HEALTH RISK ASSESSMENT ASSOCIATED WITH THE IMPLEMENTATION OF THE MADEIRA HYDROELECTRIC COMPLEX, BRAZILIAN AMAZON[1]

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Introduction

The installation of large hydroelectric projects lead to changes in natural and anthropic environments, usually interfering with disease incidence in their surrounding areas (Finkelman et al., 1984). In general, disease risk factors arise or are magnified as a consequence of these projects. Changes occurring in the structure and dynamics of the landscape and in the population's living conditions, caused by the disruption of family and social structures and the reorganization of the local economy, potentially favour outbreaks of infectious diseases, due to the introduction of new pathogenic agents and vectors or the spread of pre-existing diseases.

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The absence, lack, or inadequacy of sanitation infrastructure and health care services, including epidemiological surveillance programs, contribute to giving rise to a particularly negative context, which can be exacerbated by an increased demand by a migrant population that is susceptible to native diseases or brings pathogens that did not exist in the region, and flocks to construction sites in a relatively short space of time.

Most studies addressing the health impact of hydroelectric projects report a greater incidence of diseases directly related to water, such as malaria (Yewhalaw et al., 2009) and schistosomiasis (Steinmann et al., 2006). Few studies have focused on the indirect health implications of voluntary or involuntary migration and its effects on social networks, mental health, and the adaptation to new dwelling places, despite the intense movements of workers and dislodged people due to the construction (Cao et al., 2012).

Environmental conditions in the Amazon region, such as high rainfall and humidity, the presence of diversified and extensive water bodies (rivers, creeks, streams, and "igarapés"), are particularly favourable to the spread of diseases by vectors and parasites, and harbour a rich diversity of disease vectors. Likewise, the anthropic alterations of the landscape, largely based on economic activities conducted inside the forest and in precarious human settlements, provide various opportunities for human-vector contact (Couto, 1996; 1999). The new ecological conditions and their health impact are particularly significant when analysed alongside socioeconomic and demographic changes that occur simultaneously with environmental impacts.

The conversion process of aquatic environments, when the reservoirs are formed, changes the concentration of nutrients and organic matter in the reservoirs considerably, favouring the growth of toxic algae, such as cyanobacteria (von Sperling, 2012) and aquatic macrophytes, especially in lenthic water bodies or dammed tributaries (Junk and Mello 2005). All these changes are favourable for mosquito breeding emergence (Zeilhofer et al., 2007), especially those of the *Culex* and *Anopheles* genera (Ferrete et al., 2004), whose population densities can undergo significant increases (Bulcão, 1994).

The incidence of health problems varies in intensity depending on space (distance from reservoirs) and time (stage of the hydroelectric power projects). During the construction phase, large-scale interventions, such as deforestation and river course changes, as well as the settlement of workers and relocation of the population directly affected by the construction, intensify contact between vectors and humans. Similarly, displacement of wild animals and the introduction of domestic animals to human settlements lead to the development of new epidemiological chains (Massaro et al., 2008). This phase also sees the emergence of social conditions that favour the spread of a great variety of diseases, including sexually transmitted ones, and an increase in the number of acts of violence.

During the operation phase, the consolidation of the urbanization process around the reservoir, together with the resulting environmental impacts, is not accompanied by an adequate expansion of sanitation infrastructure and health care services. The new socioeconomic dynamics and cultural conditions promote the spread of AIDS, and social inequality is an important explanatory component (Kawachi et al., 1999). In addition, new settlements with poor sanitation conditions support the transmission of dengue fever (Costa and Natal, 1998; Barcellos and Lowe, 2014).

In Porto Velho, Rondônia, population growth has been closely associated with the various economic cycles of rubber, mining, and agricultural colonization, since 1850. The opening of the BR-364 Highway (from São Paulo to Acre), in the 1960s, was responsible for the area's widespread occupation by agriculture, which was followed by gold exploration, mainly in the 1970s and 1980s. The population of Porto Velho grew rapidly thereafter: it had 134,000 inhabitants in 1980, 330,000 in 2000, and 430,000 in 2010 (IBGE, 2012). The city grew, however, in an ineffective way in terms of infrastructure and urban services: in 2000, only 35% of households were supplied by water network, over 50% of them used a septic tank, and only 9% were served by a sewage network (IBGE, 2012).

