DOI: 10.1007/s10745-011-9400-4

ISSN: 0300-7839

Yanomami Mobility and Its Effects on the Forest Landscape[1]

Maurice Seiji Tomioka Nilsson ·● Philip Martin Fearnside

Abstract The Yanomami are a hunter-gatherer and gardener people with high mobility, wich influences the regeneration of forest in agricultural clearings. Increasing contact with the wider Brazilian and Venezuelan societies may lead to sedentarization. Population groups and clearings were mapped in the Yanomami Land in Brazil using four mosaics of Landsat images from within a two-year period. The mosaics were separated by intervals of seven years. Few groups were sedentary, and most of these maintained alternative residences. The Yanomami cleared 16,856 ha (0.17% of the Yanomami territory in Brazil) over the 21 years covered by this study. Individuals in mobile groups deforested more than those in sedentary groups, but secondary-forest regeneration occurs mainly in clearings made by mobile groups. Permanent settlements had impeded regeneration of 48% (2025 ha) of the area cleared prior to 1988. Access to health care has led to population growth but has not increased sedentarization.

keywords: Amazon rainforest, Forest regeneration, Human ecology, Landscape, Yanomami

----

M.S.T. Nilsson, · P.M. Fearnside

Instituto Nacional de Pesquisas da Amazônia - INPA

Coordenação de Pesquisas em Ecologia

Av. André Araújo, 2936

69060-001 Manaus, Amazonas, Brazil

e-mail: mauricetomioka@gmail.com

Yanomami Mobility and Its Effects on the Forest Landscape

Introduction

The Yanomami are a society of hunter-gatherers and gardeners in the Amazon forests of Venezuela and Brazil, with a relatively recent history of contact. They are characterized by wide mobility over the territory they occupy, fusing and splitting their communities and changing their occupation sites periodically. Yanomami territorial practices have been intensively studied using ecological approaches (Chagnon and Hames 1979; Colchester 1982; Good 1989; Hames 1995; Harris 1984; Lizot 1978; Smole 1976), and from a socio-political and ethnographic standpoint (Albert 1985; Chagnon 1992; Ferguson 1995; Lizot 1977).

The Yanomami began living with more intense contact with the surrounding society after the mid-1980s when their territory was invaded by gold miners (*garimpeiros*) who inflicted impacts on health and demographics. The Yanomami already lived in contact with religious missions and government outposts since the 1960s (Albert 1985) (Fig. 1). Assistance posts proliferated following the organization of the government health system, demarcation of the territory in 1991 and the approval of the Yanomami Indigenous Land (*Terra Indígena Yanomami* = TIY) in May 1992. Therefore, the population censuses of communities have become more systematic. The censuses show decreased infant mortality and increased population size (Gomez 2008).

[Fig. 1 here]

The Yanomami have organized themselves to meet the challenges of contact, culminating with the establishment in 2005 of the Hutukara Yanomami Association (Nilsson 2011). The population has expressed a clear position in defense of its territory, through the Hutukara Yanomami Association (FBV 2010). This association is currently present throughout the Yanomami territory, with a communications network and trails that interconnect the communities. This has made it possible for the problems of any community to be known and shared by others. This communication functions well despite the image of rivalry and warmongering that has been attributed to the Yanomami (e.g. Chagnon 1988, 1992; Lima and Pozzobon 2005).

Following contact with state-based societies there has been significant sedentarization and changes in patterns of mobility for most of the known indigenous societies in Amazonia (Milliken and Albert 1999; Welch *et al.* 2009). The practice of mobility is related to access to natural resources and may contribute to the maintenance of forest.

Indigenous forms of agriculture (shifting cultivation using slash-and-burn) can contribute to the maintenance of forest landscapes by causing disturbances at a small scale in the forest. Clearings are opened for cultivation with the assumption that the cultivated areas later regenerate and reestablish the processes that existed in the natural ecosystem (Denevan and Padoch 1987). The landscape resulting from many indigenous agro-ecosystems is a patchwork of forests and areas in regeneration. In indigenous agriculture, the cycle of felling, burning, cultivation, abandonment, and reuse of regeneration to return to a forest landscape is a dynamic process in time. One model for explaining high tropical biodiversity is based on intermediate disturbances that affect forest, allowing its renewal (Connell 1978). Since Amerindian populations were probably larger in the past (Clastres 1973; Denevan 1976), the influence of indigenous shifting cultivation systems in the past is probably reflected in the current forest landscape (Balée 2009). Amerindian demographics were severely affected by epidemics brought with the conquest, which decreased the population significantly. The size of the population is related to the opening of clearings for agriculture. In a study of the presence of pollen of cultivated species, Bush and Silmann (2007) showed that there was a depression in the amount of pollen (and consequently of agricultural activity) associated with the period of discovery. This may have meant a loss of landscape management practices (Clement 2006).

There is, however, the risk of over-utilization of the agro-ecosystem, reducing the capacity for resilience of forest (Lawrence *et al.* 2010). Studies using orbital images have already documented the occupation of areas where population growth and intensification of land use have changed the conditions of regeneration of the forest (Sirén 2007). Landsat images have been shown to be capable of detecting small clearings, including subsistence shifting-cultivation fields and logging activity (Nepstad *et al.* 1999). Bringing together data obtained from satellite imagery and from population censuses makes it possible to establish a correlation between population and the opening of clearings and their temporal dynamics. These dynamics are in flux due to recent events such as permanent contact with religious missions and government outposts, and the invasions that prevent the Yanomami from enjoying the exclusive use of their land as guaranteed by the Brazilian Federal Constitution of 1988 (Article 231).

Debates persist about the role of ecological models for human populations in the Amazon region, especially for those living in a delicate interdependent relationship with natural ecosystems and in relative isolation from trade. Yanomami territorial movement is, in part, related to the characteristics of the forest and the dispersion of game animals because game availability decreases in proportion to the time of residence in a given location (Good 1989). In a study in mountainous regions of Venezuela, Good (1989) reported a 28% decrease in game between the first and second year of residence in a given location. Mobility is seen as an adaptive response to obtaining protein, as is the use of alternative protein sources such as mushrooms (Prance 1987), edible seeds and nuts (some depending on extended treatment to extract toxic substances), and small animals (Colchester 1982; Lizot 1978; Milliken and Albert 1999).

In addition to environmental conditions, we must deal with the territorial relations that the Yanomami treat socially. Albert (1985) described the Yanomami interpretation of disease and death. These events enter as elements directed by enemy Yanomami groups through physical attacks and sorcery, and are mediated by a variety of entities in the land-forest. This also demonstrates the understanding of the Yanomami in regulating political alliances and rivalries, which in turn have an influence on territoriality and on settlement patterns.

Another mechanism is related to the technological revolution that has been brought on by intercultural contact. A historical economic interpretation of Yanomami settlement patterns considers the spatial configuration of settlements to be chosen in order to gain access to exogenous metal tools brought by industrial society (Ferguson 1995).

This is the current theoretical model for explaining how the Yanomami have coped with their way of life as hunter-gatherers and gardeners being revolutionized technologically upon contact. A redistribution of weights can be expected between the use of forest and agriculture: while agriculture and access to tools imply increasing sedentarism, the use of forest and access to game lead to a need for territorial movement. Technological change can result in less effort being necessary for opening swidden fields, leaving more time for activities in the forest. The new technologies are related to rapid population growth and consequent territorial expansion (Harris 1984; Lizot 1984). Sedentarization has already occurred for most of the world's human population, culminating in the advent of the state and the organization of legal ownership of land. Mobile societies are incompatible with the system of private ownership of land, unless they are governed by a different kind of statute (Little 2002), as is the case for indigenous land in Brazil.

The goal of this study is to assess the effect of Yanomami occupation on the forest landscape and test the hypothesis that a change in the pattern of high mobility to one of greater sedentarization leads to predictable changes in the forest ecosystem. Therefore, the aim is to: (1) Detect if there are residential mobility patterns of Yanomami groups over the last twenty years, (2) Detect any change in mobility patterns and in sedentarization, and (3) Make inferences about the regeneration of the forest in clearings produced by the Yanomami with different patterns of mobility. This is important in assessing whether Yanomami agro-ecosystems act as a form of forest protection.

Some predictions

The Yanomami are being induced to become sedentary, as are almost all other Amerindian peoples in contact with wider national societies. Missionaries, both protestant and catholic, have been agents of contact who have been efficiently performing this task. (Laudato 1998; Smiljanic 2006). Outposts of health agencies, Amerindian protection agencies and religious missions can be expected to differ in their effects on Yanomami mobility.

Environmental factors may be tied to the cultural practices of mobility. The ecology of some species that are used as alternative protein sources (Milliken and Albert 1999) is closely associated with regeneration from slash-and-burn agriculture. These include edible mushrooms, insects and their larvae, and many game animals that are associated with these ecosystems. It is expected that patterns of mobility will reveal some return to previously cultivated sites, but where Landsat interpretation indicates secondary forest. It is expected that Yanomami habitations will almost always have regeneration landscapes nearby. Patterns can reveal the reasons for mobility if they indicate movement to a previously occupied place.

Permanent contact tends to discourage warfare, but some practices have increased these conflicts, thereby introducing new elements in Yanomami societal dynamics (Do Pateo 2005; Ferguson 1995). As Ferguson (1995) states, warfare should not lead to population pulverization, but rather to agglomeration. Warfare was the theme of a major academic controversy that has implications for mobility. While there are links between warfare and mobility, we believe that it is possible to have mobility without warfare.

Material and methods

Study area

The present study encompasses the Brazilian portion of the Yanomami Territory: the 9,664,975-ha Yanomami Indigenous Land (4° 20' N to 0° 20' S and 66° 31' to 61° 19' W), that was decreed in Brazil in May 1992. In 2009 the area was home to 18,373 Yanomami, according to the census by the National Foundation for Health (FUNASA, 2009). This population is divided into approximately 210 communities. The term "community" is understood as the co-inhabitants of a location, but the Yanomami concept of community can vary because the populations are continually dividing and regrouping into separate communities. We use the term “population group” to refer to the set of individuals who live in a given area over the course of our 21-year study period (1988-2009) independent of splits and mergers and movements (with consequent name changes) over this period. There were 132 population groups in the Brazilian Yanomami Indigenous Land (TIY), of which we studied 90.

The Yanomami Indigenous Land consists of Amazonian forest and has considerable diversity of topographical features, some of which have characteristics that impose limits on occupation. The Yanomami have expanded their territory from the Serra Parima (Albert and Gomez 1997), which is the largest block of montane forest in the Amazon region. The Serra Parima is located on the border between Brazil and Venezuela and is contiguous with the Siapa, Auaris, Caura and Orinoco Massifs, being treated here as a single morphostructural unit formed from alkaline granitic rocks (Huber *et al*. 1984). The predominant climate is always humid, influenced by the heavy rains brought by trade winds on the Brazilian (east-facing) side of the mountains. It is a dissected plateau that includes the headwaters of various rivers. The Serra Parima is broken into numerous valleys with short distances between them. The soils are residual and tend to be deposited at the foot of the slopes and in the few intermontane sedimentary basins (Brazil 1975). The forest vegetation is only interrupted by the montane grasslands of the Serra de Surucucu (a flat-topped mountain) and the Serra do Uafaranda to the north. Other major features are the Serra da Neblina, the Serra do Tapirapecó and scarps along the border between Venezuela and the Brazilian state of Amazonas. In addition to these highlands (*serras*), there are other isolated mountains of variable size. Beyond the highlands, the TIY has mid-elevation land with an average elevation of 400 m, where the Mucajai and Uraricoera Rivers and their respective tributaries flow.

The lowlands dominate the rest of the territory, with average altitudes of 150 m in the Catrimani, Demini, Padauiri, Aracá, Cauburis and Marauiá Basins. The sedimentary soils of lowland areas overlay crystalline rocks of the Guiana Shield. There are large areas of seasonally flooded wetlands that are unfit for agriculture and are spatially adjacent to montane formations. There are also *campinaranas*, or oligotrophic woody vegetation on white-sand soils.

Data collection

Satellite Images Used

Images from the Landsat 5 satellite's Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper (ETM+) (resolution 30 m) were used for data collection. The entire TIY was covered by images at four predetermined points in time, with a periodicity of seven years: 1988-89, 1994-95, 2001-02 and 2008-09. The criteria for choosing this frequency were availability of images without clouds and the lifespan of swidden fields. Clearings made by the Yanomami for swiddens are described in the literature as being actively cultivated for 3-4 years (Albert 1992; Colchester 1982; Lizot 1980), therefore covering approximately half the length of our intervals. The seven-year interval is long enough to ensure that the end of the cultivation period is reached for any clearing that is visible at the beginning of the interval, and short enough to prevent more than one movement of gardens from occurring within a single interval.

Mapping Clearings

Polygons for all clearings detectable on the images were digitized and their origin was interpreted based on historical knowledge about the region, previous mappings, and prior knowledge of the location of communities and their populations as measured by demographic censuses (2001-08) conducted by FUNASA and by agencies working under agreements with FUNASA. The first author's living with the Yanomami over the 2000-2007 period while working for organizations that were partners of these agencies helped to identify the locations and displacements in area. Previous studies (Albert and Tourneau 2007) helped to refine the visual interpretation techniques.

Mapping was done by visual interpretation on a flat screen, allowing digitization at scales of up to 1:11,000 but adopting as the preferred scale for digitization the range from 1: 18,000 to 1:23,000, where the elementary points for color (pixels) appear but the digital reference for the polygon is not lost. The scale used for viewing was approximately 1:50,000, at which the inaccuracies are minimized. The digitalization obeyed the spectral responses, observing the color, the number of shades of gray in each channel, the texture, the pattern, and the comparison with neighboring pixels, by means of which the original vegetation was identified where each clearing was installed. For interpretation of modification of the original vegetation, differences in the spectral behavior of non-forest areas were exploited, especially differences in channels 4 and 5 of Landsat 5 TM and Landsat 7 ETM+ (Mather 2004).

In addition to clearings of Yanomami origin, other non-forest features were detected, documented and separated into (a) natural features (rock surfaces, areas of ecological tension [ecotones], areas of riverine or hydromorphic influence and natural grasslands); and (b) disturbances caused by non-Yanomami (the roadbed of the BR-210 [Northern Perimeter] Highway, sites from which bulldozers removed earth for construction of the BR-210, ranches in the region of the Ajarani River and along the BR-210 Highway, airfield runways, mining pits and other clearing of vegetation by gold-mining activity) (Almeida-Filho and Shimabukuro 2001). The areas of the clearings were calculated using the properties of the polygon expressed in decimal degrees and multiplying by a conversion factor to convert the area to square meters (see Appendix). The following information was tabulated: the area of clearings, date of the satellite pass for the image and the attributes of each polygon (community, region and the population group to which the community belongs). All of this information is needed because, when a group moves to another site, the group changes its name to that of the new location (Albert 1985; Do Pateo 2005).

