	0
Dorval	417	6 Aug. 2015	20 M 623411 9333449	Live	49.36	0	0
Dorval	420	6 Aug. 2015	20 M 623411 9333456	Live	91.72	0	0
Dorval	421	6 Aug. 2015	20 M 623419 9333449	Live	125.80	0	0
Dorval	423	6 Aug. 2015	20 M 623437 9333453	Live	53.50	0	0
Dorval	425	6 Aug. 2015	20 M 623441 9333471	Live	76.43	0	0
Dorval	119	6 Aug. 2015	20 M 623047 9333450	Live	90.76	0	0
Dorval	120	6 Aug. 2015	20 M 623043 9333462	Live	35.03	0	0
Dorval	121	6 Aug. 2015	20 M 623022 9333470	Live	105.10	0	0
Dorval	122	6 Aug. 2015	20 M 623070 9333435	Live	108.28	0	0
Dorval	125	6 Aug. 2015	20 M 623063 9333408	Live	73.25	0	0
Dorval	126	6 Aug. 2015	20 M 623044 9333414	Live	82.80	0	0
Dorval	128	6 Aug. 2015	20 M 623038 9333398	Live	127.39	0	0
Dorval	129	6 Aug. 2015	20 M 623034 9333395	Live	63.69	0	0
Dorval	130	6 Aug. 2015	20 M 623049 9333393	Live	66.88	0	0
Dorval	131	6 Aug. 2015	20 M 623052 9333400	Live	19.11	0	0
Dorval	134	6 Aug. 2015	20 M 623055 9333410	Live	22.29	0	0
Dorval	136	6 Aug. 2015	20 M 623064 9333412	Live	101.91	0	0
Dorval	137	6 Aug. 2015	20 M 623065 9333409	Live	55.73	0	0
Dorval	139	6 Aug. 2015	20 M 623072 9333406	Live	95.54	0	0
Dorval	140	6 Aug. 2015	20 M 623080 9333400	Live	70.06	0	0
Dorval	141	6 Aug. 2015	20 M 623093 9333385	Live	70.06	0	0
Dorval	142	6 Aug. 2015	20 M 623086 9333382	Live	108.28	0	0
Dorval	143	6 Aug. 2015	20 M 623119 9333382	Live	98.73	0	0
Dorval	144	6 Aug. 2015	20 M 623120 9333373	Live	60.51	0	0
Dorval	145	6 Aug. 2015	20 M 623128 9333368	Live	85.99	0	0
Dorval	146	6 Aug. 2015	20 M 623138 9333365	Live	41.40	0	0
Dorval	147	6 Aug. 2015	20 M 623126 9333396	Live	41.40	0	0
Dorval	148	6 Aug. 2015	20 M 623126 9333391	Live	108.28	0	0

Dorval	150	6 Aug. 2015	20 M 623114 9333393	Live	117.83	0	0
Dorval	151	6 Aug. 2015	20 M 623130 9333407	Live	78.66	0	0
Dorval	152	6 Aug. 2015	20 M 623136 9333401	Live	57.32	0	0
Dorval	176	6 Aug. 2015	20 M 623261 9333372	Live	108.28	0	0
Dorval	177	6 Aug. 2015	20 M 623243 9333397	Live	105.10	0	0
Dorval	178	6 Aug. 2015	20 M 623252 9333387	Live	117.83	0	0
Dorval	180	6 Aug. 2015	20 M 623210 9333382	Live	73.25	0	0
Dorval	181	6 Aug. 2015	20 M 623202 9333384	Live	31.85	0	0
Dorval	182	6 Aug. 2015	20 M 623197 9333394	Live	60.51	0	0
Dorval	183	6 Aug. 2015	20 M 623212 9333396	Live	117.83	0	0
Dorval	184	6 Aug. 2015	20 M 623207 9333418	Live	92.36	0	0
Dorval	185	6 Aug. 2015	20 M 623235 9333419	Live	9.55	0	0
Dorval	186	6 Aug. 2015	20 M 623236 9333426	Live	76.43	0	0
Dorval	187	6 Aug. 2015	20 M 623228 9333456	Live	38.22	0	0
Dorval	188	6 Aug. 2015	20 M 623262 9333453	Live	57.32	0	0
Dorval	189	6 Aug. 2015	20 M 623281 9333458	Live	73.25	0	0
Dorval	190	6 Aug. 2015	20 M 623245 9333488	Live	54.78	0	0
Dorval	191	6 Aug. 2015	20 M 623244 9333500	Live	92.36	0	0
Dorval	192	6 Aug. 2015	20 M 623239 9333504	Live	29.62	0	0
Dorval	193	6 Aug. 2015	20 M 623270 9333509	Live	47.77	0	0
Dorval	194	6 Aug. 2015	20 M 623279 9333502	Live	76.43	0	0
Dorval	195	6 Aug. 2015	20 M 623287 9333501	Live	70.06	0	0
Dorval	196	6 Aug. 2015	20 M 623292 9333518	Live	79.62	0	0
Dorval	197	6 Aug. 2015	20 M 623285 9333532	Live	66.88	0	0
Dorval	198	6 Aug. 2015	20 M 623240 9333523	Live	68.47	0	0
Dorval	199	6 Aug. 2015	20 M 623231 9333529	Live	64.65	0	0
Dorval	205	6 Aug. 2015	20 M 623184 9333505	Live	20.06	0	0
Dorval	206	6 Aug. 2015	20 M 623167 9333507	Live	85.99	0	0
Dorval	208	6 Aug. 2015	20 M 623170 9333493	Live	82.80	0	0
Dorval	209	6 Aug. 2015	20 M 623171 9333489	Live	42.36	0	0
Dorval	211	6 Aug. 2015	20 M 623174 9333485	Live	107.01	0	0
Dorval	214	6 Aug. 2015	20 M 623197 9333430	Live	73.25	0	0
Dorval	215	6 Aug. 2015	20 M 623205 9333428	Live	76.43	0	0
Dorval	216	6 Aug. 2015	20 M 623197 9333430	Live	89.17	0	0
Dorval	217	6 Aug. 2015	20 M 623182 9333438	Live	57.32	0	0
Dorval	218	6 Aug. 2015	20 M 623181 9333430	Live	28.66	0	0
Dorval	219	6 Aug. 2015	20 M 623160 9333420	Live	100.00	0	0
Dorval	220	6 Aug. 2015	20 M 623164 9333405	Live	95.54	0	0
Dorval	221	6 Aug. 2015	20 M 623161 9333469	Live	85.99	0	0
Dorval	223	6 Aug. 2015	20 M 623159 9333485	Live	71.66	0	0
Dorval	225	6 Aug. 2015	20 M 623163 9333496	Live	50.96	0	0
Dorval	227	6 Aug. 2015	20 M 623158 9333479	Live	56.69	0	0
Dorval	229	6 Aug. 2015	20 M 623133 9333479	Live	68.47	0	0
Dorval	230	6 Aug. 2015	20 M 623125 9333487	Live	58.60	0	0
Dorval	231	6 Aug. 2015	20 M 623125 9333481	Live	95.54	0	0
Dorval	233	6 Aug. 2015	20 M 623120 9333510	Live	95.54	0	0