In a broader context, deforestation in Porto Velho is directly associated with public investments in infrastructure construction works, especially road openings. Deforestation also affects indigenous territories (ITs), due to the installation of rural settlements in the surrounding area, in order to house not only the population expropriated from the sites of the hydroelectric power plants, but also the migrant population. As it is located only 93 km from Porto Velho, the IT Karitiana is strongly influenced by its proximity to the hydroelectric power plants of Santo Antônio and Jirau, thus making it especially vulnerable (Leão et al., 2004).

An important indicator of the potential damage to the integrity of native vegetation is the occurrence of forest fires. Just in 2007, around 6,500 hot spots were registered in Porto Velho, 33% of them in areas classified as "forest", around and inside indigenous territories, conservation areas, and rural settlements (Silva Filho et al., 2007).

The 14 conservation areas in Porto Velho, including ecological reserves, national forests, environmental protection areas, among other categories, have not totally prevented deforestation, and they are constant targets of illegal practices, such as land grabbing and logging. Between August 2007 and April 2008 - therefore within the period of the hydroelectric power plants' construction - around 4,000 ha of native vegetation were destroyed in the Bom Futuro National Forest, thus making it one of the conservation units in the Legal Amazon with the highest rates of deforestation during that period (Futada, 2010). According to the state government, (Governo do Estado de Rondônia, 2009), more than 750 deforestation spots were detected in Porto Velho between 1996 and 2001, resulting in the suppression of about 20,000 ha of native vegetation. From 2001 to 2006, however, deforestation surpassed 600,000 ha. Deforestation agents in Rondônia include illegal land owners, small farmers - migrants, and landless settlers, cattle farmers, and logging workers who occasionally benefit from rural lending by State-owned banks and from the installation of new infrastructure construction sites, which makes it possible to reach previously inaccessible areas.

Therefore, a study of the impact of hydroelectric power plants on the population's health must be grounded in the evaluation of socioeconomic aspects and the analysis of regional land use and occupation particularities. Knowledge of the dynamics of natural resources, the territorial appropriation and temporal structuring of the health determinant process, as well as the genesis of changes in the disease transmission chain, is important for establishing causality between factors, correlations, and risk indicators.

Several models have been proposed to establish causal relationships between changes in environmental, socioeconomic, and health conditions of the population, due to the installation of large hydroelectric power projects (Lerer and Scudder, 1999; Jobin, 1999; Horlacher et al., 2012). In this respect, the Madeira Hydroelectric Complex is particularly emblematic, due to the fact that it is the setting for radical social conflicts, besides being located in a region of insufficient sanitation coverage and health care infrastructure, and which is undergoing an accelerated agricultural frontier expansion process.

Thus, the primary aim of this article is to analyse the epidemiological risk associated with the population of Porto Velho due to the implementation of the Madeira Hydroelectric Complex, which, nowadays, represents the largest and most complex undertaking of its kind in the Amazon region. Other important large hydroelectric projects are being developed in the Amazon region, such as Belo Monte. Thus, this study can contribute to identifying the main factors related to the impact of hydroelectric projects on health conditions, as well as proposing useful methodologies for monitoring changes in the environment and the local population's health.

Methodology

Study area and characterization of the undertakings

The Madeira Hydroelectric Complex consists of the hydroelectric power plants (HPP) of Santo Antônio and Jirau and is included into the Brazilian interconnected electric system. Its primary purpose is to ensure hydroelectric power supply to the Amazon region, reducing the participation of diesel in the regional energy mix.

It may also have an international impact, as there is a possibility that Bolivia and Peru will purchase power generated by the project. The construction of hydroelectric power plants will also make the Madeira river fully navigable along its whole 1,400 km.

Both hydroelectric power plants are located in Porto Velho, in Rondonia state (Figure 1).

The reservoir area of Santo Antônio will be about 270 km^2, of which 107 km^2 will effectively be flooded by the reservoir, while Jirau's reservoir will cover about 260 km^2, with 150 km^2 corresponding to the natural flooding of the Madeira river in this stretch. Santo Antônio will have an installed capacity of 3,580 MW, and Jirau 3,300 MW.