Locations and other information regarding many episodes of invasion of the TIY over the years covered by this study were obtained through extensive archival research with documents held by the Commission for the Creation of the Yanomami Park (CCPY), a non-governmental organization based in Boa Vista, Roraima. This made it possible to map the main non-Yanomami alterations by knowing their geographical patterns as they appear on orbital images. It is difficult to distinguish between clearings made by missionaries and those of the Yanomami when they are in neighboring locations, so this distinction was not made.

Population Research

Demographics were studied using the general population censuses (FUNASA 2009) and partial paper censuses of a community on different dates (CCPY/FUNAI 1986). We tried to derive a number that was coherent with the general estimate for the Yanomami population in 1987-88. This was apportioned into the different communities and regions prior to selection of the eligible population. The whole Yanomami population was examined to obtain consistency in the data at all levels: general, regional and community (which is the Yanomami political unit). Since administrative divisions (regions) changed over time, the populations at each of the four points in time were organized into regions and communities. This was done in order to make the analysis possible.

The way that communities merged and split during the 21 years covered by this study was investigated using historical sources, some nominal censuses and conversations with social-service workers and Yanomami, who, while observing satellite images of clearings, indicated the direction of their residences with respect to the airstrip.

Defining the Sample Unit

We opted for the concept of “population group” as the sample unit for the analysis. A population group is an ensemble of communities that lived together in the same territory, dividing or merging into communities during all or part of the period of the present study (Fig. 2). In most cases, these are people who maintain matrimonial ties and exchanges, while in some cases they are agglomerations of families that are not so close. It was necessary to adopt a sample unit that corresponds to the Yanomami universe such that it would be consistent with the population dynamics in communities so that it would be possible to identify what populations group is responsible for producing clearings in a given landscape. Despite being an artificial construct, the proposed concept maintains a certain level of spatial consistency at the time of the study with concepts that are disparate with respect to each other, such as "inter-community alliances" (Albert 1985), "population blocks” (Chagnon 1992) and “neighborhood endogamic groups” (Do Pateo 2005). The concept unifies all of the spaces associated with the population in question. These spaces include second residences and temporary dwellings of one or more communities of a population group. This is important because the study aims to establish a relationship between the populations and changes in the forest landscape. The "population group" is a more precise unit than is a "region" or one of the "health posts," and it often covers different dialects in the same region.

[Fig. 2 here]

Out of a total of 132 Yanomami population groups in Brazil, 90 were selected to compose the study. These are the population groups that have complete data on demographics and clearings, and whose location was known at the time of all four Landsat mosaics, even though part of the group’s trajectory may have included Venezuela (the Venezuelan part was not included in the analysis). Clearings outside of the TIY in Brazil were not tallied for communities that lived outside of TIY (Ajarani, Apiau, Baixo Mucajai, Ironasi and Nazaré).

The definition of population groups as the research sample does not avoid referring to communities (as a part of the population group, but identified either in time or in place) or their clearings (the detectable evidence of the population groups on the land, that is, their “footprint”). Using the population group as the sample unit is necessary in order to allow temporal analysis of the trajectories of the communities.

Analysis of Displacements

To assess whether the current degree of sedentarization leads to changes in the natural vegetation, we first determined whether sedentarization had occurred by analyzing the movement patterns of the Yanomami. Two methods were used to determine which groups of the population could be considered sedentary:

a) the location of the place of residence of the communities that belong to the group at the time of each mosaic and if these locations changed in the interval between one mosaic and the next. For example, a community that remained in the same location at the time of all four mosaics was considered to be sedentary. Population groups that stayed in the same place in three of four mosaics were classified as having an intermediary degree of sedentarization. It was noted if the time when movement occurred was the last interval, which could be interpreted as a resumption of mobility.

b) the average position of the community’s clearings, regardless of the position of the residence. Evaluated by Euclidean distance, this measure is an abstraction that allows the displacement of communities in the interval between two mosaics to be inferred. The average of the positions of the communities belonging to the same population group is used to define the position of the group at a given time. Euclidean distance was calculated between the positions in the two mosaics, thus defining the movement of the community:

$$\text{Euclidian distance} = [(X_1 - X_2)^2 + (Y_1 - Y_2)^2]^{0.5}$$

The sum of the lengths of the movements of the communities of a population group defines the population group’s distance of displacement. The distances in kilometers were obtained by multiplying the values in decimal degrees by a conversion factor (111 for “X” and 109 for “Y”) (see Appendix).

The displacements of the population groups were ordered by the average distance of the clearings, as described above. This made it possible to separate the population groups that had ”small” displacements ($d < 1$ km) from those that had “macrodisplacements” ($d > 10$ km). Small displacements are defined to represent the distance covered in 20 minutes walking, which is the limit that leads to building a new house (Albert 1985: 20). Macrodisplacements are not so common because of the effort they require. All other displacements were studied with a description of their trajectories, which are interpreted as pattern of displacement.

Patterns of displacement

We have attempted to describe the patterns of displacement of the groups studied. This procedure assesses not only the movement but also the dispersion or clumping of the population groups. The patterns of displacement were examined using a geographical information system (GIS). This was able to reveal the main directions of displacement of the population groups, map their trajectories and classify the displacements into types.

Analysis of Clearing Areas

To quantify changes in the landscape of the TIY in Brazil, descriptive statistics (mean and standard deviation) were calculated. This was done for both the areas of Yanomami clearings and for other changes produced by non-Yanomami.

The areas of clearings were evaluated according to their variation in time and space, determining how much was opened in the interval between Landsat mosaics. Population is usually considered to be the key factor in determining the size of indigenous clearings in Amazonia (eg, Carneiro 1960). The establishment of a relationship between the area of clearings and population would make it possible to compare the areas of clearings between sedentary and mobile population groups.

The area of clearings as a function of population was analyzed using a linear least-squares regression, divided into measurement dates (mosaics) and topographic categories (montane versus lowland). Sedentary and mobile population groups were compared in terms of the average area of clearing per individual in both cases. The distinction between montane and lowland groups was made due to the significant differences between these environments (Colchester 1982; Hames 1995; Smole 1976). Sedentary and mobile communities were characterized according to demographics, paying particular attention to the largest groups (more than 275 inhabitants).

Analysis of the Regeneration of the Clearings

Secondary vegetation present in 2009 in the clearings produced in each time interval was quantified and compared between sedentary and mobile groups. Special attention was given to clearings made prior to 1988. The determination of whether there was regeneration of each clearing at the time of Landsat mosaic No. 4 (2008-09) was done by comparing the spectral response of a clearing with that of the surrounding forest. The clearing was considered to be in "regeneration" when the differences in the shade of gray in channel 4 (near infra-red) did not exceed 50/255 as compared to the value for immediately adjacent pixels, These comparisons always considered situations of similar topography and luminosity.

Results

Analysis of Displacements

The 90 population groups studied encompass 85% of the communities (180 out of 210 communities, based on the mean number present in the four Landsat mosaics) and represents 80% of the 2009 Yanomami population. Reviewing the location of residences in the intervals between the four Landsat mosaics, residential mobility was noted for most population groups (n = 71). The 12 population groups that did not move the position of their households in any of the three time intervals were: Maturacá, Maiá, Marari, Këpropë (Ajuricaba), Fuduaduinha (Yekuana), Auaris, Pedra Branca (Yekuana), Aiamo, Kulapoipu, Uxiximau, Xaruna and Karawë/Marauiá Mission. The five population groups that remained with their residence fixed for two time intervals were: Watorikö (Demini), Novo Demini, Mausia, Pookohipi and Kalisi. Two sedentary groups had part of their populations move to new communities: Pohoroa and Mauuxiu (see Fig. 3 and Table 1).

[Fig. 3 & Table 1 here]

The average displacement of the clearings of the Yanomami population groups shows some change in behavior: some groups moved in all three intervals, while others moved in one of the three (Fig. 4). The Krokonaia, Kokoiu and Kuwaiu groups made movements in all three intervals. Several groups alternated macrodisplacements with intervals with no significant movement: the Cauburis and Kuremö/Haxiu only moved in the middle interval. There are also differences between the population groups in the lowland and in the montane areas, with greater distances moved for groups in the lowlands (Fig. 5 A and B).

[Figs. 4 & 5 here]

The result of the analysis of average movement of clearings can be compared with the location of the communities. A large number of clearing movements was detected in population groups with sedentary communities and fixed residences.

Macrodisplacements

Macrodisplacements were detected in all three intervals in the study; four were in the first interval, six in the second and four in the third, totaling 14 displacements. The Alto Catrimani and the Kayanau made major moves in the first interval, the Cauburis and Kuremö/Haxiu in the second and the Mausia and Krokonaia (Uxiu) in the third. The Alto Catrimani population group formed the Tëpërësipiu and Xaãtha communities, which lived at the edge of the montane area and migrated to the headwaters of the Catrimani River in the first period. The Kuremö lived near the airstrip used by gold miners in Homoxi and, through successive displacements, arrived at Haxiu, where they live today. The Mausia moved in 2007 to the region of Olomai, downstream from Auaris (Fig. 6).

[Fig. 6 here]

Small Displacements

Small displacements were detected that are related to the renewal of shifting-cultivation fields, which are not always accompanied by a change in the place of residence. There were no significant differences among the three intervals with respect to the number of population groups with low mobility. A total of 24 groups moved their clearings less than 500 m in at least one of the intervals, and 61 moved less than 1 km in at least one interval. Only six groups moved their clearings less than 500 m and 12 groups had displacements of their clearings less than 1 km in all three intervals, indicating small distances moved throughout the study period (Fig. 4). In the case of small displacements it is difficult to determine whether the habitation has been relocated.

Sedentary Communities

The sedentary communities are not homogeneous. Some have small populations and are stationary for reasons that are not associated with any exogenous attraction factor: Pedra Branca, Aiamo, Hasatau (in the region of Auaris) and Xaruna/Iromopë (Parima River, Parafuri). In 2009 the most populous groups that were strictly sedentary and were located near a contact post were Maturacá and Auaris (Fig. 7). These two stand out from the other groups in the study because of their significant populations and the large size of their clearings (a consequence of the large populations).

[Fig. 7 here]

Patterns of displacement

The most frequent patterns of displacement detected were:

Back-and-forth displacements (retromigrations), where, after some time, a group returns to a previously occupied site at a considerable distance from the previous residence. The Pukima re-occupied a site at the foot of the montane area where they had lived, after living on the banks of the Marauiá River since 1994. In cases of back-and-forth movement in the lowlands, the groups often return to the slopes of the montane area (n = 5).

Directional displacements, characterized by a linear sequence of shifting-cultivation fields that advance further with each interval. Examples are the Aracaçá, the Okiola/Sikaima, both following the watercourse where they live, and some in Xitei.

Radial displacements (centripetal movements) characterized by an expansion of clearings in different directions from the residence at increasing distances from the original position. Sometimes this is accompanied by a change in the location of the dwellings, which may or may not split the communities of the population group.

Intraregional displacement in which the group occupies a given territory and moves within the limits of this area; the Katharoa, the Porapii, and the Houmakö/Xahõxe are examples of this type of movement.

Yanomami Continue to Have Residential Mobility

The analyses indicate that there was no significant change in the mobility of the Yanomami during the three intervals studied. The major sedentary communities already existed prior to the first interval in the study, and a resumption of displacements was observed in the most recent intervals. Even groups that were characterized as sedentary (based on their residences) had displacements of their clearings. Excluding the population groups that had a total displacement of over 10 km (n = 56), the first interval had an average displacement of 0.96 km, the second 0.69 km and the third 0.96 km. The distances of the displacements of the groups in the three intervals ranged from 0.8 to 1.93 km.

Areas of Yanomami and Non-Yanomami Clearings

An area of 4432 ha was detected that had been altered by gold mining. A separate area of 4365 ha was detected that had been altered by ranches and invasions, especially in the region of Ajarani. The first clearings were opened in the first two intervals. The transformation to as non-forest landscape caused by the invasions of ranches impeded detection of clearings made by the Ajarani (Yawaripë) population group, leaving them out of the analysis

During the 21 years covered by the three time intervals in this study, the Yanomami population cleared 16,856 ha of old-growth forest (0.17% of the TIY in Brazil). The analysis was restricted to this area of clearings. In addition, there were 1594 ha of older clearings that had already been abandoned by the Yanomami before the first Landsat mosaic in the study but that were still observable by visual interpretation of Landsat imagery. The 18,450 ha total area present in clearings at some time during the 21-year study period represents 0.19% of the TIY in Brazil. .

The average annual increase in per-capita area of clearing differed significantly between montane and lowland areas, with larger openings in the montane area in all four Landsat mosaics. In the most recent periods this per-capita increase was more than twice the corresponding increase in the lowlands (Table 2).

The temporal dynamics of the clearings (Fig. 8) indicate a considerable decrease in activity between the 1987-88 and the 1994-95 mosaics. In an attempt to identify possible causes, a separation was made of population groups most affected by gold mining between 1987 and 1995, gold mining being the primary historical suspect. Approximately 80% of the population that was hardest hit by gold mining is in the montane area, which has clearings that are proportionately larger than in the lowlands.

[Fig. 8 here]

The hypothesis that the fixation of population living near a contact post implies an increased area of clearing per inhabitant was not confirmed. The average area cleared per capita for all population groups was greater than the average for the set of groups with populations of less than 275 inhabitants. This means that population groups with more than 275 inhabitants deforest less per capita than does the population as a whole (Fig. 9).

[Fig. 9 here]

Regeneration of Clearings

Regeneration of clearings occurred in increasing percentages as a function of increasing age. However, there was a considerable area that remained occupied in all four Landsat mosaics, but that was not undergoing regeneration. Of the clearings with more than 20 years, 52% (4200 ha) had already engaged in the process of regeneration and did not have much distinction in their spectral signatures from the surrounding forest. Of the clearings with ages between 14 and 20 years, 45% (2000 ha) also had spectral behavior similar to the surrounding original forest, and 30% of the clearings between 7 and 14 years of age (4400 ha) also followed the same pattern. Considering the areas altered between the third mosaic (2001-02) up to the last mosaic (2008-09), areas with spectral behavior similar to the forest accounted for 29.8% of the area in regeneration.

Comparing the area of clearings under regeneration for localities inhabited permanently and localities that are no longer occupied, it is apparent that the population groups with mobility had 37% of their area of clearings undergoing regeneration, versus 20% in the areas used in the same period by sedentary population groups. Excluding areas under regeneration in 2009, the size of the population explains 60% of the variation in the area of clearing per capita (Fig. 10).