Dorval	234	6 Aug. 2015	20 M 623106 9333483	Live	128.34	0	0
Dorval	236	6 Aug. 2015	20 M 623152 9333446	Live	85.99	0	0
Dorval	237	6 Aug. 2015	20 M 623156 9333444	Live	76.43	0	0
Dorval	238	6 Aug. 2015	20 M 623153 9333429	Live	63.69	0	0
Dorval	239	6 Aug. 2015	20 M 623145 9333405	Live	87.58	0	0
Dorval	241	6 Aug. 2015	20 M 623112 9333412	Live	81.53	0	0
Dorval	242	6 Aug. 2015	20 M 623113 9333416	Live	101.91	0	0
Dorval	243	6 Aug. 2015	20 M 623127 9333429	Live	92.36	0	0
Dorval	244	6 Aug. 2015	20 M 623121 9333433	Live	85.99	0	0
Dorval	245	6 Aug. 2015	20 M 623096 9333425	Live	81.53	0	0
Dorval	249	6 Aug. 2015	20 M 623075 9333424	Live	112.42	0	0
Dorval	250	6 Aug. 2015	20 M 623078 9333424	Live	75.16	0	0
Dorval	254	6 Aug. 2015	20 M 623063 9333460	Live	62.74	0	0
Dorval	256	6 Aug. 2015	20 M 623078 9333456	Live	43.31	0	0
Dorval	257	6 Aug. 2015	20 M 623078 9333454	Live	42.68	0	0
Dorval	258	6 Aug. 2015	20 M 623077 9333482	Live	33.44	0	0
Dorval	259	6 Aug. 2015	20 M 623077 9333479	Live	79.62	0	0
Dorval	260	6 Aug. 2015	20 M 623040 9333438	Live	54.14	0	0
Dorval	261	6 Aug. 2015	20 M 623025 9333438	Live	15.92	0	0
Dorval	262	6 Aug. 2015	20 M 623022 9333485	Live	85.99	0	0
Mundico	523	5 Aug. 2015	20 M 620289 9327943	Live	52.55	30	30
Mundico	55	5 Aug. 2015	20 M 621027 9329219	Live	133.76	0	0
Mundico	56	5 Aug. 2015	20 M 621033 9329154	Live	85.99	0	0
Mundico	57	5 Aug. 2015	20 M 621071 9329169	Live	82.80	0	0
Mundico	58	5 Aug. 2015	20 M 621116 9329252	Live	117.83	0	0
Mundico	59	5 Aug. 2015	20 M 621161 9329255	Live	57.32	0	0
Mundico	60	5 Aug. 2015	20 M 621199 9329258	Live	57.32	0	0
Mundico	61	5 Aug. 2015	20 M 621190 9329296	Live	127.39	0	0
Mundico	62	5 Aug. 2015	20 M 621228 9329302	Live	106.69	0	0
Mundico	63	5 Aug. 2015	20 M 621234 9329310	Live	130.57	0	0
Mundico	64	5 Aug. 2015	20 M 621244 9329301	Live	103.18	0	0
Mundico	65	5 Aug. 2015	20 M 621229 9329346	Live	85.99	0	0
Mundico	66	5 Aug. 2015	20 M 621235 9329234	Live	127.39	0	0
Mundico	67	5 Aug. 2015	20 M 621203 9329218	Live	127.39	0	0
Mundico	68	5 Aug. 2015	20 M 621247 9329179	Live	111.46	0	0
Mundico	69	5 Aug. 2015	20 M 621275 9329164	Live	41.40	0	0
Mundico	70	5 Aug. 2015	20 M 621284 9329159	Live	60.51	0	0
Mundico	71	5 Aug. 2015	20 M 621321 9329166	Live	130.57	0	0
Mundico	72	5 Aug. 2015	20 M 621320 9329185	Live	68.47	0	0
Rosland	500	15 Aug. 2015	20 M 622702 9333066	Live	108.28	30	34.4
Rosland	504	15 Aug. 2015	20 M 622707 9333021	Live	143.31	30	34.4
Mundico	75	5 Aug. 2015	20 M 621211 9329148	Live	125.80	0	0
Mundico	76	5 Aug. 2015	20 M 621245 9329150	Live	63.69	0	0
Mundico	77	5 Aug. 2015	20 M 621231 9329102	Live	148.73	0	0
Mundico	78	5 Aug. 2015	20 M 621221 9329099	Live	89.17	0	0
Mundico	79	5 Aug. 2015	20 M 621227 9329051	Live	146.50	0	0