The Santo Antônio and Jirau dams are equipped with 44 bulb turbines which operate in a run-of-river mode, thus avoiding the flooding of large areas, minimizing losses and increasing effectiveness in the hydraulic circuit, compared to other kinds of turbine. Similarly, they enable an outflow of up to 70% of the nominal flow, and they also prevent sediments from reaching the vicinity of the water outlet (Moreira, 2004). This architecture provides for a better use of the Madeira river's hydroelectric potential, and is more appropriate to meet the conservation needs of the Amazon biome.

Data Processing

For this study, socioeconomic, health, and environmental indicators were selected as markers of possible impacts of the deployment of hydroelectric power plants on the

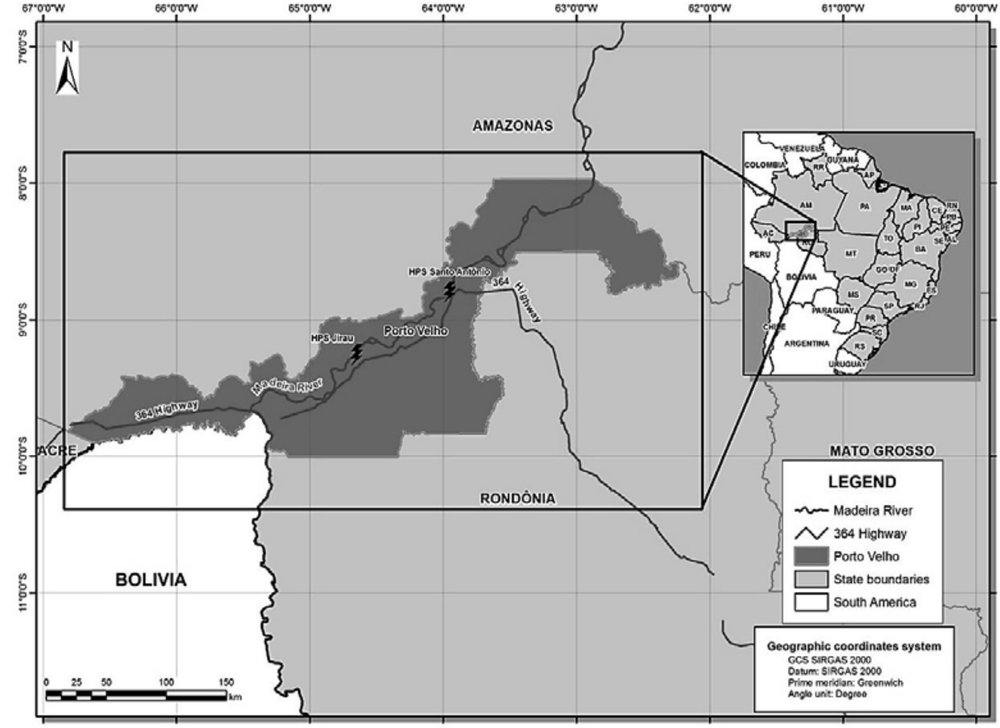

Figure 1. Location of the HPP in the Madeira Hydroelectric Complex. **Source.** Prepared by the authors.

incidence of dengue fever, leishmaniosis, malaria, and AIDS. The selected health indicators are sensitive to changes in the socio-demographic and land use structure and they are included in the list of compulsory notification diseases with high incidence in Porto Velho.

The socioeconomic indicators were population, total number of inhabitants per household, the population's education and income levels, proportion of recent migrants, water supply, sewage, and garbage collection, based on the 2000 and 2010 Demographic Census (IBGE, 2012).

Health data were obtained from the Municipal Health Secretariat of Porto Velho (SEMUSA), by consulting the following health information systems: Mortality Information System (SIM), Disease Notification Information System (SINAN), Live Birth Information System (SINASC), and Hospital Inpatient System (SIH). Thus, it was possible to follow up the events related to individual clinical history, such as births, hospitalizations, illnesses, and deaths, according to residential address. The combination of variables was useful for identifying indicators of population health status and changes in the endemic and epidemic levels of diseases.

The presence and capacity of health care services were evaluated based upon the Survey of Health Service Provision (AMS) conducted in 1999 (IBGE, 2012), and the number of hospitals, beds, and health care units involved with epidemiological surveillance.