[Fig. 10 here]

Considering clearings made prior to 1988 that had not yet returned to forest (as identified from Landsat) by 2008-09, we found that settled groups were responsible for the four largest clearings in the ranking of clearings that were without regeneration (Fig. 11). These clearings have remained open for a long time (more than 20 years), have large continuous areas (over 20 ha), and are positioned adjacent to new openings, which place them at a considerable distance from the edge of the forest (up to approximately 800 m).

[Fig. 11 here]

Discussion

This study detected a considerable amount of movement, revealing patterns of mobility that are more elaborate than the simple mobile/sedentary duality (Kelly 1992). We did not detect any clear trend in mobility changes over the three time intervals studied. Communities with fixed residences for over twenty years still have mobility associated with their second residences. A significant decrease in the area under secondary forest regeneration occurred in the case of sedentarization. A reduction in forest resilience is expected for sites over the 21-year interval of non-regeneration observed for communities with a sedentary residence pattern.

Sedentarization has not Increased in the Last 21 Years

The sedentarization process is associated with access to sources of services and tools from the surrounding society. The existence of sedentary communities in Yanomami territory is related to intercultural contact and is clearly associated with missions. With the exception of a few missions and government outposts built between 1965 and 1992, most of the posts have only been offering assistance since 2000. It is therefore too early to detect whether there is any change of behavior in relation to the presence of new posts, most of which do not have a religious purpose. There was a suspicion that the improvement in health conditions and population growth could affect ecological processes in the TIY (Py-Daniel and Souza 2004). However, the doubling of the population in 21 years apparently had little effect on the Yanomami way of life, although this effect is, perhaps, a little more evident in the montane area where resources are scarcer and population densities are higher. Current fertility rates call into question some of the assumptions in the debate on protein scarcity. According to several authors, population densities were being regulated to low levels by war and contraceptive methods, in addition to infanticide (Gross 1975; Harris 1984). Recent population growth as a result of improved health care (especially in reducing infant and child mortality) suggests that epidemics were probably responsible for the lower indigenous population densities in the region in the past. The danger of new epidemics is also not trivial. Past epidemics caused significant declines in population (Pithan 2005).

Differences found between the length of displacements in the montane areas and in the lowlands are probably due to physical characteristics of the sites. When the first author worked in the TIY walking extensively in both the montane and the lowland areas, only 60% of the distance could be covered in the montane area as compared to the distance covered in the same amount of time in the lowlands. This information can be found in the reports of the health organizations that have worked in the TIY (Urihi 2004). The greater density of water courses allows occupation of more sites places than in lowlands, where the Yanomami face a more severe hydrological seasonality.

The history of contact is older in lowland areas that have river access. Historically, contact haas generally induced indigenous people to become sedentary (Oliveira 1973, Zent 2009), this being associated with a greater abundance of natural resources enabling permanence on a site. in some communities, however, there is an increase in displacements. A historical perspective to explain mobility today suggests that the dynamics of mobility versus sedentism is not a one-way process.

The dynamics and practices of hunting in lowland environments are still poorly studied. Yanomami strategies for wildlife management can be important elements for understanding these dynamics. In this study movements were detected of groups returning to old regeneration areas, indicating a preference for these environments. The existence of second residences in various sedentary communities suggests a mobility strategy, while at the same time maintaining a residence near attraction posts such as the religious missions.

The fact that mobility strategies are maintained suggests how important mobility is to the Yanomami people, despite contact posts now being widespread in the TIY with resulting pressure for sedentarization. In some cases, the non-Yanomami partners deal with respect to the Yanomami's way of life, as is assured by the Brazilian constitution, but in many cases the reasons for Yanomami mobility are still poorly understood. The Yanomami movement in defense of their rights plays a role in guaranteeing the conditions needed to maintain mobility, since the Yanomami know that understanding the functioning of State-based societies is a condition for cultural survival after contact.

Macrodisplacements

The macrodisplacements observed in the past have had causes related to contact and its consequences, such as the environmental, social and health disruption caused by invasion of the area by gold miners (eg, Ramos 1993). The Kuremö had to leave a region where they had conflicts in the time of gold rush. The Xaatha and Tëpërësipiu groups moved to form the Alto Catrimani communities in order to escape the miners.

The concentrating effect of the presence of both a mission and an outpost of the special border detachment of the Brazilian army in Auaris may have been augmented by the epidemics that occurred during the gold-mining outbreak, implying forced migration to gain proximity to health care. Environmental disruption by external agents may be responsible for many macrodisplacements (Ramos 1993, 1995). Recently, demographic pressures in the Auaris region led the Mausia group to re-establish residence at Olomai in the middle stretch of Auaris River, a site that was formerly occupied by a mixed group of Sanöma and Yekuana (Birraux/CCPY 1984). The Auaris River below the falls has larger fish than the upper portion of the river and was without human occupation for a long time, thus ensuring recovery of the fauna.

Small displacements

Small displacements of clearings are strictly associated with garden renewal (Albert 1985), so we cannot be sure when these displacements result in moving the place of residence. However, these small displacements can eventually lead to relocation of the residence. In a case reported in the literature, (Albert and Tourneau 2007), the Demini community renewed their gardens in 2006, moving them to a site more than 20 minutes walk from their roundhouse. They built a number of little houses near of the new clearings, as second residences, maintaining the roundhouse. These little houses were intensively used at the times of slashing, burning and planting the gardens.

The fact that short displacements represent the most common kind of movement in the montane area could be a consequence of greater concentration of fragmented communities and population groups. The Serra Parima is the location of almost half of the Yanomami population but represents only 15% of the TIY. It is a place where natural conditions impose restrictions similar to those described by Good (1989) in Venezuela. Nutritional problems were observed in children in the more densely populated southern portion of the montane area in Brazil. Reports from the Yanomami indicate difficulties due to the inadequate quantity of available game. This effect of a population that is already concentrated in a delicate ecosystem may have been aggravated by successive years of gold prospecting. Evidence of this includes the reports in the late 1990s of reduced populations of peccary (*Tayassu peccari*), an animal that lives in bands and constitutes an essential protein source in the Yanomami diet (Fragoso 2004).

Previously Existing Sedentarization

Of the non-native installations in the TIY, older missions have had a decisive role in changing the Yanomami mode of land occupation. The presence of missions along navigable water courses in the state of Amazonas defined an intercultural contact pattern that is distinct from that in the montane area. The Yanomami have been encouraged to adopt a sedentary way of life in the lowland region. At the endpoint of this process are the three largest communities in the drainage basin of the Cauaburis River (Maturacá, Ariabu and Maiá). These communities are associated with the Salesian Mission (established in 1959) and an outpost of the Brazilian army's special border detachment.

There are more groups which were sedentary during the first and second intervals but restarted to move recently, so we can interpret this as a real resumption of the mobility strategy. It was particularly felt in the Marauiá River Basin, where, since 1990, there was a trend to remain closer to navigable rivers while today there are communities deep in the forest. The results of the present study show that less than a decade after sedentarization a reverse movement occurred in some locations, and in others the Yanomami employed a variety of strategies to maintain mobility.

Smaller populations can stay sedentary much longer because they exert less pressure on resources than do larger populations. Sedentary populations exert more pressure on game populations, and hunters from these groups must travel great distances to find game. The abundance of fish in the rivers in the lowlands can reduce pressure on game populations. Another technological change is in the use of boats with outboard motors to extend the radius accessible to hunting. This is possible in the lowlands and, to a much lesser degree, in the montane area. Because of the cost of such solutions, these technological changes do not necessarily cover the entire population. Such wealth-related distinctions within the population may be arising in Maturacá, where the population grew by assimilating surrounding groups (Smiljanic 2002). Distinctions between old inhabitants (*Përöamö* – residents) and recent inhabitants (*kasi* – peripherals) have been reported (Smiljanic 2002). In addition, shifting-cultivation fields established in recently cleared forest areas should, in theory, be more productive. These factors may imply some sort of nutritional deficiency in sedentary communities. Two academic studies on nutritional health in children in both sedentary and non-sedentary communities found high morbidity in the Cauburis communities, which are in a region with a more advanced process of sedentarization and greater pressure for assimilation (Borgoin 1998), while in Marauiá (a less-sedentary region) child health is at normal levels (Istria and Gazin 2002). The use of second residences is probably the main strategy used by sedentary groups to compensate for declining game densities near the fixed residence. Second residences were detected in almost all of the sedentary population groups.

Patterns of Displacement in the Territory

Displacement patterns reveal considerable diversity of movements and these may be associated with effective strategies for exploitation of natural resources. Our interpretation of results will follow a geographical subdivision of the TIY, choosing two regions for detail based on historical and ecological aspects: (1) Serra Parima, and (2) lowland areas along tributaries to the Rio Negro that lie within the limits of the indigenous land.

Intraregional displacements were observed in montane communities that have only recently been covered by the health system (Pellegrini 1998). The Kõkara, Porapii and Katharoa have this type of territorial occupation within a circumscribed region. The short distances moved may be linked to the concentration of population in this region. The proximity of rival groups could discourage the demand for new territories (Chagnon 1992; Kelly 1992). For the Pothomatha, a movement pattern has been documented that is similar to moving within a circumscribed territory (Do Pateo 2005). Intraregional movements in the Serra Parima are already resulting in a multitemporal landscape mosaic of forests in regeneration.

Patterns of back-and-forth displacement appear to be related to the establishment of second residences. The coexistence of two residences suggests an ecological strategy that allows the use of the regions that have been least affected by human presence. Dual residence expands hunting territories and provides access to locations with resources that are inaccessibles from the main residence. In the lowlands, return to the main housing groups near the montane area suggests that the regeneration areas are probably local attractions to the Yanomami and mark an implicit territoriality of places of historical importance to a group.

Back-and-forth movements show a pattern of approaching the montane area, thereby providing access to areas with ecological characteristics that are deliberately chosen. Older stands of secondary vegetation are useful for gathering a variety of resources. The establishment of the new residence is almost always near the secondary forests of the former occupation, reflectng the importance of these ecosystems. In the first author's visits to the area, return movements to the old crops were observed and secondary forests from old crops were preferential places for one-week hunting expeditions to obtain game for cerimonial occasions (*henimou*).

Area of Clearing

Data on the area of clearing per capita per annum measured in this study are comparable to data collected in other studies on the Yanomami, with considerable difference between the montane and the lowland areas. The mean areas of clearing per capita per annum found by Hames (1995) were up to three times higher than the values found in the present study: 1300 m^2 in the montane area and 770 m^2 in the lowlands for the swiddens that existed at the time the studies by Hames (1995) were done. Another recent study found higher values for cultivated areas in the lowlands (2700 m^2) in Demini, which is a community in the process of sedentarization (17 years in the same location) but that retains second residences (Albert and Tourneau 2007). The difference from the previous study reflects differences in sedentarization with consequent effects on the landscape, with an average annual increment of 7.14 ha. In Demini, swidden is productive for a longer period than is the case for the swiddens of mobile populations (4-6 years). In the present study, calculations were made taking into consideration a period in which cleared area was increasing. This allows an evaluation of how much is incremented annually, on average (see Table 2). Despite the differences, the values suggest that there are no significative differences between sedentary and non-sedentary communities in their annual per-capita increment in cleared area.

There are no systematic entries of industrialized food in the TIY, except in the vicinity of the towns of São Gabriel da Cachoeira and Santa Isabel do Rio Negro (both located by waterways) and near the Ajarani, Mucajai and Apiau regions. In the lowlands the majority of the Yanomami population has little access to markets, having the forest, swidden agriculture and the rivers as their main sources of subsistence resources. Money earned by Yanomami who work as teachers, health agents or other kinds of employees, is used to acquire durable goods. These goods, such as fish hooks, agricultural tools and utensils, help provide access to natural resources (Milliken and Albert 1999).

Shifting-cultivation fields established in recently cleared forest areas should, in theory, be more productive. This may imply some sort of nutritional deficiency in sedentary communities. Two academic studies on nutritional health in children in both sedentary and non-sedentary communities found high morbidity in the Cauburis communities, which are in a region with a more advanced process of sedentarization and greater pressure for assimilation (Borgoin 1998), while in Marauiá (a non-sedentary region) child health is at normal levels (Istria and Gazin 2002).

The landscape of the Yanomami territory can be thought of from a long-term historical perspective because there is relative consensus on the existence of ancient occupation in Serra Parima, and a more recent history of occupation in the lowlands. Within Yanomami ecological knowledge, partly due to their technological possibilities, certain species of plants and plant communities are indicators of soils suitable for opening swidden fields (Milliken and Albert 1999). This suggests that not all forests are appropriate for swidden. This finding fits with our results, which use a micro-spatial geographical approach to identify Yanomami preferences for opening swiddens at certain geotopic levels and that indicate a certain spatial grouping of clearings.

Significance of Successional Seres

The landscape resulting from the practice of mobility over the long term, in a territory where Yanomami are historically concentrated, would be a mosaic of secondary-vegetation stands of various ages. There would also be locations where forest is not felled, as the analyses showed preferences by specific topography and soil.

The literature suggests that secondary vegetation retains elements of the agro-ecosystems from which they are derived (Junqueira *et al.* 2010; Lizot 1980), This vegetation is useful as a territory with differentiated features, including hunting animals that are adapted to this habitat, such as the brocket deer (*Mazama americana*) and the agouti (*Agouti paca*). Secondary vegetation is also used for gathering mushrooms (Milliken and Albert 1999; Prance 1987), small animals and plants and fruits remaining from the previous agro-ecosystem, such as manioc (*Manihot esculenta*), and the fruit and seeds of papaya (*Carica papaya*) and peach palm (*Bactris gasipaes*).

Some of the species that comprise the successional sere of a secondary forest have food value for the Yanomami. The Yanomami obtain significant quantities of game from secondary vegetation in their fallow swiddens. Certain animal species show preference for Yanomami secondary environments (*hutu wãropata*). The importance of hunting in secondary formations and old swiddens is known from other indigenous groups (Nietschmann 1973; Smith 2005).

From the point of view of biodiversity, the coexistence between forest and other sucessional vegetation increases local biodiversity and provides a path to renewal of the forest. The practice of cutting and burning swiddens associated with mobility of the Yanomami and other indigenous peoples can be understood according to the mechanism of intermediate disturbance in forest cultivation (Balée 2009). The use of secondary vegetation should not be thought of as incidental practice. This study reveals that the choice of new sites suggests an intentional use of areas in regeneration, which are useful for specific purposes and are part of the Yanomami's ecosystemic knowledge of resources and ecological relationships. Such intent in the use of secondary forest by Yanomami is consistent with the use patterns observed in other Amazonian peoples (Balée 1989; Posey 1987).