Rosland	505	15 Aug. 2015	20 M 622704 9333013	Live	95.54	30	34.4
Rosland	631	15 Aug. 2015	20 M 622487 9332764	Dead	152.87	30	34.4
Rosland	635	15 Aug. 2015	20 M 622444 9332734	Dead	171.97	30	34.4
Mundico	493	7 Aug. 2015	20 M 620874 9327975	Live	133.76	40	37.0
Mundico	494	7 Aug. 2015	20 M 620863 9327975	Live	130.57	40	37.0
Mundico	86	7 Aug. 2015	20 M 621176 9328970	Live	127.39	50	39.7
Mundico	485	7 Aug. 2015	20 M 621020 9328262	Live	146.50	50	39.7
Rosland	668	15 Aug. 2015	20 M 622414 9332611	Dead	143.31	50	39.7
Rosland	610	15 Aug. 2015	20 M 622448 9333010	Live	50.96	50	39.7
Rosland	611	15 Aug. 2015	20 M 622441 9332998	Live	66.88	50	39.7
Mundico	98	5 Aug. 2015	20 M 621294 9329098	Live	88.54	60	42.3
Rosland	462	15 Aug. 2015	20 M 622798 9333026	Live	25.48	60	42.3
Rosland	465	15 Aug. 2015	20 M 622811 9333060	Live	36.62	60	42.3
Rosland	482	15 Aug. 2015	20 M 622719 9333078	Live	152.87	60	42.3
Rosland	506	15 Aug. 2015	20 M 622694 9332991	Live	117.83	60	42.3
Rosland	569	15 Aug. 2015	20 M 622479 9333018	Live	63.69	60	42.3
Rosland	571	15 Aug. 2015	20 M 622478 9333009	Live	11.15	60	42.3
Rosland	572	15 Aug. 2015	20 M 622474 9333003	Live	54.14	60	42.3
Rosland	573	15 Aug. 2015	20 M 622480 9333000	Live	35.03	60	42.3
Rosland	574	15 Aug. 2015	20 M 622474 9333013	Live	85.99	60	42.3
Mundico	103	5 Aug. 2015	20 M 621256 9328884	Live	165.61	0	0
Mundico	521	7 Aug. 2015	20 M 620308 9327912	Live	70.06	70	45.0
Mundico	105	5 Aug. 2015	20 M 621184 9328931	Live	92.36	0	0
Mundico	106	5 Aug. 2015	20 M 621192 9328948	Live	111.46	0	0
Mundico	524	7 Aug. 2015	20 M 620338 9327987	Live	76.43	70	45.0
Rosland	463	15 Aug. 2015	20 M 622818 9333058	Live	19.11	70	45.0
Rosland	464	15 Aug. 2015	20 M 622814 9333061	Live	38.22	70	45.0
Rosland	565	15 Aug. 2015	20 M 622492 9333025	Live	47.77	70	45.0
Rosland	613	15 Aug. 2015	20 M 622458 9332906	Live	73.25	70	45.0
Mundico	84	5 Aug. 2015	20 M 621079 9329052	Live	86.62	75	46.3
Mundico	85	5 Aug. 2015	20 M 621081 9329043	Live	54.14	75	46.3
Mundico	54	5 Aug. 2015	20 M 620943 9329288	Live	95.54	80	47.6
Mundico	74	5 Aug. 2015	20 M 621312 9329269	Live	63.69	80	47.6
Rosland	496	15 Aug. 2015	20 M 622752 9333009	Live	95.54	80	47.6
Rosland	542	15 Aug. 2015	20 M 622497 9332997	Live	85.99	80	47.6
Mundico	495	7 Aug. 2015	20 M 620774 9327955	Live	105.10	82	48.2
Mundico	486	7 Aug. 2015	20 M 620957 9328225	Live	79.62	85	49.0
Mundico	53	5 Aug. 2015	20 M 620851 9329491	Live	95.54	90	50.3
Mundico	507	7 Aug. 2015	20 M 620583 9328079	Live	21.34	90	50.3
Rosland	530	15 Aug. 2015	20 M 622548 9332983	Live	57.32	90	50.3
Rosland	531	15 Aug. 2015	20 M 622551 9332977	Live	78.03	90	50.3
Rosland	607	15 Aug. 2015	20 M 622441 9333036	Live	85.99	90	50.3
Mundico	109	5 Aug. 2015	20 M 621036 9328795	Live	121.02	100	52.9
Mundico	110	5 Aug. 2015	20 M 621085 9328761	Live	100.32	100	52.9
Mundico	505	7 Aug. 2015	20 M 620672 9328056	Live	66.88	100	52.9
Rosland	754	15 Aug. 2015	20 M 622763 9332817	Live	57.32	100	52.9

Rosland	477	15 Aug. 2015	20 M 622739 9333084	Live	63.06	100	52.9
Rosland	497	15 Aug. 2015	20 M 622763 9333002	Live	9.55	100	52.9
Rosland	563	15 Aug. 2015	20 M 622502 9333035	Live	41.40	100	52.9
Rosland	644	15 Aug. 2015	20 M 622323 9332907	Live	127.39	100	52.9
Rosland	664	15 Aug. 2015	20 M 622397 9332538	Live	41.40	100	52.9
Rosland	666	15 Aug. 2015	20 M 622412 9332513	Live	108.28	100	52.9
Rosland	673	15 Aug. 2015	20 M 622491 9332580	Live	19.11	110	55.6
Rosland	674	15 Aug. 2015	20 M 622476 9332569	Live	92.36	110	55.6
Rosland	709	15 Aug. 2015	20 M 622589 9332193	Live	143.31	110	55.6
Rosland	770	15 Aug. 2015	20 M 622653 9332894	Live	87.58	110	55.6
Rosland	519	15 Aug. 2015	20 M 622573 9332990	Live	12.74	110	55.6
Rosland	612	15 Aug. 2015	20 M 622479 9332977	Live	50.96	110	55.6
Rosland	779	15 Aug. 2015	20 M 622654 9332979	Live	27.07	115	56.9
Rosland	780	15 Aug. 2015	20 M 622651 9332981	Live	113.69	115	56.9
Rosland	781	15 Aug. 2015	20 M 622652 9332975	Live	15.92	115	56.9
Mundico	82	5 Aug. 2015	20 M 621132 9329040	Live	87.58	120	58.2
Mundico	511	7 Aug. 2015	20 M 620482 9327876	Live	152.87	120	58.2
Mundico	489	7 Aug. 2015	20 M 620941 9327983	Live	97.13	120	58.2
Rosland	671	15 Aug. 2015	20 M 622489 9332609	Live	66.88	120	58.2
Rosland	682	15 Aug. 2015	20 M 622504 9332464	Live	90.76	120	58.2
Rosland	748	15 Aug. 2015	20 M 622777 9332803	Live	44.59	120	58.2
Rosland	749	15 Aug. 2015	20 M 622778 9332805	Live	60.51	120	58.2
Rosland	753	15 Aug. 2015	20 M 622771 9332821	Live	22.29	120	58.2
Rosland	516	15 Aug. 2015	20 M 622593 9332987	Live	63.69	120	58.2
Mundico	97	5 Aug. 2015	20 M 621318 9329063	Live	73.25	125	59.6
Mundico	73	5 Aug. 2015	20 M 621324 9329209	Live	98.73	130	60.9
Mundico	519	7 Aug. 2015	20 M 620380 9327783	Live	130.57	130	60.9
Mundico	487	7 Aug. 2015	20 M 620902 9328232	Live	57.32	130	60.9
Mundico	490	7 Aug. 2015	20 M 620981 9327867	Live	82.80	130	60.9
Mundico	496	7 Aug. 2015	20 M 620746 9327963	Live	101.91	130	60.9
Mundico	501	7 Aug. 2015	20 M 620848 9328164	Live	57.32	130	60.9
Mundico	509	7 Aug. 2015	20 M 620544 9328155	Live	95.54	130	60.9
Rosland	750	15 Aug. 2015	20 M 622766 9332814	Live	73.25	130	60.9
Mundico	111	5 Aug. 2015	20 M 621078 9328711	Live	76.43	140	63.5
Rosland	667	15 Aug. 2015	20 M 622441 9332571	Live	105.10	140	63.5
Rosland	768	15 Aug. 2015	20 M 622664 9332890	Live	57.32	140	63.5
Rosland	769	15 Aug. 2015	20 M 622657 9332882	Live	22.29	140	63.5
Mundico	513	7 Aug. 2015	20 M 620443 9327838	Live	85.99	0	0
Mundico	514	7 Aug. 2015	20 M 620434 9327807	Live	121.02	0	0
Mundico	515	7 Aug. 2015	20 M 620522 9327769	Live	175.16	0	0
Mundico	516	7 Aug. 2015	20 M 620506 9327725	Live	98.73	0	0
Rosland	525	15 Aug. 2015	20 M 622549 9332994	Live	76.43	140	63.5
Rosland	539	15 Aug. 2015	20 M 622511 9333020	Live	57.32	145	64.9
Rosland	540	15 Aug. 2015	20 M 622509 9333017	Live	23.57	145	64.9
Mundico	520	7 Aug. 2015	20 M 620328 9327875	Live	66.88	0	0
Rosland	541	15 Aug. 2015	20 M 622502 9333012	Live	19.11	145	64.9