The environmental indicators used were the percentage of deforested area from 2004 to 2009; percentage of urbanized area; percentage of area with different phytophysiognomic types (variants of ombrophilous forest, pioneer formations, savannas, "campinaranas"); percentage of area with secondary vegetation; and percentage of area with pastures. Data on land use and coverage were provided by the Project for Conservation and Sustainable Use of the Brazilian Biological Diversity (PROBIO/MMA), derived from Landsat images mainly obtained in 2002, on a scale of 1:250,000 (MMA, 2013). The deforestation data was derived from the Real Time Deforestation Detection System (DETER) produced by the National Institute for Space Research (INPE), covering the 2004-2009 period (INPE, 2012).

The Geographical Information System (GIS) was used to gather and organize spatial data from different sources. All socioeconomic, health and environmental data were assigned to district polygons obtained from IBGE. Other cartographic data were also incorporated to analyze socio-spatial groups, such as indigenous territories (National Indian Foundation - FUNAI), roads, airports, mining areas (National Department of Mineral Production - DNPM), and land use (Chico Mendes Institute for Biodiversity Conservation - ICMBio).

The set of socioeconomic, health (epidemiological and health care services) and environmental data was geocoded according to administrative districts of Porto Velho, and consisted of two phases: pre-HPP period (2001-2006) and HPP construction period (2007-2010) of Santo Antônio and Jirau.

The selected variables were grouped into three different spatial units of analysis, formed by groups of districts: 1) directly influenced area (DIA), aggregating the districts directly intercepted by the borders of the reservoirs; 2) indirectly influenced area (IIA), encompassing districts contiguous to those of DIA that have similar socioeconomic characteristics; and 3) control area (CA), consisting of the remaining districts of Porto Velho, contiguous to IIA, which are less influenced by the economic and social dynamics of DIA and IIA (Figure 2).

Data were organized by using a database manager and statistical package (SPSS, version 14) and GIS software (Terraview, version 4). The matrix generated by tabulating data was exported to SPSS, in order to perform multivariate analysis (normality tests) and multiple linear regression analysis, with health indicators as dependent variables and the socioeconomic and environmental indicators as independent variables. Final variables of the model were selected through the backward method, to establish groups of indicators representing more specific factors, to avoid redundancy between variables. Multivariate analysis of a set of social and environmental indicators, in particular, has been one of the most frequently used ways of distinguishing between regions that form a mosaic of spatial units under various influences (Paim, 1997).

The results of the analysis of secondary data were systematized into maps to express the main explanatory variables, according to the associations arising from the multivariate regression model. The layers of variables were interpolated using the Inverse Distance Weighting (IDW) method to calculate the spatial moving average and estimate