The cultural change represented by sedentarization makes itself felt in the landscape despite there being no demonstrated increase in per-capita area cultivated. The portion of the Yanomami clearings that has not undergone regeneration detectable on Landsat imagery indicates that there is a match between these areas and the sites currently occupied by Yanomami populations. The concentration of people in an ecosystem can result in decreased forest resilience because of successive re-burnings, a mechanism that has been demonstrated in other parts of the world (Lawrence *et al*. 2010). The present study showed a significant decrease in the area that is undergoing regeneration in the case of sedentarization. The interruption of the swidden cycle of the Yanomami produces a pattern of succession that is distinct from that in areas undergoing the process of regeneration. In the montane area the re-burnings tend to produce simplified ecosystems dominated by the fern *Pteridium aquilinum*, whereas in the lowlands successive re-burnings also diminish the resilience of the forest, which does not regenerate and is replaced by grasses. This is similar to the deflected successions dominated by either ferns or grasses in Campa swidden fallows in the Gran Pajonal area in Peru (Scott 1978). Such landscapes were observed by the first author on two Yanomami permanent-ocupation sites in the montane area and at three such sites in the lowlands, providing preliminary but non-conclusive evidence of reduced reslience. On a larger scale, two situations were observed in terms of non-Yanomami activties causing reduction of the forest's capacity for resilience: (a) in Homoxi, where gold-mining activity has produced several *Pteridium aquilinum* areas that are still present (Milliken *et al.* 2002), and (b) in Ajarani, where occupation by ranchers (who are still present) maintains non-forest in a vast area of grazing (4365 ha, assessed in this study). Both ferns (Scott 1978) and pasture grasses (Fearnside and Guimarães 1996) can indicate loss of resilience in forest regeneration in Amazonia.

Conclusion

The Yanomami retain a significant degree of mobility within their territory, despite opposing forces. A resumption of residential displacements has occurred in the lowlands, where pressure for sedentarization has been strong. This suggests the importance of the phenomenon for maintenance of the Yanomami productive system.

Sedentary communities have strategies for maintaining mobility and access to other territories. There was no increase of sedentarization, despite the universalization of health care and consequent population growth. If the current demographic progression continues, it is possible that within a few generations population growth will produce negative effects on the mobility of the Yanomami and on their forest.

The sedentarization of population aggregated around missions and contact posts tends to maintain or diminish the area of clearing per individual, but there is a reduction in the forest regeneration, with areas staying open rather than returning to forest. There is therefore a risk of already existing sedentary systems in the Yanomami territory becoming compromised by overuse of the soil.

The effects of Yanomami mobility on the forest landscape are demonstrated by the regeneration of most clearings that were opened by 1988. Slash-and-burn agriculture associated with mobility may assist forest renewal processes by causing disturbances at an intermediate scale. Sedentarization, on the other hand, implies a break in the cycle of renewal. The considerable area of clearings more than twenty years old that has not regenerated, which are associated with sedentary communities, is an indication that the system of regenerative agriculture may be at risk, and, along with it, ecological processes that are still poorly studied.

Acknowledgements

The National Council of Scientific and Technological Development (CNPq) provided fellowships to both authors. The National Institute for Space Research (INPE) provided Landsat imagery and the System for the Protection of Amazonia (SIPAM) provided SAR radar imagery. Logistical support was provided by the National Institute for Research in Amazonia (INPA), the National Foundation for Health (FUNASA), the Service for Cooperation with the Yanomami People (Secoya), the Socio-Environmental Institute (ISA), the Ministry of Education and Culture (MEC), and by many Yanomami, especially Davi Kopenawa. Valuable comments were provided by François Le Tourneau, William Milliken, Janet Chernela, Charles Clement, Rita Mesquita, Henrique Pereira, Reinaldo Imbrozio Barbosa, Paulo Mauricio Lima de Alencastro Graça, Flavia Capelloto Costa, Bruce Nelson, Eduardo Venticinque, William Magnusson, Albertina Lima and Euler Nogueira. We thank Sueli Costa, Julia Salem, Desirée Paço and Jucilene Silva for their help in obtaining a research license from the National Council for Ethics in Research (CONEP).

Appendix

Each of the four Landsat mosaics corresponds to at least twelve scenes (Table A-1), for a total of 67 scenes. A tolerance of two years per mosaic was adopted due to the difficulty of finding satisfactory coverage without cloud cover. Clearings are areas of forest felled for cultivation that are detectable on Landsat images. Yanomami clearings rarely exceed 3 ha (equivalent to approximately 33 pixels); these are difficult to detect and the difficulty can increase with partial cloud cover or with atmospheric interference. The age of regeneration detectable on Landsat images can vary from a minimum of seven years (in cases of ephemeral openings in continuous forest, with the regeneration reaching a height up to 8 m in the TIY) up to an undefined limit that depends on the degree of disturbance and the dimensions of the clearing. Scenes from intermediate years were used to resolve doubts, allowing a refinement of temporal dynamics of opening swiddens, insuring greater certainty in the interpretation with greater convergence of evidence (Jensen 2009).

[Table A-1 here]

Treatment of Images

The images were georeferenced using a Geocover2000 mosaic, scene N 20 00, converted to decimal degrees. Since the region is located near the Equator (0 to 4° N), the distortion caused by the map projection should be minimal because it is distributed uniformly throughout the study area.

Channels 3, 4 and 5 were treated individually to maximize the gain in contrast. The progressive decline in the sensitivity of the sensors since the satellite was launched in 1984 was considered (Chander and Markham 2003), producing differences between the images of the two initial mosaics as compared to the images of the two most recent mosaics.

The Geocover image that provided the basis for georeferencing was geometrically corrected to Universal Transverse Mercator (UTM) units, which allows good accuracy in the calculation of area. The conversion factor was:

Area (m^2) = polygon area (in square decimal degrees) × 12,484,703,500.

The conversion factor was calibrated using measures of the circumference of the Earth at the equator (NASA, IBGE, UFRJ) for calculating the distance corresponding to one degree of longitude. The distance corresponding to one degree of latitude was calculated using the same sources. Values were calibrated empirically with existing databases for the region using the numbers closest to the official calculations (area of the state of Roraima from IBGE, areas of indigenous lands from Funai/ISA, and areas of conservation units from MMA/ICMBio).

Categories of alteration

Two categories of legend were established, to distinguish types of alteration:

A) "Altered/in regeneration" – areas that are vegetated but where the spectral response indicates vegetation of lower stature than the forest (highest reflectance value in channel 4);

B_) “open"– open areas, indicating a clearing opened near the date of passage, burning of the vegetation producing the spectral behavior of exposed soil (highest reflectance value in channel 5).

References

Albert, B. (1985). Temps du sang, temps des cendres: representation de la maladie, système rituel e espace politique chez les Yanomami des Sud-est (Amazonnie Brasilienne). Doctoral thesis, Paris X, Nanterre, Paris, France.

Albert, B. (1992). Urihi: terra, economia e saúde Yanomami. Série Antropologia 119: 1-20. http://vsites.unb.br/ics/dan/Serie119empdf.pdf

Albert, B. (1997). Terra, ecologia e saúde indígena: o caso Yanomami. In Barbosa, R. I., Gondim, E. J., and Castelón, E. G. (eds.), Homem, Ambiente e Ecologia no estado de Roraima. Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus, Amazonas, Brazil, pp. 65-83.

Albert, B., and Gomez, G. G. (1997). Saúde Yanomami: Um Manual Etnolingüístico. Museu Paraense Emilio Goeldi, Belém, Pará, Brazil.

Albert, B. and Tourneau, F.M.L. (2007). Etnogeography and resource use among the Yanomami: Towards a model of reticular space. Current Antropology 48: 584-592.

Almeida-Filho, R., and Shimabukuro, Y. E. (2001). Digital processing of a Landsat-TM time series for mapping and monitoring degraded areas caused by independent gold miners, Roraima State, Brazilian Amazon. Remote Sensing of Environment 79: 42-50.

Balée, W. (1989). The Culture of Amazonian forests. In Posey, D., and Balée, W. (eds.), Resource Management in Amazonia: Indigenous and Folk Strategies. New York Botanical Garden, New York , Vol. 7, pp. 1-21.

Balée, W. (2009). Culturas de distúrbio e diversidade em substratos amazônicos. In Teixeira, W. G., Kern, D. C., Madari, B., Lima, H. N., and Woods, W. (eds.), As Terras Pretas de Índio da Amazônia: Sua Caracterização e Uso deste Conhecimento na Criação de Novas Áreas. Embrapa Amazônia Ocidental, Manaus, Amazonas, Brazil. pp. 48-52.

Borgoin, P.-E. (1998). Enquête epidémiologique des communautés Yanomami du Rio Cauaburi Parc National du Neblina État d'Amazonas-Brésil. Doctoral thesis, Faculté de Médecine de Marseille, Marseille, France.

Brazil (1975). Projeto Radambrasil, Levantamento de Recursos Naturais, Departamento Nacional de Produção Mineral, Rio de Janeiro, RJ, Brazil.

Bush, M. B., and Silman, M. R. (2007). Amazonian exploitation revisited: ecological asymmetry and policy pendulum. Frontiers in Ecology and the Environment 5(9): 457-465.

Carneiro, R. L. (1960). Slash and burn agriculture: a closer look at its implications for settlement patterns. In Wallace, F. C. (ed.), Men and Cultures: Selected Papers of the Fifth International Congress of Anthropological and Ethnological Sciences, September1956. University of Pennsylvania Press, Philadelphia, Pennsylvania, pp. 229-234.

Carneiro, R. L, (1983). The cultivation of manioc among the Kuikuro of the Upper Xingu. In Hames R. B., and Vickers W. T. (eds.), Adaptative Responses of Native Amazonians. Academic Press, New York, pp. 65-108.

Chagnon, N. A. (1988). Life histories, blood revenge, and warfare in a tribal population. Science 239: 985-992.

Chagnon, N. A. (1992). Yanomamö. 4th edition HBJ Ed. Standford University, Fort Worth, Texas.

Chagnon, N. A., and Hames, R. B. (1979). Protein deficiency and tribal warfare in Amazonia: new data. Science 203: 910-913.

Chander, G., and Markham, B. (2003). Revised Landsat-5 TM radiometric calibration procedures and postcalibration dynamic ranges. IEEE Transactions on Geoscience and Remote Sensing 41: 2674-677.

Clastres, P. (1973). Elementos de demografia amerindia. L'Homme, Revue Française d'Anthropologie 13: 23-26.

Clement, C. R. (2006). Demand for two classes of traditional agroecological knowledge in modern Amazonia. In Balick, M., and Posey, D. (eds.), Human Impacts on Amazonia: The Role of Traditional Knowledge in Conservation and Development. Columbia University Press, New York, pp. 33-50.

Colchester, M. (1982). The economy, ecology and ethonobiology of the Sanema Indians of southern Venezuela, Vol I. Doctoral thesis, Oxford University, Oxford, UK.

Connell, J. H. (1978). Diversity in tropical rain forests and coral reefs. Science 199: 1302-310.

Denevan, W. (1976). The Aboriginal population of Amazonia. In Denevan, W. (ed.), The Native Population in the Americas in 1492. University of Wisconsin Press, Madison, Wisconsin, pp. 205-234.

Denevan, W. M., and Padoch, C. (1987). Swidden fallow agroforestry in the Peruvian Amazon. Advances in Economic Botany 5: 1-104.

Do Pateo, R. D. (2005). Niyayou: Antagonismo e aliança entre os Yanomami da Serra da Surucucus, RR. Doctoral thesis, Universidade de São Paulo, São Paulo, SP, Brazil.

FBV (2010). Yanomami fazem manifestação em frente à Funai. Folha de Boa Vista (FBV), Boa Vista Roraima, Brazil (http://www.folhabv.com.br/fbv/Noticia_Impressa.php?id=83718)

Fearnside, P. M., and Guimarães, W. M. (1996). Carbon uptake by secondary forests in Brazilian Amazonia. Forest Ecology and Management 80: 35-46.

Ferguson, B. (1995). Yanomami Warfare, A Political History. School of American Research Press, Santa Fe, New Mexico.

Fragoso, J. M. V. (2004). A Long-term study of white-lipped peccary (*Tayassu pecari*) population fluctuations in Northern Amazonia: Anthropogenic vs. "Natural" Causes. In Silvius, K. M., Bodmer, R. E., and Fragoso, J. M. V. (eds.), People in Nature: Wildlife Conservation in South and Central America. Columbia University Press / New York, pp. 286-297.

FUNASA. (2009). Demographic Census of indigenous societies, Fundação Nacional da Saúde (FUNASA), Brasília, DF, Brazil. http://sis.funasa.gov.br/transparencia _publica/siasiweb

Gomez, G. G. (2008). Forest disturbance and health risks to the Yanomami. In: Colfer, C. J. P. (ed.) Human Health and forests a global overview of issues, practice and policy. Earthscan / People and Plants International, London, UK, pp. 239-257.

Good, K. R. (1989). Yanomami hunting patterns: Trekking and garden relocation as an adaptation to game availability in Amazonia, Venezuela. doctoral thesis, University of Florida, Gainesville, Florida.

Gross, D. (1975). Protein capture and cultural development in the Amazon Basin. American Anthropologist 77: 526-549.

Hames, R. B. (1995). Yanomamö, varying adaptations of foraging horticulturalists. http://www.unl.edu/rhames/212/YANREADG.htm. Accessed: 10 Oct. 2009.

Hames, R. B., and Vickers, W. T. (eds.) (1983). Adaptive Responses of Native Amazonians. Academic Press, New York.

Harris, M. (1984). Animal capture and Yanomamo warfare: retrospect and new evidence. Journal of Anthropological Research 40(1): 183-201.

Huber, O., Steyermark, J. A., Prance, G. T., and Alès, C. (1984). The vegetation of the Serra Parima Venezuela Brasil: Some results of recent exploration. Brittonia 36: 104-139.

Istria, J., and Gazin, P. (2002). O estado nutricional de crianças Yanomami do Médio Rio Negro, Amazônia. Revista da Sociedade Brasileira de Medicina Tropical 35: 233-236.

Jensen, J. R. (2009). Sensoriamento Remoto do Ambiente: Uma Perspectiva em Recursos Terrestres. Parentese, São José dos Campos, São Paulo, Brazil.

Junqueira, A. B., Clement, C. R., and Sheppard Jr., G. H. (2010). Secondary forests on anthropogenic soils in Brazilian Amazonia conserve agrobiodiversity. Biodiversity Conservation 19: 1933-961.

Kelly, R. L. (1992). Mobility/sedentism: concepts, archaeological measures, and effects. Annual Review of Anthropology 21: 43-66.

Laudato, L. (1998). Yanomami Pey Këyo: O Caminho Yanomami. Universa, Brasília, DF, Brazil.

Lawrence, D., Radel, C., Tully, K., Schmook, B., and Schneider, L. (2010). Untangling a decline in tropical forest resilience: constraints on the sustainability of shifting cultivation across the globe. Biotropica 42: 21-29.