Mundico	83	5 Aug. 2015	20 M 621105 9329081	Live	60.51	150	66.2
Mundico	51	5 Aug. 2015	20 M 620894 9329443	Live	63.69	150	66.2
Mundico	517	7 Aug. 2015	20 M 620431 9327745	Live	130.57	150	66.2
Mundico	522	7 Aug. 2015	20 M 620270 9327903	Live	98.73	150	66.2
Mundico	488	7 Aug. 2015	20 M 620947 9328084	Live	130.57	150	66.2
Rosland	681	15 Aug. 2015	20 M 622509 9332457	Live	66.88	150	66.2
Rosland	512	15 Aug. 2015	20 M 622618 9332996	Live	117.83	150	66.2
Rosland	559	15 Aug. 2015	20 M 622503 9333045	Live	82.80	150	66.2
Mundico	107	5 Aug. 2015	20 M 621112 9328889	Live	76.43	160	68.8
Mundico	483	7 Aug. 2015	20 M 620852 9328345	Live	137.58	0	0
Mundico	484	7 Aug. 2015	20 M 620939 9328310	Live	114.65	0	0
Rosland	466	15 Aug. 2015	20 M 622813 9333062	Live	73.25	160	68.8
Rosland	513	15 Aug. 2015	20 M 622599 9332996	Live	165.61	160	68.8
Rosland	514	15 Aug. 2015	20 M 622601 9332990	Live	28.66	160	68.8
Rosland	526	15 Aug. 2015	20 M 622547 9332992	Live	25.48	160	68.8
Rosland	543	15 Aug. 2015	20 M 622502 9333023	Live	42.36	160	68.8
Rosland	548	15 Aug. 2015	20 M 622517 9333033	Live	14.01	160	68.8
Mundico	87	5 Aug. 2015	20 M 621236 9329015	Live	95.54	170	71.5
Mundico	491	7 Aug. 2015	20 M 620982 9327813	Live	117.83	170	71.5
Mundico	497	7 Aug. 2015	20 M 620729 9327958	Live	85.99	170	71.5
Mundico	499	7 Aug. 2015	20 M 620849 9328010	Live	79.62	170	71.5
Rosland	705	15 Aug. 2015	20 M 622617 9332361	Live	175.16	170	71.5
Rosland	507	15 Aug. 2015	20 M 622668 9333029	Live	101.91	170	71.5
Rosland	537	15 Aug. 2015	20 M 622538 9333011	Live	41.40	170	71.5
Rosland	538	15 Aug. 2015	20 M 622539 9333011	Live	9.55	170	71.5
Rosland	557	15 Aug. 2015	20 M 622508 9333047	Live	12.74	170	71.5
Rosland	558	15 Aug. 2015	20 M 622507 9333047	Live	19.11	170	71.5
Mundico	529	7 Aug. 2015	20 M 620425 9327947	Live	117.83	176	73.1
Mundico	96	5 Aug. 2015	20 M 621337 9329051	Live	111.46	180	74.1
Mundico	104	5 Aug. 2015	20 M 621239 9328847	Live	95.54	180	74.1
Rosland	669	15 Aug. 2015	20 M 622480 9332628	Live	66.88	180	74.1
Rosland	670	15 Aug. 2015	20 M 622481 9332630	Live	44.59	180	74.1
Rosland	775	15 Aug. 2015	20 M 622701 9332938	Live	146.50	180	74.1
Rosland	776	15 Aug. 2015	20 M 622695 9332942	Live	101.91	180	74.1
Rosland	536	15 Aug. 2015	20 M 622542 9333012	Live	40.45	180	74.1
Rosland	774	15 Aug. 2015	20 M 622684 9332922	Live	50.96	185	75.5
Rosland	520	15 Aug. 2015	20 M 622560 9332993	Live	31.85	185	75.5
Mundico	46	5 Aug. 2015	20 M 620633 9329323	Live	168.79	190	76.8
Mundico	47	5 Aug. 2015	20 M 620637 9329327	Live	22.29	190	76.8
Mundico	52	5 Aug. 2015	20 M 620858 9329483	Live	98.73	190	76.8
Mundico	504	7 Aug. 2015	20 M 620707 9328066	Live	89.17	190	76.8
Rosland	745	15 Aug. 2015	20 M 622784 9332803	Live	98.73	190	76.8
Rosland	746	15 Aug. 2015	20 M 622789 9332801	Live	38.22	190	76.8
Rosland	747	15 Aug. 2015	20 M 622790 9332802	Live	15.92	190	76.8
Rosland	521	15 Aug. 2015	20 M 622556 9332992	Live	19.11	190	76.8
Rosland	545	15 Aug. 2015	20 M 622513 9333033	Live	14.01	190	76.8