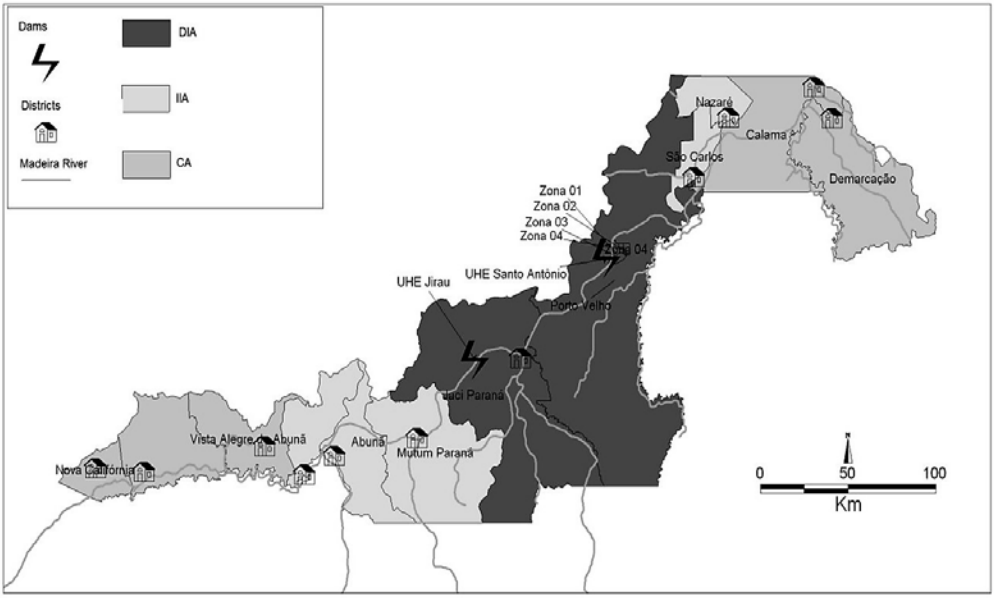

Figure 2. Data aggregation scheme arranged into spatial units. DIA: directly influenced area; IIA: area indirectly influenced area; CA: control area. **Source.** Prepared by the authors.

local tendencies. The continuous surface obtained underwent a vectorization process for delimiting polygons according to value class, which was presented as a new layer in GIS. The epidemiological risk map was obtained through the superimposition of the main explanatory variables regarding the incidence of the diseases to observe their intersections.

Subsequently, the results obtained were discussed with public health professionals of Porto Velho, in order to better understand the causal relationships between social and environmental processes and health status.

Results

The analysis of the indicators provided evidence of the impact of the deployment of the Madeira Hydroelectric Complex regarding socioeconomic, health, and environmental aspects, based on spatial (distance from HPP, according to the three areas of influence) and temporal (pre-HPP period and construction period) variations. Thus, it was possible to identify the changes in health indicators in the influence areas after the HPP's implementation (Figure 3).

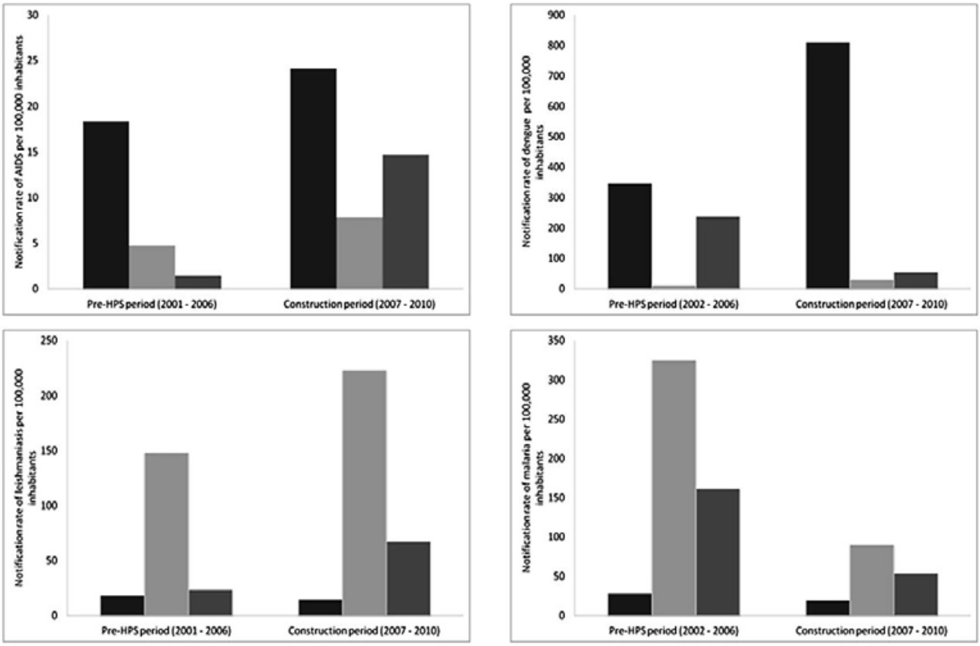

Figure 3. Variation in the incidence rates of (a) AIDS, (b) dengue fever, (c) leishmaniosis, and (d) malaria in the areas of influence (DIA, IIA, and CA) during the period before (2001-2006) and after (2007-2010) the beginning of construction of the Madeira Hydroelectric Complex. **Source**: Prepared by the authors.

Data on AIDS show that there was an increase in incidence rates during the construction period. This increase was observed in both IIA and CA. The highest average rate was registered in DIA, with 24 cases per 100,000 inhabitants, and the largest growth in CA, where the average rate increased from 1 to 15 cases per 100,000 inhabitants.