Lima, D., and Pozzobon, J. (2005). Amazônia socioambiental. Sustentabilidade ecológica e diversidade social. Estudos Avançados 19: 46-76.

Little, P. (2002). Territórios sociais e povos tradicionais no Brasil: por uma antropologia da territorialidade. Série Antropologia 322: 1-31. http://vsites.unb.br/ics/dan/Serie322empdf.pdf

Lizot, J. (1977). Population, resources and warfare among the Yanomami. Royal Anthropological Institute of Great Britain and Ireland 12, pp. 497-517.

Lizot, J. (1978). Économie primitive et subsistence - essai sur le travail et la alimentacion chez les Yanomami. Libre 78: 69-111.

Lizot, J. (1980). La agricultura Yanomami. Antropologica 94.

Lizot, J. (1984). Historia, organización y evolución de la población Yanomami. L'Homme, Revue Française d'Anthropologie 24 : 5-40.

Mather, P. M. (2004). Computer processing of remotely-sensed images: An Introduction, 3rd ed., John Wiley & Sons, New York.

Meggers, B., and Altenfelder Silva, F. (1963). Cultural development in Brasil. In Meggers, B. J., and Evans, C. (eds.), Aboriginal Cultural Development in Latin America: An Interpretative Review. Vol. 146, Smithsonian Institution, Washington, DC, pp. 119-29.

Milliken, W., and Albert, B. (1999). Yanomami: A Forest People. Royal Botanic Gardens, Kew, UK.

Milliken, W., Albert, B., Tourneau, F. M. L., DoPateo, R. D., and Pereira, E .S. (2002). Degraded areas in the Yanomami Territory, Roraima, Brasil: ethnoenvironmental evaluation of the Homoxi region, Boa Vista. Roraima, Brazil. www.proyanomami.org.br. Accessed 21 Dec. 2006.

Moran, E. F. (1990). A Ecologia Humana das Populações da Amazônia. Vozes, Petropolis, Rio de Janeiro, Brazil.

Nepstad, D. C., Veríssimo, A., Alencar, A., Nobre, C., Lima, E., Lefebvre, P., Schlesinger, P., Potterk, C., Moutinho, P., Mendoza, E., Cochrane, M., and Brooks, V. (1999). Large-scale impoverishment of Amazonian forests by logging and fire. Nature 398: 505-507.

Nietschmann, B. (1973). Between Land and Water. Seminar Press, New York.

Nilsson, M. S. T. (2011). Organização indígena Yanomami: das ameaças ao seu território à representação política numa sociedade sem Estado. Revista Agrária 9 (in press).

Oliveira, R. C. (1973). Povos indígenas e mudança socio-cultural na Amazônia. Série Antropologia 1 1-20. http://vsites.unb.br/ics/dan/Serie1empdf.pdf.

Pellegrini, M. (1998). Falar e comer: um estudo sobre os novos contextos de adoecer e buscar tratamento entre os Yanomamè do Alto Parima, MSc dissertation. Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brazil.

Pithan, O. A. (2005). O Modelo hekura para interromper a transmissão da malária: uma experiência de ações integradas de controle com os indígenas Yanomami na virada do século XX. MSc. dissertation, Fundação Oswaldo Cruz, Boa Vista, Roraima, Brazil.

Posey, D. (1987). Manejo da floresta secundária, capoeiras campos e cerrados (Kayapó). In Ribeiro, D. (ed.), Suma Etnológica Brasileira, Vol. 1, Vozes, Petrópolis, Rio de Janeiro, Brazil. pp. 173-185.

Prance, G. T. (1987). Etnobotânica de algumas tribos da Amazônia. In Ribeiro, D. (ed.), Suma Etnológica Brasileira Vol. 1. Vozes/Finep, Petrópolis, RJ, Brazil, pp. 119-133.

Py-Daniel, V., and Souza, F. S. (2004). O Sistema brasileiro de atendimento à saúde indígena e algumas de suas implicações na cultura Yanomami. http://nerua.inpa.gov.br/ Accessed 3 July 2008.

Ramos, A. R. (1990). Memórias Sanumá: Espaço e Tempo em uma Sociedade Yanomami. Marco Zero/ UnB, São Paulo, SP & Brasília, DF, Brazil.

Ramos, A. R. (1993). O papel político das epidemias: o caso Yanomami. Série Antropologia 153: 1-21. http://vsites.unb.br/ics/dan/Serie153empdf.pdf.

Ramos, A. R. (1995). Por falar em paraíso terrestre. Série Antropologia 191: 1-9. http://vsites.unb.br/ics/dan/Serie191empdf.pdf.

Ricketts, T. H., Soares-Filho, B., Fonseca, G. A. B., Nepstad, D., Pfaff, A., Petsonk, A., Anderson, A., Boucher, D., Cattaneo, A., Conte, M., Creighton, K., Linden, L., Maretti, C., Moutinho, P., Ullman, R., and Victurine, R. (2010). Indigenous lands, protected areas, and slowing climate change. PLOS Biology 8: 1-4.

Roosevelt, A. (1980). Parnama: pre historic maize and manioc subsistence along the Amazon and the Orinoco. Academic Press, New York.

Scott, G. A. J. (1978). Grassland Development in the Gran Pajonal of Eastern Peru, a Study of Soil-Vegetation Nutrient Systems, University of Hawaii, Manoa Honolulu, Hawaii.

Sirén, A. H. (2007). Population growth and land use intensification in a subsistence-based indigenous community in the Amazon. Human Ecology 35: 669-680.

Smiljanic, M. I. (2002). Os enviados de Dom Bosco entre os Masiripiwëiteri. O impacto missionário sobre o sistema social e cultural dos Yanomami ocidentais (Amazonas, Brasil). Journal de la Société des Américanistes 88: 137-158.

Smith, D. (2005). Garden game: shifting cultivation, indigenous hunting and wildlife ecology in Western Panama. Human Ecology 33: 505-537.

Smole, W. (1976). Yanoama, A Cultural Geography. Texas Press, Austin, Texas.

Urihi. (2004). Informações gerais sobre as regiões assistidas: Arathau, Haxiu, Homoxi. www.urihi.org.br/downloads. Accessed 23 Dec. 2009.

Welch, J. R., Ferreira, A. A., Santos, R. V., Gugelmin, S. A., Werneck, G., and Coimbra, C. E. A. (2009). Nutrition transition socioeconomic differentiation, and gender among adult Xavante Indians, Brazilian Amazon. Human Ecology 37: 13-26.

Zent, S. (2009). The political ecology of ethnic frontiers and relations among the Piaroa of the middle Orinoco. In Alexiades, M. N. (ed.), Mobility and Migration in Indigenous Amazonia, Berghahm Books, London, UK. pp.167-194.

Figure legends

Fig. 1 Map of the Yanomami Indigenous Land (*Terra Indígena Yanomami* =TIY) showing the posts and the year when each was established. The limit between lowlands and highlands is shown based on 600 m elevation above sea level.

Fig. 2 Hypothetical temporal evolution of the communities that compose a population group at four points in time with a schematic representation of possible fissions and mergings within a group, including possible population exchanges with other groups.

Fig. 3 Map of the Yanomami Indigenous Land (TIY) with the Yanomami population groups represented in three of the four Landsat mosaics; the numbers are associated with Table 1.

Fig. 4 Movements in each interval between Landsat mosaics of all population groups: The 90 population groups are ordered by the sum of the displacements (in km) assessed from the average movement of the clearings. The arrows indicate the limits between the population groups that moved less than 500 m (n = 6)**,** less than 1000 m (n = 12) and less than 10 km (n = 56). A 10-km move was established as the minimum to be considered a macro-displacement

Fig. 5 The distribution of displacement for highland population groups (**A**) and lowland population groups (**B**). The 20 groups with the largest displacement are shown for each topographic region. The three intervals studied are indicated by shading:. The groups are ordered by the total distance of displacement (in km) assessed from the movement of the clearings..

Fig. 6 Two cartograms showing examples of Macrodisplacements: A) Auaris region, showing the displacement of the Mausia community to the region of Olomai. Note the concentration of clearings at the place of origin. B) Alto Catrimani, showing the trajectories of the Xaãtha and Tëpërësipiu communities, which moved to the Alto Catrimani and became the Apuruhipi and Heramapi communities, respectively.

Fig. 7 Relation between size of the population group and sedentarism using the criterion of the average location of the clearings of population groups with displacements of less than 3.5 km (n = 25). The shading indicates the three intervals of displacement: light gray (lower portion) = movement between 1987-88 and 1994-95; dark gray (middle portion) = movement between 1994-95 and 2001-02, and gray (upper portion) = movement between 2001-02 and 2008-09.

Fig. 8 Evolution of the area (ha) of clearings by population groups, in the three seven-year intervals between the four survey dates (Landsat mosaics). Data are separated to distinguish communities affected by gold mining (continuous line, n = 58) and the communities not affected by mining (dashed line, n = 32): There is an obvious difference for the second survey date (1994-95), with a considerable decrease in clearing activity that is coincident with the invasion of the TIY by gold miners.

Fig. 9 Population groups and the relationship between number of inhabitants and the area of clearings (data from all four Landsat mosaics). The black dots represent the population groups with over 250 inhabitants; the smaller groups are represented by gray dots. The trend lines show "the whole population" (black line) and groups with fewer than 250 inhabitants (grey line) (n = 456). The graph shows that the most populous groups are responsible for a smaller deforested area per capita than the population as a whole.

Fig. 10 The relationship between the area (in hectares) of clearings remaining open in 2009 and the population (number of individuals) of the groups in that year explains 60% of the size of the area of open clearings (n = 90, R^2 = 60.45, p = 0.000).

Fig. **11** Area (ha) of clearings with at least 20 years old that have not yet entered the process of regeneration. The area of clearings for each community is shown in gray and the area in regeneration is shown in black.

Table 1 - Population groups, their identification numbers on the map (Fig. 1) and the attributes for the four Landsat mosaics indicated with numbers in the headers of the columns: 1= 1987-88, 2= 1994-95, 3= 2001-02 e 4=2008-09. The table attributes are: Displacements in km (D), number of communities (C), number of individuals in the population group (P), area of clearings in ha (A), area of remaining clearings in ha (2009), area of regeneration (Regen), patterns of mobility (Mob) and sedentary (Sed) (number of periods in which the group remained mobile or sedentary). Movement patterns are: mobility with dispersion of communities, radial (Mbdis), sedentary disperser (sedis), intraregional mobility (Mintra) and directional (Dir). The last column indicates the year of establishment of the permanent post, followed by the letters (F) to indicate federal agencies (e.g., FUNAI & FUNASA), and (M) for a religious mission.

	ID	Displacement (km)			Number of communities				Population (inhabitants)				Area of clearings (ha)				Clearings in	Regener ation	Mobili	Post: year of esta
Population group	num	D 1 2	D 2 3	D 3 4	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	2009 (ha)	(ha)	ty	blishment
Aiamo	1	0.05	0.30	0.49	1	1	1	1	10	13	16	15	13.8	4.3	7.3	3.9	29.4	0.0	Sed	
Alto Catrimani	2	13.96	9.69	1.49	4	2	5	12	99	98	135	253	90.7	34.0	41.7	68.7	175.8	59.3	Mob	
Aracaça	3	4.01	6.69	4.18	1	1	1	1	120	140	174	83	109.2	29.0	14.3	34.2	186.6	0.0	Dir	
Aracá	4	0.27	0.42	9.23	2	2	2	2	8	8	20	19	1.0	4.8	4.0	11.0	16.0	4.8	Mob2	1990M
Arathau,Kurapo	5	2.03	1.73	0.69	2	1	2	1	88	77	170	117	137.8	55.7	93.4	17.8	80.3	224.3	Sed3	
Auaris	6	0.10	0.46	0.40	1	1	1	1	62	83	185	261	69.1	11.3	77.8	17.3	154.5	21.0	Sed	1965M
Cauburis	7	0.19	50.26	0.21	1	1	1	1	48	51	40	53	29.0	5.0	3.4	13.8	17.2	33.9	Mob1	
Ericó	8	1.79	3.72	5.90	5	5	4	5	87	128	195	244	35.7	17.0	53.1	47.3	103.7	49.4	Mob	
Fuduaduinha	9	2.08	2.21	0.28	2	1	2	2	211	201	276	316	174.4	41.5	231.8	100.7	433.8	114.5	Sed	1965M
Hasatau	10	0.17	0.21	0.46	1	1	1	1	10	14	12	27	4.1	3.5	7.6	16.0	23.1	8.1	Mob2	
Herou	11	0.90	0.18	1.29	2	3	4	2	67	87	71	67	12.9	20.8	21.4	21.2	37.6	38.6	Mob	
Hewënahipi	12	4.47	5.56	1.54	3	3	5	4	128	96	139	179	45.6	20.7	46.5	32.7	83.0	62.4	Mob	
Hirihimakoko	13	2.58	3.85	0.45	1	1	1	1	65	65	35	40	4.8	4.6	2.9	7.5	9.6	10.1	Mob	1970M
Houmakö/ Xahoxe	14	0.47	2.70	0.93	4	2	4	5	197	57	159	307	108.5	35.7	63.0	177.7	200.9	184.1	Mintr	
Hoyamou	15	0.40	2.56	0.37	2	3	2	3	80	70	87	79	26.0	80.0	44.5	44.7	195.2	0.0	Mbdis	
Ironasi	16	6.03	6.59	10.25	1	2	3	1	73	79	121	134	33.6	24.7	26.7	31.4	116.4	0.0	Dir	
Kõkara	17	1.08	0.97	1.90	5	4	6	3	83	80	113	143	35.9	17.3	58.2	60.6	136.2	35.9	Mintr	
Kalisi	18	5.86	0.30	0.15	1	1	1	1	154	205	135	186	86.5	32.6	61.2	14.7	194.9	0.0	Mob2	
Karawë	19	9.45	0.12	9.58	1	2	2	1	17	24	25	68	5.0	4.3	26.8	21.4	53.1	4.4	Sed	1965M
Katahia	20	0.33	0.55	0.29	1	1	1	1	114	110	224	186	149.8	7.2	55.2	66.8	200.7	78.3	Dir	
Katharoa	21	0.26	0.78	2.36	2	2	5	3	157	114	230	183	72.4	41.0	122.5	30.7	189.9	76.7	Mintr	
Katimani	22	1.69	2.15	0.08	1	1	2	2	61	90	116	157	68.9	18.9	50.0	42.7	174.6	5.7	Mob2	
Katonau/Kalioko	23	0.41	1.01	0.32	2	2	1	1	44	90	66	120	31.7	7.0	12.1	32.5	52.9	30.4	Mob2	
Kayanau	24	9.69	10.71	1.87	3	3	3	4	90	111	127	136	74.6	44.4	15.5	17.0	151.3	0.0	Mob	
Kepropë	25	0.56	0.36	0.40	1	1	1	1	34	50	59	160	24.9	11.6	11.2	38.0	77.1	8.6	Sed	1960F
Ketawa/Totoya	26	4.28	1.10	0.86	2	2	1	2	103	66	128	201	125.9	33.1	70.0	60.6	135.6	154.1	Mob	
Kokoiu	27	5.18	65.27	26.99	1	2	3	3	41	85	105	130	26.8	10.6	23.1	25.4	56.4	29.6	Mob	