Rosland	547	15 Aug. 2015	20 M 622516 9333032	Live	47.77	190	76.8
Mundico	492	7 Aug. 2015	20 M 620891 9328004	Live	38.22	195	78.1
Mundico	80	5 Aug. 2015	20 M 621223 9329011	Live	44.59	200	79.4
Mundico	95	5 Aug. 2015	20 M 621356 9328985	Live	41.40	200	79.4
Mundico	45	5 Aug. 2015	20 M 620693 9329347	Live	111.46	200	79.4
Mundico	48	5 Aug. 2015	20 M 620852 9329336	Live	57.32	200	79.4
Betinho	131	11 Aug. 2015	20 M 640483 9337270	Live	72.29	200	79.4
Betinho	132	11 Aug. 2015	20 M 640480 9337287	Live	94.27	200	79.4
Rosland	772	15 Aug. 2015	20 M 622671 9332895	Live	82.80	200	79.4
Rosland	478	15 Aug. 2015	20 M 622728 9333096	Dead	82.80	200	79.4
Rosland	480	15 Aug. 2015	20 M 622727 9333101	Live	54.14	200	79.4
Rosland	532	15 Aug. 2015	20 M 622537 9332999	Live	45.86	200	79.4
Rosland	534	15 Aug. 2015	20 M 622542 9333002	Live	81.21	200	79.4
Rosland	535	15 Aug. 2015	20 M 622550 9333007	Live	45.86	200	79.4
Rosland	554	15 Aug. 2015	20 M 622504 9333047	Live	43.31	200	79.4
Rosland	603	15 Aug. 2015	20 M 622424 9333060	Live	38.22	200	79.4
Rosland	605	15 Aug. 2015	20 M 622405 9333053	Live	98.73	200	79.4
Mundico	49	5 Aug. 2015	20 M 620856 9329326	Live	15.92	205	80.8
Mundico	526	7 Aug. 2015	20 M 620334 9328057	Live	73.25	205	80.8
Mundico	20	5 Aug. 2015	20 M 620597 9329000	Live	58.92	207	81.3
Mundico	88	5 Aug. 2015	20 M 621285 9328986	Live	164.01	210	82.1
Mundico	89	5 Aug. 2015	20 M 621301 9328977	Live	176.75	210	82.1
Mundico	512	7 Aug. 2015	20 M 620492 9327908	Live	114.65	210	82.1
Mundico	518	7 Aug. 2015	20 M 620381 9327739	Dead	95.54	210	82.1
Mundico	528	7 Aug. 2015	20 M 620413 9328003	Live	114.65	210	82.1
Betinho	149	11 Aug. 2015	20 M 640044 9337173	Live	66.88	210	82.1
Rosland	744	15 Aug. 2015	20 M 622796 9332794	Live	73.25	210	82.1
Rosland	593	15 Aug. 2015	20 M 622450 9333062	Live	70.06	210	82.1
Rosland	645	15 Aug. 2015	20 M 622314 9332932	Live	95.54	210	82.1
Mundico	10	5 Aug. 2015	20 M 620419 9329072	Live	35.03	220	84.7
Mundico	16	5 Aug. 2015	20 M 620501 9329103	Dead	133.76	220	84.7
Mundico	502	7 Aug. 2015	20 M 620803 9328134	Dead	57.32	220	84.7
Mundico	508	7 Aug. 2015	20 M 620543 9328088	Live	63.69	220	84.7
Rosland	765	15 Aug. 2015	20 M 622675 9332882	Live	38.22	220	84.7
Rosland	499	15 Aug. 2015	20 M 622777 9332996	Live	22.29	220	84.7
Rosland	515	15 Aug. 2015	20 M 622590 9333001	Live	38.22	220	84.7
Betinho	147	11 Aug. 2015	20 M 640060 9337258	Live	45.54	226	86.3
Rosland	688	15 Aug. 2015	20 M 622581 9332461	Live	31.85	230	87.4
Rosland	689	15 Aug. 2015	20 M 622591 9332462	Live	52.55	230	87.4
Rosland	527	15 Aug. 2015	20 M 622546 9332992	Live	22.29	230	87.4
Rosland	528	15 Aug. 2015	20 M 622542 9332994	Live	82.80	230	87.4
Rosland	529	15 Aug. 2015	20 M 622543 9332991	Live	49.36	230	87.4
Betinho	148	11 Aug. 2015	20 M 640036 9337239	Live	178.34	235	88.7
Betinho	118	11 Aug. 2015	20 M 640799 9337422	Live	67.83	236	89.0
Betinho	119	11 Aug. 2015	20 M 640798 9337412	Live	70.06	236	89.0
Mundico	11	5 Aug. 2015	20 M 620416 9329081	Live	57.32	240	90.0

Mundico	12	5 Aug. 2015	20 M 620429 9329114	Live	96.82	240	90.0
Betinho	154	11 Aug. 2015	20 M 639930 9337114	Live	33.44	240	90.0
Betinho	153	11 Aug. 2015	20 M 639948 9337130	Live	127.39	240	90.0
Betinho	122	11 Aug. 2015	20 M 640648 9337376	Live	172.61	240	90.0
Betinho	123	11 Aug. 2015	20 M 640651 9337375	Live	192.68	240	90.0
Mundico	19	5 Aug. 2015	20 M 620610 9328993	Live	132.17	245	91.4
Mundico	50	5 Aug. 2015	20 M 620872 9329353	Live	87.58	248	92.1
Mundico	38	5 Aug. 2015	20 M 620531 9329252	Live	23.57	250	92.7
Mundico	527	7 Aug. 2015	20 M 620398 9328050	Live	62.74	250	92.7
Betinho	128	11 Aug. 2015	20 M 640527 9337305	Live	82.48	250	92.7
Betinho	143	11 Aug. 2015	20 M 640098 9337305	Live	143.31	250	92.7
Rosland	755	15 Aug. 2015	20 M 622746 9332825	Live	54.14	250	92.7
Rosland	756	15 Aug. 2015	20 M 622742 9332824	Live	25.48	250	92.7
Mundico	18	5 Aug. 2015	20 M 620557 9329070	Live	130.57	255	94.0
Mundico	525	7 Aug. 2015	20 M 620294 9328086	Live	76.43	260	95.3
Rosland	683	15 Aug. 2015	20 M 622559 9332418	Dead	66.88	260	95.3
Rosland	696	15 Aug. 2015	20 M 622700 9332429	Live	28.66	260	95.3
Rosland	697	15 Aug. 2015	20 M 622699 9332423	Live	60.51	260	95.3
Rosland	698	15 Aug. 2015	20 M 622700 9332418	Live	19.11	260	95.3
Rosland	699	15 Aug. 2015	20 M 622706 9332426	Live	54.14	260	95.3
Mundico	4	5 Aug. 2015	20 M 620301 9329163	Dead	46.82	265	96.7
Rosland	602	15 Aug. 2015	20 M 622430 9333066	Dead	54.14	265	96.7
Mundico	81	5 Aug. 2015	20 M 621199 9329013	Live	98.73	270	98.0
Mundico	5	5 Aug. 2015	20 M 620310 9329161	Dead	43.63	270	98.0
Mundico	6	5 Aug. 2015	20 M 620327 9329157	Dead	181.53	270	98.0
Mundico	500	7 Aug. 2015	20 M 620845 9328096	Live	38.22	270	98.0
Mundico	506	7 Aug. 2015	20 M 620578 9328053	Live	79.62	270	98.0
Betinho	120	11 Aug. 2015	20 M 640750 9337422	Live	147.13	270	98.0
Betinho	121	11 Aug. 2015	20 M 640745 9337419	Live	164.65	270	98.0
Betinho	168	11 Aug. 2015	20 M 640117 9337217	Live	179.30	270	98.0
Mundico	13	5 Aug. 2015	20 M 620440 9329121	Dead	63.69	272	98.5
Mundico	24	5 Aug. 2015	20 M 620495 9329244	Dead	149.68	280	100.6
Mundico	42	5 Aug. 2015	20 M 620541 9329417	Dead	73.25	280	100.6
Mundico	44	5 Aug. 2015	20 M 620636 9329471	Dead	89.17	280	100.6
Betinho	133	11 Aug. 2015	20 M 640481 9337317	Live	84.39	280	100.6
Betinho	129	11 Aug. 2015	20 M 640511 9337265	Live	140.13	280	100.6
Betinho	130	11 Aug. 2015	20 M 640505 9337221	Live	143.31	280	100.6
Mundico	23	5 Aug. 2015	20 M 620478 9329223	Dead	108.28	290	103.3
Mundico	25	5 Aug. 2015	20 M 620484 9329228	Dead	31.85	290	103.3
Betinho	61	11 Aug. 2015	20 M 640417 9338083	Live	106.37	290	103.3
Betinho	150	11 Aug. 2015	20 M 640028 9337149	Dead	53.82	292	103.8
Betinho	151	11 Aug. 2015	20 M 640009 9337136	Live	63.06	292	103.8
Rosland	675	15 Aug. 2015	20 M 622510 9332554	Live	108.28	0	0
Rosland	676	15 Aug. 2015	20 M 622539 9332559	Live	89.17	0	0
Rosland	677	15 Aug. 2015	20 M 622539 9332553	Live	19.11	0	0
Rosland	678	15 Aug. 2015	20 M 622547 9332552	Live	130.57	0	0