In the case of dengue fever, the increase was especially noticeable in DIA, which increased from 350 cases per 100,000 inhabitants, from 2002 to 2006, to 810 cases per 100,000 inhabitants, between 2007 and 2010. In parallel, in CA there was a decrease in the average incidence rate during the construction period.

Regarding leishmaniosis, there was an increase in the incidence rate in IIA and CA and a decrease in DIA during the construction period. The values were high compared to national standards: 14 notified cases per 100,000 in DIA, 67 cases in CA, and 223 cases in IIA.

Malaria showed a significantly decrease in incidence during the deployment of HPP in all areas under analysis. The highest incidence rates were observed in IIA. Despite the efforts to control the disease, incidence rates may still be regarded as being high, ranging from 19 cases per 100,000 inhabitants, in DIA, to 90 cases per 100,000 inhabitants, in IIA.

The results of the multiple linear regression for AIDS showed that belonging to DIA, the proportion of migrants and illiterate residents were the main explanatory variables (table 1). The final model, with the three selected variables, has a correlation coefficient of 0.73, i.e., a high significance level. The incidence of AIDS increased throughout the study period and a concentration of new cases was detected especially in DIA, as indicated by the direct correlation between the incidence rate and the fact of belonging to this area of influence. The association with migratory processes and the areas of influence, along with the low education level may indicate that the epidemic is reaching highly mobile population groups and socially vulnerable ones. Due to the HIV virus's long incubation period, higher incidences can be expected in coming years.

Table 1: Parameters of the multiple linear regression model (standardized β coefficient and p significance) of the rates of AIDS, dengue fever, malaria and leishmaniosis.

AIDS	
Variables	**β (p value)**
Area directly influenced by the HPS	0.07 (0.79)
Proportion of migrants in the population	0.65 (0.11)
Proportion of residents with no schooling	0.12 (0.73)
Dengue fever	
Variables	**β (p value)**
Area directly influenced by the HPS	-0.18 (0.56)
Proportion of residents with < 5 years of schooling	0.55 (0.07)
Percentage of deforested area	0.33 (0.20)
Malaria	
Variables	**β (p value)**
Average deforestation rate	0.52 (0.06)
Proportion of households with other kinds of water supply	0.42 (0.08)
Proportion of households with other ways of garbage disposal	0.31 (0.22)
Leishmaniosis	
Variables	**β (p value)**
Percentage of deforested area in 2007	0.78 (0.00)
Households with sink sewage	0.62 (0.00)
Percentage of area with secondary vegetation	-0.26 0.05)

Source. Prepared by the authors.

As for the incidence of dengue fever, the results of the multiple linear regression indicate that the main explanatory variables are DIA, the proportion of residents with less than 5 years of schooling, and the percentage of recently deforested areas (table 1).

DIA has the highest incidence rates, even after controlling for the other factors which may influence this relationship, such as land use and demographic profile. The final model shows a correlation coefficient of 0.73, i.e., a high degree of adherence between observed and expected values.

In the case of malaria, the results of the regression model revealed that the main explanatory variables were the percentage of deforested area, the proportion of households with improvised water supply provision (those without a water supply network), and, also, alternative garbage disposal (i.e., without systematic garbage collection) (table 1). All variables were directly associated with malaria and contribute to the final model, which has a correlation coefficient of 0.72. Accordingly, the main explanatory variables were related to land use, and inadequate housing conditions.

The main explanatory variables for the incidence of leishmaniosis are related to the percentage of deforested area, the proportion of households with improvised sewage disposal, and the percentage of area with secondary vegetation (table 1). The standardized β values, representing the weight of coefficients in the final model, indicate that leishmaniosis incidence rates increase as a response to the increment in deforested areas, in districts with improvised sewer and decrease in secondary vegetation areas. The final model shows a correlation coefficient of 0.91, i.e., a high adherence level between observed and expected values.

The migration and deforestation variables are the main factors underlying changes in social and environmental dimensions, embodying the transformation of regional socioeconomics. These variables have a significant weight in the analysis of the studied diseases and were therefore used to prepare the epidemiological risk map (Figure 4). This map shows synthetically how the variables are distributed in the study area.