	ID	Displacement (km)			Number of communities				Population (inhabitants)				Area of clearings (ha)				Clearings in	Regeneration	Mobili	Post: year of esta
Population group	num	D 1 2	D 2 3	D 3 4	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	2009 (ha)	(ha)	ty	blishment
Kolulu	28	1.06	0.40	1.11	1	1	1	1	0	26	33	171	4.6	21.1	40.1	77.3	125.1	18.1	Mob	
Komomasipë	29	1.23	0.85	0.12	1	1	1	1	55	54	92	95	3.6	2.8	19.4	15.1	40.9	0.0	Mob2	
Kotaimatiu	30	3.52	3.36	3.28	1	1	1	1	38	30	33	39	7.4	7.1	73.4	17.0	35.3	69.5	Mob2	
Koxexinapë	31	1.57	5.10	0.94	3	3	4	2	80	55	173	68	47.4	69.7	134.1	57.8	148.1	160.9	Mob	
Krepösipiu	32	9.24	4.21	1.11	1	1	1	1	0	25	9	13	20.6	6.1	16.0	16.4	32.4	26.7	Mob	
Krokonaia	33	0.41	26.61	25.18	1	1	2	1	67	70	85	120	30.5	5.2	18.6	45.7	57.6	42.4	Mob	
Kulapoipu	34	0.82	0.77	0.41	1	1	1	1	26	43	59	68	4.7	14.5	71.8	17.9	96.3	12.6	Sed	
Kumatha	35	0.19	4.14	0.70	1	1	1	1	17	20	57	69	0.7	13.4	4.3	46.0	50.3	14.1	Mintr	
Kuremö Haxiu	36	1.48	10.29	0.07	1	1	1	1	71	43	163	163	53.0	41.0	17.3	105.7	135.2	81.7	Mob2	
Kuwai u	37	8.62	8.00	7.52	2	1	2	1	73	57	96	48	53.3	9.0	63.6	12.9	46.1	92.7	Mob	
Maharau	38	1.71	0.17	1.11	1	2	4	3	61	33	79	85	2.1	9.1	40.8	17.8	46.3	23.5	Mob2	
Maimasi	39	2.76	0.48	2.84	4	3	3	6	220	296	324	468	118.7	26.9	32.4	56.5	234.5	0.0	Mob	
Maiá	40	1.41	0.97	1.68	1	1	1	1	28	38	81	159	23.3	18.3	25.4	76.4	97.2	46.2	Sed	1987M
Makapei	41	6.43	1.47	3.62	1	1	1	1	51	26	58	73	20.8	15.3	8.8	27.0	31.8	40.2	Mob2	
Marari	42	10.43	0.14	4.35	2	2	2	6	416	394	395	894	92.5	42.1	111.6	164.5	410.7	0.0	Sed	1980M
Masiripöwei	43	16.39	6.69	9.00	1	4	3	5	150	445	383	709	27.9	45.5	80.7	112.5	235.2	31.3	Mbdis	
Maturacá	44	0.23	0.09	0.20	2	2	2	2	570	735	949	1205	240.6	89.5	116.9	69.9	494.9	22.1	Sed	1959M
Mauuxiu	45	0.41	6.96	3.53	1	1	3	4	62	68	135	179	3.5	36.0	29.9	53.2	108.2	14.4	Mbdis	1965M
Boemopë	46	2.75	4.88	2.54	2	1	2	3	129	46	119	137	55.9	20.4	40.0	45.1	61.7	99.7	Mintr	
Moxahi	47	0.72	0.25	0.27	1	1	1	1	37	56	67	89	6.5	28.7	26.4	33.5	41.6	53.4	Mintr	
Nazaré	48	1.18	1.26	0.46	1	1	1	1	44	66	98	114	23.6	3.2	14.2	3.4	44.4	0.0	Sed	
Novo Demini	49	6.42	6.10	1.82	3	2	1	1	243	211	228	241	113.8	69.5	51.0	74.1	213.8	94.5	Sed3	1993M
Okiola	50	1.14	1.05	4.85	1	4	5	1	26	57	172	185	1.4	18.3	130.9	104.5	105.1	150.1	Dir	
Okopiu	51	0.75	0.54	0.72	1	1	1	1	36	36	106	87	32.4	41.3	23.8	37.3	56.6	78.1	Mintr	
Olomai	52	4.52	8.17	6.63	2	1	2	1	56	50	54	98	75.2	18.1	104.0	45.5	135.9	106.8	Mob	
Olomai(Mausia)	53	0.38	0.35	15.97	1	1	1	2	54	62	56	170	25.9	7.6	30.9	43.8	100.3	7.9	Sed3	
Palimiu	54	0.25	1.39	0.13	1	1	1	1	146	127	97	114	66.0	12.8	96.3	65.6	186.4	54.2	Mob	1965M
Parimau	55	3.83	7.12	2.14	1	1	1	2	51	36	56	117	61.5	4.7	88.2	158.4	257.0	55.7	Mintr	
Pedra Branca	56	0.47	0.46	0.06	1	1	1	1	35	38	14	15	15.3	1.0	29.9	9.6	55.8	0.0	Sed	
Pirisi	57	3.22	1.12	4.22	1	1	1	1	42	82	95	104	3.3	10.9	39.4	82.1	84.3	51.6	Mob2	
Pohoroa/Rapirapi	58	3.54	1.39	17.76	2	1	4	7	513	316	450	655	81.9	46.3	214.5	104.3	297.7	149.2	Sedis	
Pookohipi	59	0.44	0.58	0.19	1	1	1	1	22	25	33	44	15.6	4.4	0.7	5.0	6.5	19.2	Sed3	

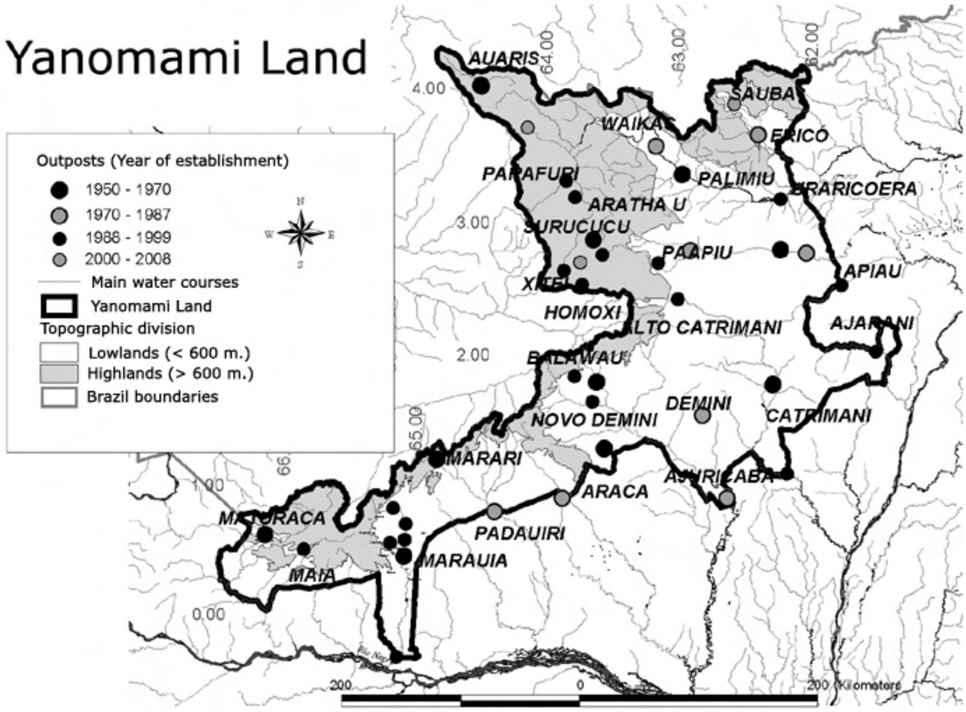
Population group	ID num	Displacement (km) D 1 2	D 2 3	D 3 4	Number of communities C1	C2	C3	C4	Population (inhabitants) P1	P2	P3	P4	Area of clearings (ha) A1	A2	A3	A4	Clearings in 2009 (ha)	Regeneration (ha)	Mobility	Post: year of establishment
Porapi/Warimahi	60	4.26	3.19	5.42	1	1	2	1	42	42	100	64	24.6	20.6	27.6	12.7	29.0	56.5	Mob	
Porapii	61	1.52	0.24	1.42	3	2	2	1	74	66	102	99	89.1	29.4	22.0	61.2	141.7	60.1	Mintr	
Porau/Moxiu	62	3.56	2.17	2.60	1	2	1	1	34	62	47	46	31.3	25.7	21.9	4.8	43.9	39.8	Mob	
Posto Yano	63	4.28	3.18	5.35	6	3	5	1	110	36	203	116	69.6	36.2	59.4	22.7	132.0	56.0	Mbdis	
Pothomatha	64	0.72	3.27	2.82	5	5	5	5	136	156	143	261	106.9	46.2	68.2	104.5	220.9	105.0	Mintr	
Puuthau	65	2.12	14.48	4.40	1	1	2	1	27	49	156	103	4.4	8.5	158.4	42.7	179.1	34.9	Mob	
Rahakapoko	66	6.28	6.55	1.35	2	1	5	8	68	75	165	331	80.2	39.5	53.6	215.9	342.6	46.5	Mob	
Rapahikö/Sinatha	67	6.97	5.33	4.76	1	2	3	3	147	102	144	265	62.5	19.0	18.1	26.1	46.4	79.4	Mob	
Roko	68	0.85	1.05	2.28	1	2	2	1	71	123	129	96	5.3	28.8	111.7	30.0	175.8	0.0	Mob2	
Sa·ba	69	6.38	3.37	2.23	2	4	4	4	87	102	112	136	14.8	26.8	23.4	41.7	74.3	32.5	Mob2	
Sikaimapi	70	0.61	5.01	8.15	1	1	2	2	59	62	144	208	12.4	9.0	7.4	76.4	105.2	0.0	Mob	
Sikoi	71	5.92	0.53	1.57	1	1	1	1	34	39	22	30	10.9	13.7	24.4	11.1	11.1	49.1	Mob	
Taremou	72	0.85	1.22	3.71	2	2	2	1	109	89	206	129	92.7	21.9	96.7	18.1	31.2	198.2	Mob	
Tiporei/Uxipei	73	1.40	8.99	0.22	1	2	1	2	19	44	44	61	17.7	25.0	26.3	26.6	77.5	18.1	Mob	
Uxixima u	74	2.45	2.64	0.70	1	2	1	1	29	33	33	36	14.0	4.3	8.4	2.3	28.9	0.0	Sed	
Waharu	75	1.75	1.07	2.44	1	1	1	1	0	0	64	80	1.7	1.0	28.7	17.5	33.5	15.3	Mob2	
Waicas	76	0.30	1.08	0.89	1	1	1	1	55	59	77	99	33.3	29.2	31.7	27.7	68.6	53.2	Mob2	
Wakahusipiu	77	0.54	1.17	0.94	1	1	5	3	63	55	70	86	25.3	3.8	26.1	14.1	38.1	31.2	Mbdis	
Walëpiu	78	1.32	0.72	2.44	4	2	3	2	185	148	178	176	258.4	30.9	212.9	36.7	111.7	427.1	Mbdis	
Wanapiki/Kaxipi	79	0.47	0.70	5.59	4	4	3	1	84	83	83	86	69.1	17.0	32.7	28.1	45.9	101.1	Mob	
Waputha	80	5.55	0.62	2.01	1	1	1	1	34	37	91	136	48.9	38.7	43.5	96.3	118.9	108.4	Mob	
Warareu/Axapatha	81	0.44	18.21	0.15	1	1	1	1	8	10	12	47	6.2	4.0	7.2	19.1	26.3	10.2	Mob	
Warëpiu/Paxotou	82	4.71	1.41	0.77	2	2	3	1	106	46	131	74	22.4	11.6	14.4	13.2	14.0	47.6	Mob	
Watatasi	83	0.90	1.21	1.53	1	1	2	3	70	91	180	176	32.9	2.5	84.6	43.8	141.2	22.7	Mintr	1992M
Watorikö	84	3.40	0.22	1.27	1	1	1	1	89	101	128	163	20.7	22.5	12.2	13.9	50.2	19.2	Sed3	1993F
Weyuku	85	3.75	0.20	1.19	1	1	1	1	22	22	35	45	10.9	5.6	14.2	10.2	40.8	0.0	Mob2	
Xaruna/Iromopë	86	0.41	0.36	0.35	1	1	1	1	22	24	48	58	4.3	1.9	10.3	15.0	31.4	0.0	Sed	
Xiho	87	10.57	7.87	3.88	1	2	1	2	43	47	42	50	2.1	22.8	6.6	1.5	1.5	31.5	Mob	
Xirimihikö	88	0.10	0.47	2.81	1	1	2	2	40	43	60	140	16.4	7.2	1.6	8.3	33.4	0.0	Mintr	
Xëxënapi	89	0.14	0.10	5.51	1	1	1	1	133	131	87	108	82.4	43.3	56.6	22.0	55.8	148.5	Dir	
Yamasipiu	90	4.56	0.35	2.37	2	2	2	1	70	128	106	30	35.8	48.8	55.8	35.2	82.2	93.4	Dir	

Table 1 - Annual increment in the average area of clearing in m^2 per capita for highland (montane) and lowland population groups. Values refer to fellings made in the three seven-year intervals between Landsat mosaics. The data for clearings made prior to 1988 were discarded because there is no control over the date of felling the forest.

Topography	n	1994	2001	2008	Average
lowlands	41	237	218	216	224
highlands	49	434	729	501	555

Table A-1. - Landsat 5 and 7 satellite images: Path, row and dates of passage from each of the four Landsat mosaics used to interpret Yanomami clearings.