Rosland	679	15 Aug. 2015	20 M 622549 9332523	Live	121.02	0	0
Rosland	680	15 Aug. 2015	20 M 622538 9332488	Live	127.39	0	0
Mundico	90	5 Aug. 2015	20 M 621303 9328968	Live	63.69	300	105.9
Mundico	91	5 Aug. 2015	20 M 621305 9328959	Dead	84.71	300	105.9
Mundico	99	5 Aug. 2015	20 M 621304 9328948	Live	50.96	300	105.9
Mundico	101	5 Aug. 2015	20 M 621306 9328934	Live	89.17	300	105.9
Mundico	108	5 Aug. 2015	20 M 621081 9328867	Live	106.69	300	105.9
Mundico	21	5 Aug. 2015	20 M 620637 9329080	Dead	108.28	300	105.9
Mundico	43	5 Aug. 2015	20 M 620585 9329412	Dead	44.59	300	105.9
Mundico	498	7 Aug. 2015	20 M 620869 9328039	Dead	73.25	300	105.9
Mundico	503	7 Aug. 2015	20 M 620746 9328149	Live	98.73	300	105.9
Betinho	127	11 Aug. 2015	20 M 640535 9337307	Live	26.43	300	105.9
Betinho	126	11 Aug. 2015	20 M 640544 9337294	Live	29.30	300	105.9
Betinho	171	11 Aug. 2015	20 M 640131 9337248	Live	35.99	300	105.9
Betinho	124	11 Aug. 2015	20 M 640605 9337294	Live	39.49	300	105.9
Betinho	136	11 Aug. 2015	20 M 640290 9337373	Live	61.78	300	105.9
Betinho	125	11 Aug. 2015	20 M 640564 9337293	Dead	66.88	300	105.9
Betinho	173	11 Aug. 2015	20 M 640124 9337270	Live	92.36	300	105.9
Betinho	172	11 Aug. 2015	20 M 640129 9337255	Live	92.99	300	105.9
Rosland	735	15 Aug. 2015	20 M 622762 9332711	Live	76.43	300	105.9
Rosland	736	15 Aug. 2015	20 M 622759 9332707	Live	70.06	300	105.9
Rosland	710	15 Aug. 2015	20 M 622582 9332139	Live	235.67	0	0
Rosland	737	15 Aug. 2015	20 M 622758 9332707	Live	28.66	300	105.9
Rosland	762	15 Aug. 2015	20 M 622693 9332797	Dead	46.18	300	105.9
Rosland	517	15 Aug. 2015	20 M 622580 9332998	Live	38.22	300	105.9
Rosland	518	15 Aug. 2015	20 M 622569 9332993	Live	25.48	300	105.9
Betinho	164	11 Aug. 2015	20 M 640031 9337072	Live	163.69	309	108.3
Betinho	163	11 Aug. 2015	20 M 640023 9337079	Live	174.20	309	108.3
Betinho	162	11 Aug. 2015	20 M 640007 9337084	Dead	176.75	309	108.3
Betinho	165	11 Aug. 2015	20 M 640057 9337095	Live	187.26	309	108.3
Mundico	100	5 Aug. 2015	20 M 621308 9328931	Live	39.81	310	108.6
Mundico	113	5 Aug. 2015	20 M 621237 9328715	Live	89.17	310	108.6
Mundico	40	5 Aug. 2015	20 M 620480 9329399	Dead	104.14	310	108.6
Betinho	155	11 Aug. 2015	20 M 639923 9337081	Live	57.96	310	108.6
Betinho	174	11 Aug. 2015	20 M 640131 9337282	Live	115.61	310	108.6
Rosland	695	15 Aug. 2015	20 M 622688 9332426	Dead	73.25	310	108.6
Mundico	114	5 Aug. 2015	20 M 620790 9328996	Live	44.59	315	109.9
Mundico	27	5 Aug. 2015	20 M 620430 9329237	Dead	64.65	315	109.9
Mundico	102	5 Aug. 2015	20 M 621290 9328824	Live	114.65	320	111.2
Mundico	36	5 Aug. 2015	20 M 620491 9329280	Dead	89.17	320	111.2
Mundico	39	5 Aug. 2015	20 M 620607 9329219	Live	89.17	320	111.2
Betinho	117	11 Aug. 2015	20 M 640883 9337449	Live	43.95	320	111.2
Betinho	170	11 Aug. 2015	20 M 640091 9337231	Live	63.69	320	111.2
Betinho	169	11 Aug. 2015	20 M 640096 9337228	Live	100.64	320	111.2
Betinho	138	11 Aug. 2015	20 M 640208 9337356	Live	105.73	320	111.2
Betinho	140	11 Aug. 2015	20 M 640232 9337305	Live	249.04	320	111.2