Path	Row	1987-88	1994-95	2001-02	2008-09
001	057	20 Aug. 88	25 Nov. 94 and 12 Jan. 95	28 Mar. 02	12 Sep. 08
001	058	20 Aug. 88	25 Nov. 94	12 Nov. 01 and 28 Mar. 02	28 Sep., 01 Dec. 08 and 18 Nov. 09
001	059	20 Aug. 88 and 17 Jul. 87	25 Nov. 94 and 12 Jan. 95	12 Nov. 01 and 28 Mar. 02	28 Sep. 08
001	060	20 Aug. 88 and 05 Oct. 87	10 Feb., 25 Jul. 94 and 12 Jan. 95	07 Oct. 02	13 Jul. 09
002	057	05 May 87	09 Apr. 94 and 03 Jan. 95	11 Jan. 01	20 Jul. 09
002	059	05 May 87	03 Jan. 95	11 Jan. 01	23 Jan. 08 and 20 Jul. 09
002	060	05 May 87 and 21 May 87	29 Sep. 94	26 Aug. 02	23 Jan., 05 Oct. 08 and 20 Jul. 09
232	058	10 Dec. 94	06 May 95	21 Oct. 01	07 Apr. 08
232	059	10 Dec. 94 and 24 Nov. 94	07 Aug. 94 and 06 May 95	21 Oct. 01	07 Apr. 08
233	057	19 Dec. 88	13 May 95	13 Nov. 01	23 Oct. 08
233	058	19 Dec. 88 and 12 Sep. 87	13 May 95	13 Nov. 01 and 16 Jan. 02	23 Oct. 08
233	059	19 Dec. 88 and 04 Mar. 87	13 May 95	13 Nov. 01and 27 Jul. 02	29 Mar. 08



Yanomami Land
Outposts (Year of establishment)
1950 - 1970
1970 - 1987
1988 - 1999
2000 - 2008
Main water courses
Yanomami Land
Topographic division
Lowlands (< 600 m.)
Highlands (> 600 m.)
Brazil boundaries
AUARIS
WAIKAS
SAUBA
ERICO
PARAFURI
PALIMIU
URARICOERA
ARATHA U
SURUCUCU
PAAPIU
APIAU
XITEI
HOMOXI
ALTO CATRIMANI
AJARANI
BALAWAU
DEMINI
NOVO DEMINI
CATRIMANI
MARARI
AJURICABA
ARACA
MATURACA
PADAUIRI
MARAUIA
MAIA
4.00
3.00
2.00
1.00
0.00
64.00
63.00
62.00
65.00
66
200
0
200 Kilometers

Fig. 1

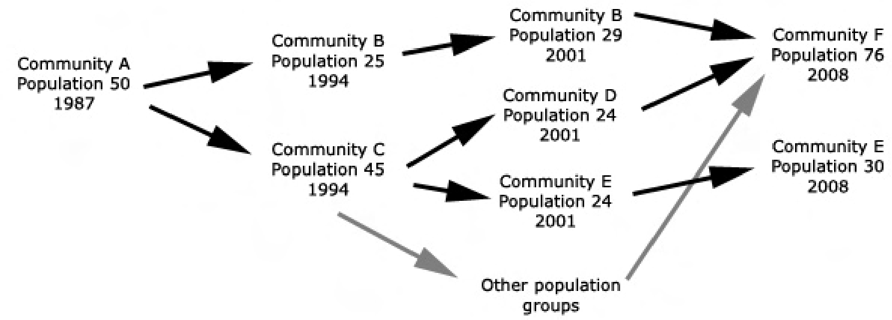

Community A
Population 50
1987
Community B
Population 25
1994
Community C
Population 45
1994
Community B
Population 29
2001
Community D
Population 24
2001
Community E
Population 24
2001
Other population
groups
Community F
Population 76
2008
Community E
Population 30
2008

Fig. 2

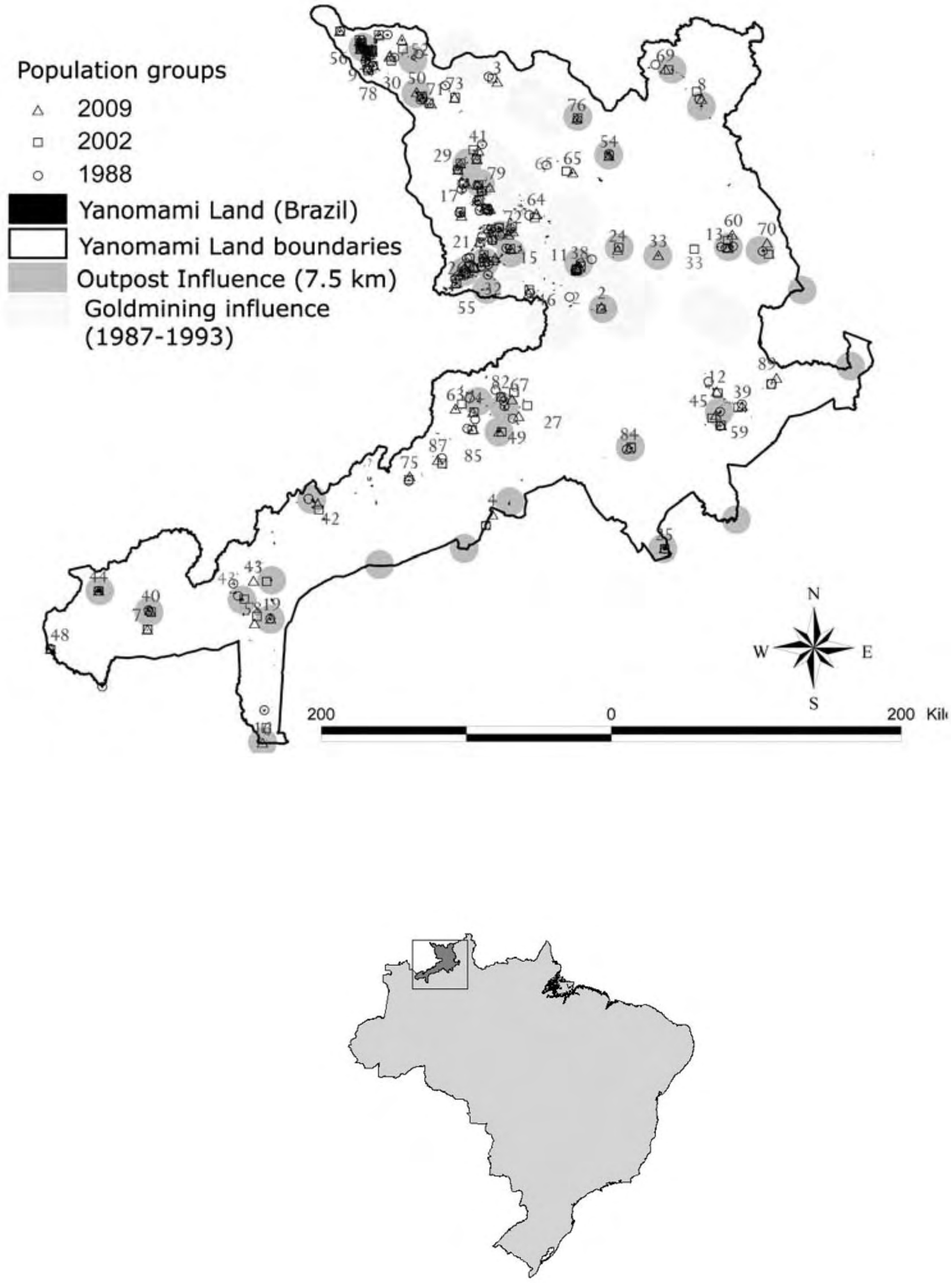
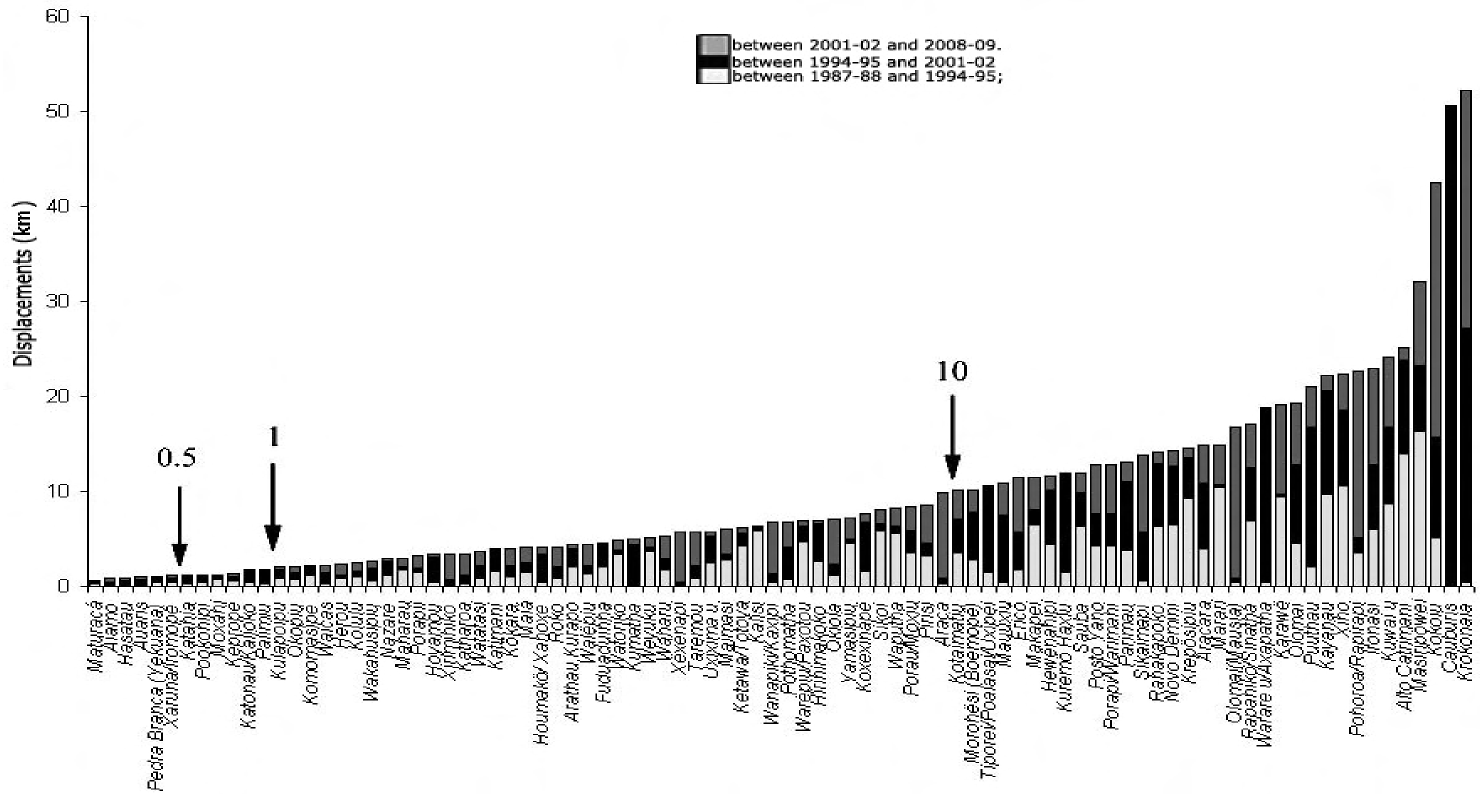
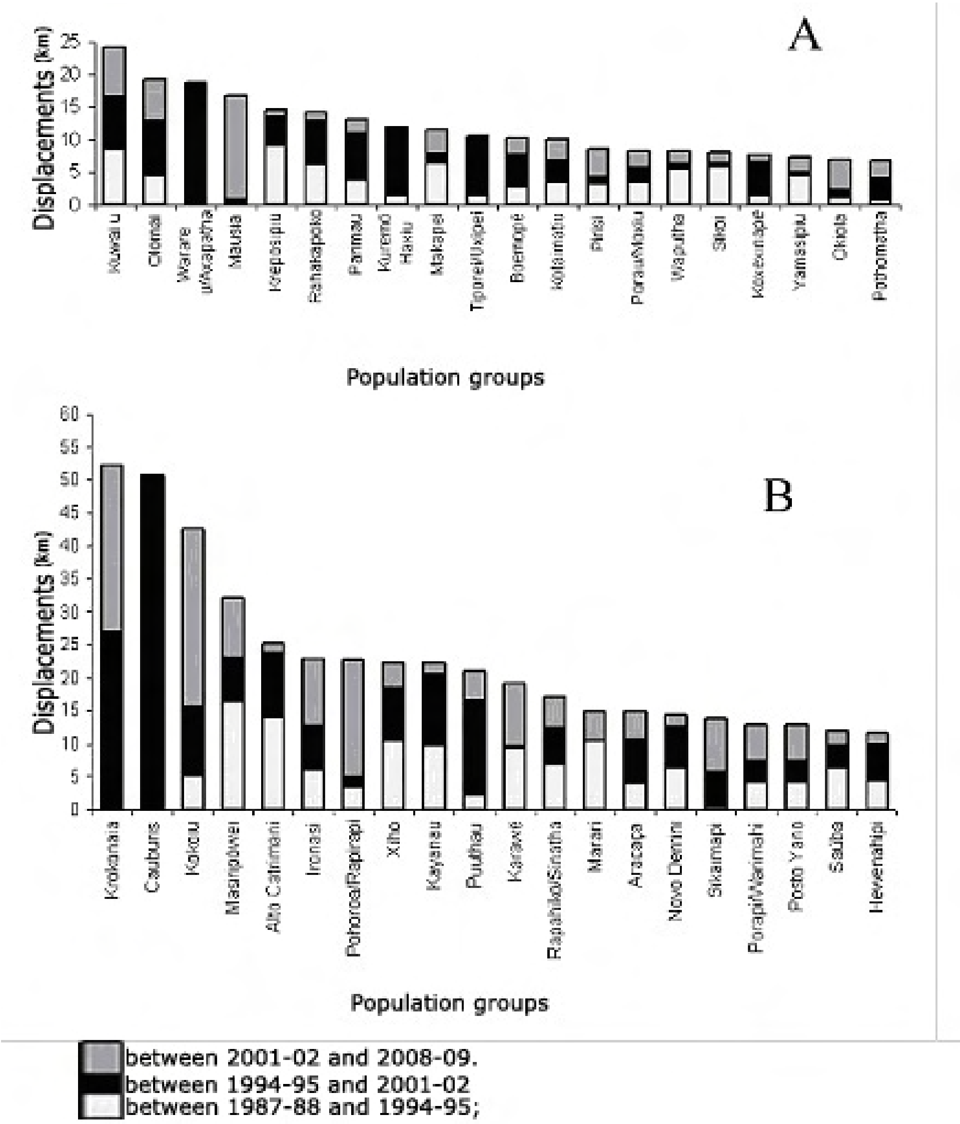

Population groups
2009
2002
1988
Yanomami Land (Brazil)
Yanomami Land boundaries
Outpost Influence (7.5 km)
Goldmining influence
(1987-1993)
N
W
E
S
200
0
200

Fig. 3.