Rosland	694	15 Aug. 2015	20 M 622672 9332428	Live	89.17	320	111.2
Rosland	719	15 Aug. 2015	20 M 622688 9332307	Live	38.22	320	111.2
Rosland	757	15 Aug. 2015	20 M 622728 9332824	Live	101.91	320	111.2
Rosland	758	15 Aug. 2015	20 M 622731 9332830	Live	12.74	320	111.2
Rosland	759	15 Aug. 2015	20 M 622710 9332809	Live	15.92	320	111.2
Betinho	134	11 Aug. 2015	20 M 640392 9337379	Live	47.13	324	112.3
Mundico	9	5 Aug. 2015	20 M 620403 9329053	Dead	84.71	330	113.9
Mundico	33	5 Aug. 2015	20 M 620434 9329296	Dead	121.02	330	113.9
Mundico	41	5 Aug. 2015	20 M 620520 9329425	Dead	92.36	330	113.9
Betinho	161	11 Aug. 2015	20 M 639920 9337046	Live	56.69	330	113.9
Rosland	687	15 Aug. 2015	20 M 622588 9332452	Live	57.32	330	113.9
Rosland	717	15 Aug. 2015	20 M 622690 9332259	Dead	63.69	330	113.9
Mundico	26	5 Aug. 2015	20 M 620474 9329201	Dead	68.47	334	114.9
Betinho	160	11 Aug. 2015	20 M 639927 9337038	Live	73.25	335	115.2
Mundico	479	7 Aug. 2015	20 M 620536 9328921	Live	81.21	340	116.5
Betinho	107	11 Aug. 2015	20 M 640886 9337521	Live	49.68	340	116.5
Betinho	111	11 Aug. 2015	20 M 640951 9337480	Dead	81.85	340	116.5
Betinho	109	11 Aug. 2015	20 M 640879 9337504	Live	100.64	340	116.5
Betinho	106	11 Aug. 2015	20 M 640888 9337537	Live	122.61	340	116.5
Rosland	458	15 Aug. 2015	20 M 622820 9333049	Live	57.32	0	0
Rosland	459	15 Aug. 2015	20 M 622817 9333048	Live	15.92	0	0
Rosland	460	15 Aug. 2015	20 M 622817 9333049	Live	38.22	0	0
Rosland	692	15 Aug. 2015	20 M 622640 9332423	Dead	57.32	340	116.5
Rosland	693	15 Aug. 2015	20 M 622626 9332415	Dead	54.14	340	116.5
Rosland	522	15 Aug. 2015	20 M 622550 9332997	Live	15.92	340	116.5
Rosland	523	15 Aug. 2015	20 M 622549 9332999	Live	41.40	340	116.5
Mundico	32	5 Aug. 2015	20 M 620438 9329275	Live	74.52	345	117.9
Betinho	112	11 Aug. 2015	20 M 640978 9337530	Dead	271.66	346	118.1
Mundico	22	5 Aug. 2015	20 M 620616 9329109	Live	121.97	350	119.2
Mundico	37	5 Aug. 2015	20 M 620523 9329286	Live	57.32	350	119.2
Betinho	141	11 Aug. 2015	20 M 640189 9337347	Live	103.18	350	119.2
Rosland	711	15 Aug. 2015	20 M 622621 9332096	Live	82.80	350	119.2
Rosland	712	15 Aug. 2015	20 M 622650 9332068	Dead	140.13	350	119.2
Rosland	486	15 Aug. 2015	20 M 622723 9333062	Live	168.79	0	0
Rosland	489	15 Aug. 2015	20 M 622744 9333058	Live	47.77	0	0
Rosland	490	15 Aug. 2015	20 M 622753 9333050	Live	114.65	0	0
Rosland	491	15 Aug. 2015	20 M 622760 9333046	Live	127.39	0	0
Rosland	492	15 Aug. 2015	20 M 622767 9333034	Live	136.94	0	0
Rosland	493	15 Aug. 2015	20 M 622766 9333034	Live	50.96	0	0
Rosland	494	15 Aug. 2015	20 M 622783 9333038	Live	73.25	0	0
Rosland	495	15 Aug. 2015	20 M 622794 9333044	Live	79.62	0	0
Rosland	760	15 Aug. 2015	20 M 622709 9332809	Live	66.88	350	119.2
Rosland	761	15 Aug. 2015	20 M 622700 9332807	Live	19.11	350	119.2
Mundico	28	5 Aug. 2015	20 M 620388 9329267	Dead	121.02	352	119.7
Mundico	29	5 Aug. 2015	20 M 620403 9329264	Dead	16.24	352	119.7
Mundico	30	5 Aug. 2015	20 M 620400 9329271	Dead	22.29	352	119.7

Mundico	17	5 Aug. 2015	20 M 620531 9329053	Dead	143.31	355	120.5
Mundico	14	5 Aug. 2015	20 M 620437 9329130	Dead	101.91	360	121.8
Betinho	13	11 Aug. 2015	20 M 639750 9337702	Live	46.50	360	121.8
Betinho	114	11 Aug. 2015	20 M 641005 9337587	Live	104.46	360	121.8
Betinho	14	11 Aug. 2015	20 M 639758 9337709	Live	116.88	360	121.8
Rosland	684	15 Aug. 2015	20 M 622559 9332418	Live	63.69	360	121.8
Rosland	685	15 Aug. 2015	20 M 622563 9332421	Live	14.33	360	121.8
Rosland	713	15 Aug. 2015	20 M 622678 9332146	Live	21.02	360	121.8
Rosland	714	15 Aug. 2015	20 M 622679 9332147	Dead	47.77	360	121.8
Rosland	467	15 Aug. 2015	20 M 622807 9333079	Live	79.62	360	121.8
Mundico	7	5 Aug. 2015	20 M 620349 9329106	Dead	57.32	365	123.2
Mundico	8	5 Aug. 2015	20 M 620345 9329101	Dead	28.66	365	123.2
Betinho	41	11 Aug. 2015	20 M 640048 9337752	Live	53.18	370	124.5
Betinho	36	11 Aug. 2015	20 M 640015 9337759	Live	60.51	370	124.5
Betinho	35	11 Aug. 2015	20 M 639977 9337732	Live	64.33	370	124.5
Betinho	40	11 Aug. 2015	20 M 640020 9337731	Live	92.68	370	124.5
Betinho	158	11 Aug. 2015	20 M 639906 9336975	Live	60.83	376	126.1
Betinho	156	11 Aug. 2015	20 M 639912 9337016	Live	64.33	376	126.1
Betinho	157	11 Aug. 2015	20 M 639918 9336990	Live	85.99	376	126.1
Mundico	34	5 Aug. 2015	20 M 620462 9329310	Dead	121.02	380	127.1
Mundico	35	5 Aug. 2015	20 M 620482 9329305	Dead	107.64	380	127.1
Betinho	33	11 Aug. 2015	20 M 639950 9337743	Live	52.87	380	127.1
Betinho	34	11 Aug. 2015	20 M 639958 9337727	Live	58.92	380	127.1
Rosland	718	11 Aug. 2015	20 M 622699 9332288	Live	41.40	380	127.1
Rosland	691	15 Aug. 2015	20 M 622638 9332428	Dead	57.32	385	128.5
Betinho	77	11 Aug. 2015	20 M 640564 9338094	Live	44.90	390	129.8
Betinho	78	11 Aug. 2015	20 M 640556 9338093	Live	70.38	390	129.8
Betinho	79	11 Aug. 2015	20 M 640538 9338121	Live	73.25	390	129.8
Mundico	15	5 Aug. 2015	20 M 620440 9329150	Dead	56.37	400	132.4
Mundico	31	5 Aug. 2015	20 M 620406 9329295	Dead	66.88	400	132.4
Betinho	103	11 Aug. 2015	20 M 640776 9337626	Dead	33.12	400	132.4
Betinho	104	11 Aug. 2015	20 M 640796 9337633	Dead	54.14	400	132.4
Betinho	55	11 Aug. 2015	20 M 640341 9337918	Live	56.37	400	132.4
Betinho	105	11 Aug. 2015	20 M 640796 9337638	Dead	58.92	400	132.4
Betinho	49	11 Aug. 2015	20 M 640284 9337906	Live	66.24	400	132.4
Betinho	54	11 Aug. 2015	20 M 640336 9337924	Live	83.76	400	132.4
Betinho	102	11 Aug. 2015	20 M 640708 9337639	Dead	97.77	400	132.4
Betinho	74	11 Aug. 2015	20 M 640531 9338058	Dead	117.83	400	132.4
Betinho	47	11 Aug. 2015	20 M 640181 9337810	Dead	188.54	400	132.4
Rosland	715	15 Aug. 2015	20 M 622678 9332169	Live	46.18	400	132.4
Rosland	763	15 Aug. 2015	20 M 622694 9332875	Dead	70.06	400	132.4
Betinho	43	11 Aug. 2015	20 M 640109 9337777	Live	54.78	403	133.2
Betinho	42	11 Aug. 2015	20 M 640066 9337800	Live	100.32	403	133.2
Betinho	19	11 Aug. 2015	20 M 639790 9337693	Live	28.34	410	135.1
Betinho	25	11 Aug. 2015	20 M 639859 9337679	Live	35.03	410	135.1
Betinho	22	11 Aug. 2015	20 M 639794 9337679	Dead	44.59	410	135.1

Betinho	86	11 Aug. 2015	20 M 640579 9338108	Live	70.06	410	135.1
Betinho	82	11 Aug. 2015	20 M 640608 9338180	Live	71.97	410	135.1
Betinho	17	11 Aug. 2015	20 M 639754 9337718	Live	72.93	410	135.1
Betinho	83	11 Aug. 2015	20 M 640631 9338154	Live	76.43	410	135.1
Betinho	26	11 Aug. 2015	20 M 639860 9337642	Live	105.73	410	135.1
Betinho	20	11 Aug. 2015	20 M 639791 9337694	Dead	114.33	410	135.1
Betinho	23	11 Aug. 2015	20 M 639812 9337690	Live	114.97	410	135.1
Betinho	84	11 Aug. 2015	20 M 640597 9338130	Dead	200.64	410	135.1
Rosland	468	15 Aug. 2015	20 M 622807 9333078	Live	95.54	410	135.1
Rosland	498	15 Aug. 2015	20 M 622769 9332987	Live	117.83	410	135.1
Betinho	101	11 Aug. 2015	20 M 640643 9337604	Live	34.08	440	143.0
Rosland	614	15 Aug. 2015	20 M 622469 9332896	Live	41.40	0	0
Rosland	615	15 Aug. 2015	20 M 622475 9332886	Live	38.22	0	0
Rosland	616	15 Aug. 2015	20 M 622490 9332887	Live	47.77	0	0
Rosland	618	15 Aug. 2015	20 M 622473 9332870	Live	108.28	0	0
Rosland	619	15 Aug. 2015	20 M 622461 9332875	Live	50.96	0	0
Rosland	620	15 Aug. 2015	20 M 622461 9332857	Live	19.11	0	0
Rosland	621	15 Aug. 2015	20 M 622478 9332861	Live	15.92	0	0
Rosland	622	15 Aug. 2015	20 M 622490 9332853	Live	70.06	0	0
Rosland	623	15 Aug. 2015	20 M 622470 9332856	Live	27.07	0	0
Rosland	624	15 Aug. 2015	20 M 622446 9332843	Live	54.14	0	0
Rosland	625	15 Aug. 2015	20 M 622458 9332833	Live	111.46	0	0
Rosland	626	15 Aug. 2015	20 M 622471 9332815	Live	79.62	0	0
Rosland	627	15 Aug. 2015	20 M 622481 9332800	Live	140.13	0	0
Rosland	629	15 Aug. 2015	20 M 622487 9332788	Live	76.43	0	0
Betinho	100		20 M 640541 9337587	Dead	46.18	440	143.0
Rosland	632	15 Aug. 2015	20 M 622465 9332779	Live	76.43	0	0
Rosland	634	15 Aug. 2015	20 M 622451 9332750	Live	200.64	0	0
Betinho	98	11 Aug. 2015	20 M 640550 9337619	Live	85.99	440	143.0
Rosland	637	15 Aug. 2015	20 M 622450 9332796	Live	24.84	0	0
Rosland	638	15 Aug. 2015	20 M 622437 9332809	Live	70.06	0	0
Rosland	639	15 Aug. 2015	20 M 622418 9332826	Live	111.46	0	0
Rosland	640	15 Aug. 2015	20 M 622422 9332840	Live	66.88	0	0
Rosland	641	15 Aug. 2015	20 M 622388 9332872	Live	76.43	0	0
Rosland	642	15 Aug. 2015	20 M 622380 9332860	Live	95.54	0	0
Rosland	643	15 Aug. 2015	20 M 622362 9332890	Live	152.87	0	0
Betinho	99	15 Aug. 2015	20 M 640557 9337600	Live	119.43	440	143.0
Rosland	742	15 Aug. 2015	20 M 622777 9332734	Live	31.85	450	145.7
Rosland	648	15 Aug. 2015	20 M 622317 9332848	Live	66.88	0	0
Rosland	649	15 Aug. 2015	20 M 622316 9332838	Live	17.52	0	0
Rosland	652	15 Aug. 2015	20 M 622333 9332734	Live	38.22	0	0
Rosland	653	15 Aug. 2015	20 M 622340 9332690	Live	79.62	0	0
Rosland	740	15 Aug. 2015	20 M 622768 9332715	Live	38.22	460	148.3
Rosland	741	15 Aug. 2015	20 M 622774 9332724	Dead	66.88	460	148.3

Table S-2. Mortality in Brazilnut trees (*B. excelsa*, H. & B.) as a function of DBH (cm) for all trees sampled. DBH = diameter at breast height (1.3 m above the ground).

DBH (cm)	Live (No.)	Dead (No.)	Total (No.)	Live (%)	Dead (%)
0-10	2	0	2	100	0
10-20	24	1	25	96	4
20-30	22	2	24	91.7	8.3
30-40	25	2	27	92.6	7.4
40-50	29	7	36	80.6	19.4
50-60	35	10	45	77.8	22.2
60-70	34	8	42	81	19
70-80	39	4	43	90.7	9.3
80-90	32	6	38	84.2	15.8
90-100	27	3	30	90	10
100-110	22	5	27	81.5	18.5
110-120	22	2	24	91.7	8.3
120-130	14	3	17	82.4	17.6
130-140	13	1	14	92.9	7.1
140-150	11	4	15	73.3	26.7
150-160	3	1	4	75	25
160-170	7	0	7	100	0
170-180	7	2	9	77.8	22.2
180-190	2	1	3	66.7	33.3
190-200	1	0	1	100	0
200-210	2	0	2	100	0
210-220	0	0	0	-	-
220-230	1	0	1	100	0
230-240	0	0	0	-	-
240-250	1	0	1	100	0
250-260	0	0	0	-	-
260-270	0	1	1	0.0	100
Total	375	63	438	85.6	14.4

Table S-3: Mortality in Brazilnut trees as a function of duration of asphyxia

Asphyxia (days)	Mortality (%)	N
80-90	18	17
90-100	19	32
100-110	35	46
110-120	33	43
120-130	29	28
130-140	43	28
140-150	29	7

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