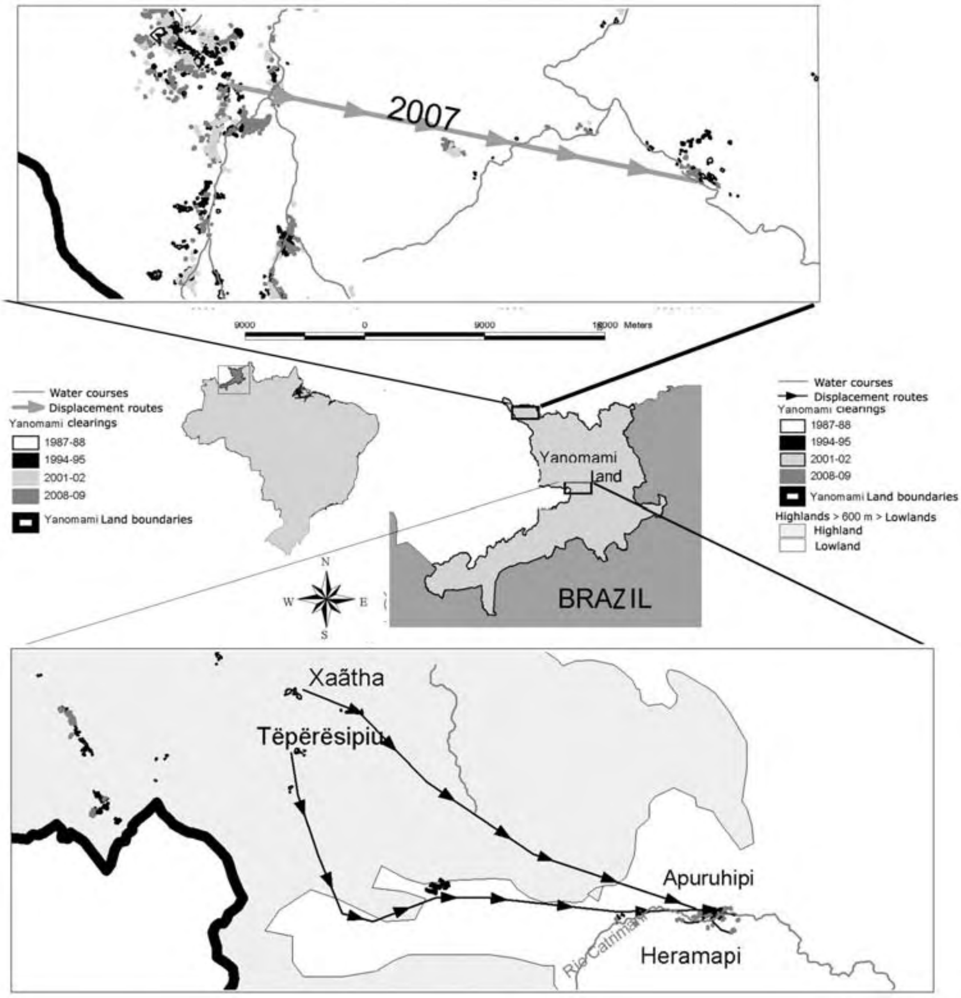
between 2001-02 and 2008-09.
between 1994-95 and 2001-02
between 1987-88 and 1994-95;
Displacements (km)
60
50
40
30
20
10
0
0.5
1
10

Fig. 4



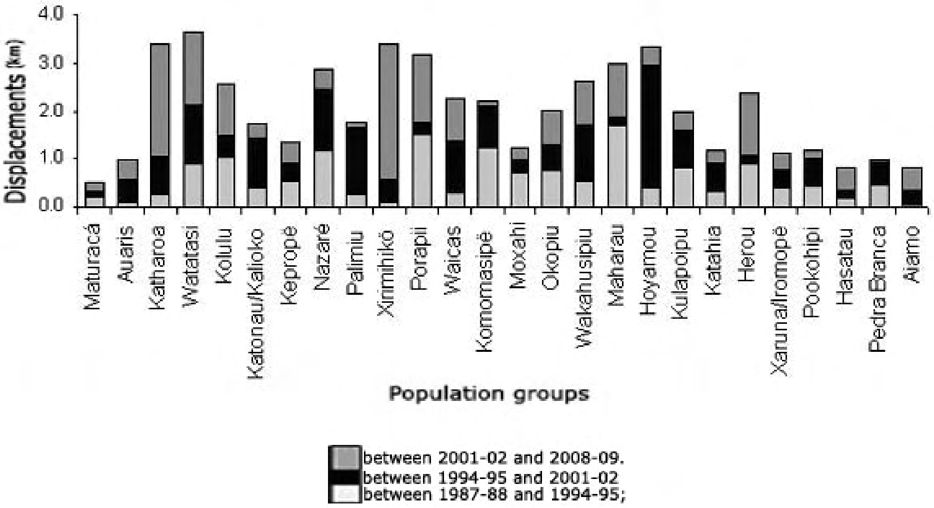
A
Displacements (km)
Population groups
B
Displacements (km)
Krokanaia
Cauburis
Kokoiu
Alto Catrimani
Ironasi
Pohoroa/Rapirapi
Xiho
Kayanau
Puuhau
Marari
Novo Demini
Sikamapi
Posto Yano
Saúba
Population groups
between 2001-02 and 2008-09.
between 1994-95 and 2001-02
between 1987-88 and 1994-95;

Fig. 5



2007
9000
0
9000
18000 Meters
Water courses
Displacement routes
Yanomami clearings
1987-88
1994-95
2001-02
2008-09
Yanomami Land boundaries
Yanomami
Land
BRAZIL
N
W
E
S
Highlands > 600 m > Lowlands
Highland
Lowland
Xaãtha
Tëpërësipiu
Apuruhipi
Heramapi

Fig. 6



4.0
3.0
2.0
1.0
0.0
Displacements (km)
Maturacá
Auaris
Katharoa
Watatasi
Kolulu
Katonau/Kalioko
Kepropë
Nazaré
Palimiu
Xirimihikö
Porapii
Waicas
Komomasipë
Moxahi
Okopiu
Wakahusipiu
Maharau
Hoyamou
Kulapoipu
Katahia
Herou
Xaruna/Iromopë
Pookohipi
Hasatau
Pedra Branca
Aiamo
Population groups
between 2001-02 and 2008-09.
between 1994-95 and 2001-02
between 1987-88 and 1994-95;

Fig. 7

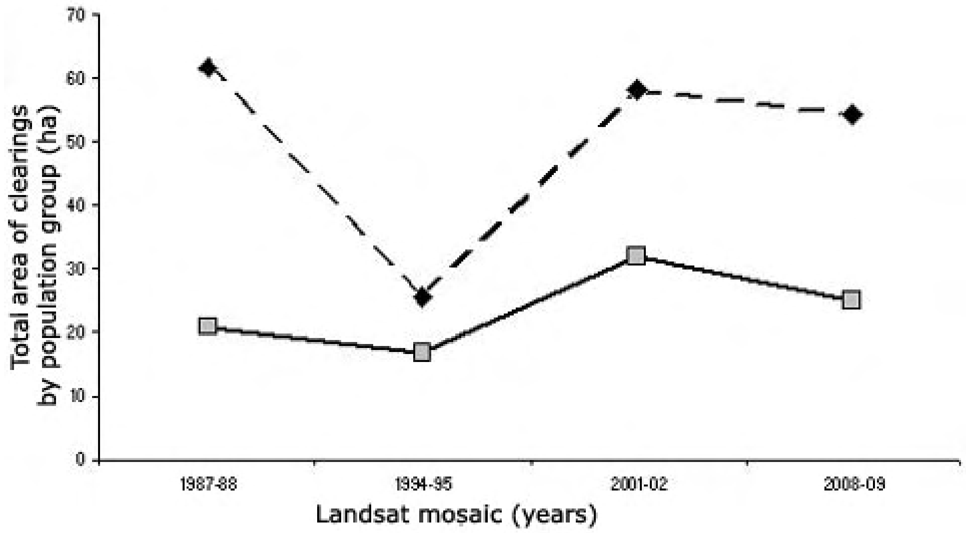
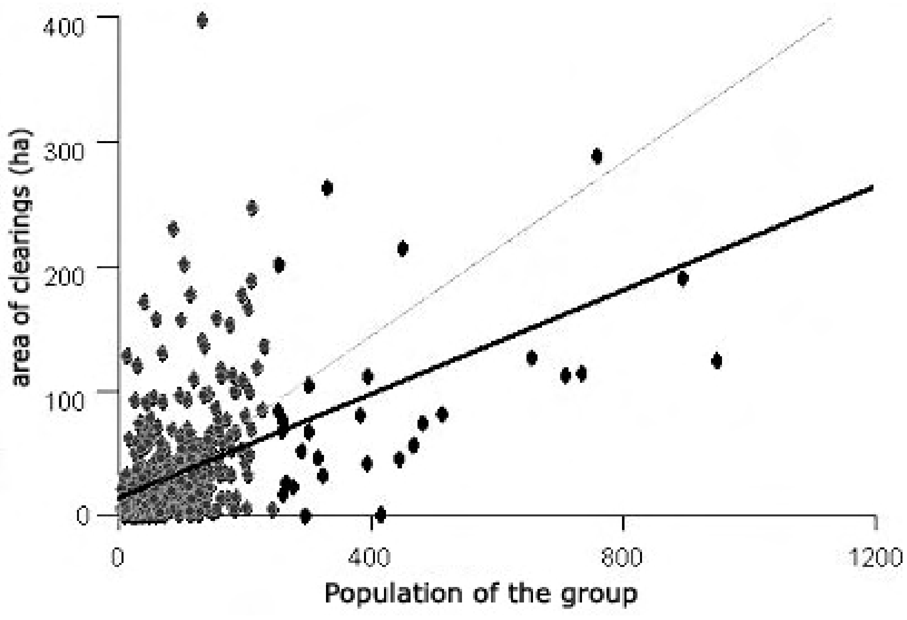
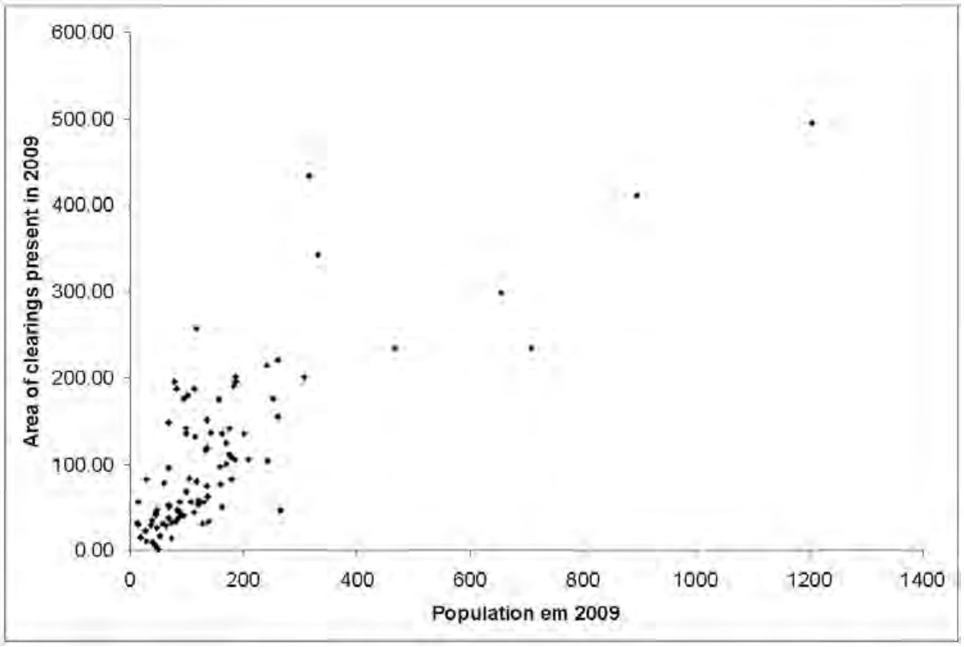

Total area of clearings by population group (ha)
70
60
50
40
30
20
10
0
1987-88
1994-95
2001-02
2008-09
Landsat mosaic (years)

Fig. 8



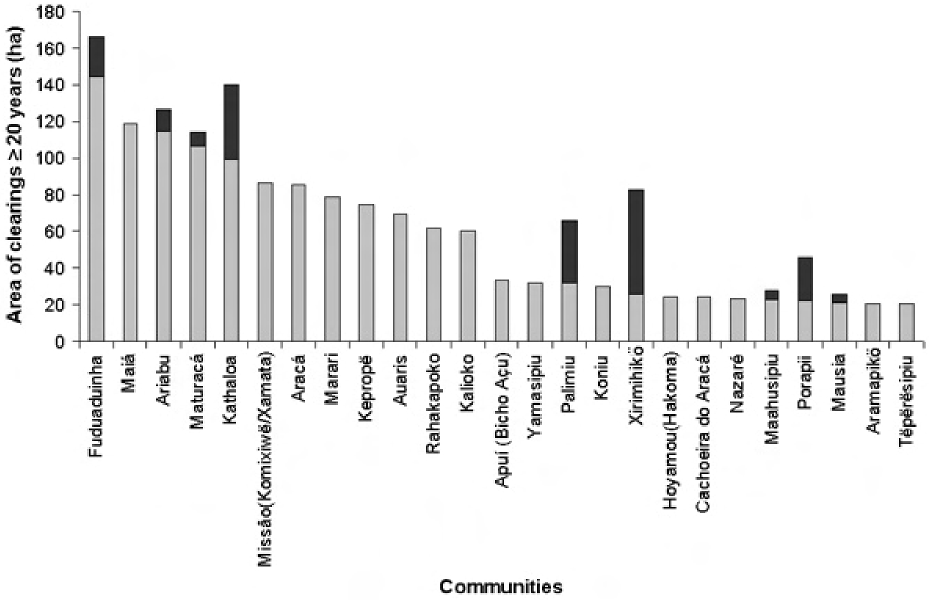
400
300
200
100
0
area of clearings (ha)
0
400
800
1200
Population of the group

Fig. 9



600.00
500.00
400.00
300.00
200.00
100.00
0.00
Area of clearings present in 2009
0
200
400
600
800
1000
1200
1400
Population em 2009

Fig. 10



Area of clearings ≥ 20 years (ha)
180
160
140
120
100
80
60
40
20
0
Fuduaduinha
Maiá
Ariabu
Maturacá
Kathaloa
Missão(Komixiwë/Xamata)
Aracá
Marari
Kepropë
Auaris
Rahakapoko
Kalioko
Apuí (Bicho Açu)
Yamasipiu
Palimiu
Koniu
Xirimihikö
Hoyamou(Hakoma)
Cachoeira do Aracá
Nazaré
Maahusipiu
Porapii
Mausia
Aramapikö
Tëpërësipiu
Communities

Fig. 11