Discussion

According to the results, it is possible to identify relations between the construction of the Madeira River Hydroelectric Complex and the incidence of diseases in Porto Velho municipality. In addition, there is a close association between migration and deforestation rates due, to a large extent, to the new socioeconomic dynamics in the areas influenced by the HPP works.

In particular, these variables underlie changes in the social framework and local geography. However, the migrants should not be regarded as a uniform population. Their origin had influence on disease risks, indicate the existence of different population subgroups whose vulnerability may vary.

A part of the migration flows observed in the city was due to infrastructure construction works of the Madeira Hydroelectric Complex, whose major effects were felt in the central region of Porto Velho. They came from various regions, and concentrated mainly in DIA. The largest number of migrants were from the state of Rondônia, followed by Amazonas, Acre, São Paulo, and Maranhão. Districts closer to the HPP have shown strong growth in recent years, and have been the most affected by the construction works. In the surrounding areas of Santo Antônio and Jirau, there is a great reliance on public

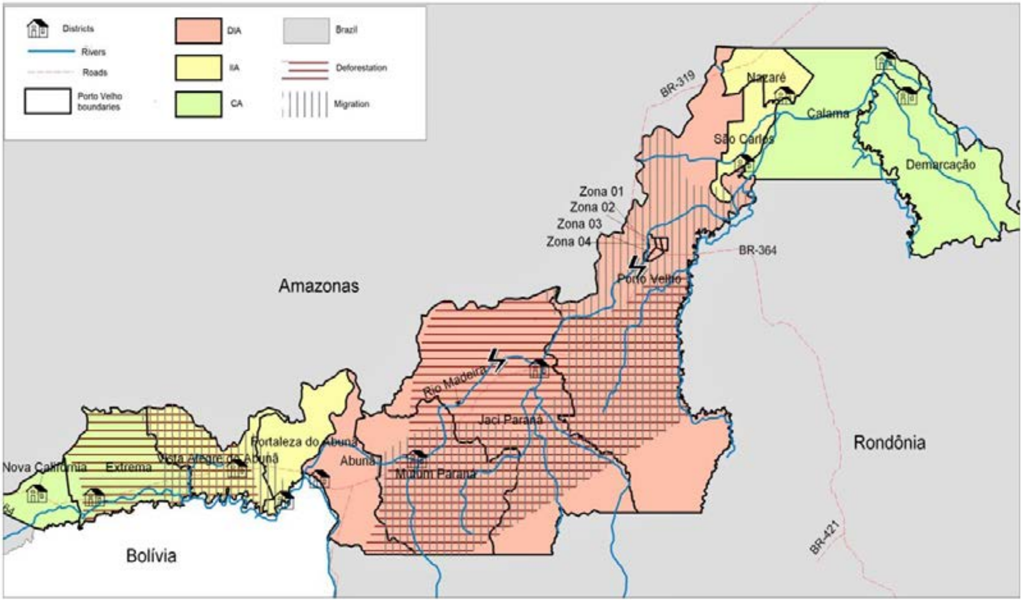

Figure 4. Epidemiological Risk Map of the Madeira Hydroelectric Complex. **Source**. Prepared by the authors.

services, which increases as the construction works advance, resulting in increasing land occupation and land disputes.

Another migration flow was observed in the western region of Porto Velho, where the main economic activity is the native forest logging accompanied by the advance of animal farming and land disputes, in a territorial matrix consisting of rural settlements, large proprieties and unoccupied lands. The sanitation coverage and health care infrastructure are ineffective in this area, leaving the population, especially the migrants, vulnerable to diseases (Katsuragawa et al., 2010).

The migrant population, whether or not absorbed by the construction works in Santo Antônio and Jirau, is supposed to spread across the region, tending to concentrate along the main highways, in accesses to the construction sites, in close urban areas, or in the riparian areas. The dispersion of these population groups consequently creates favourable conditions for the emergence of diseases, which can be aggravated by the absence or inadequacy of basic sanitation and health care services and proper housing conditions.

The attraction of migrant populations and the boost to the economy provided by the installation of hydroelectric power plants contribute to higher deforestation rates. Thus, the border between Porto Velho and the state of Acre has undergone intense deforestation due to strategic economic development factors, such as the confluence of major highways and rivers used for transportation of people and goods. In this region, the economic sectors, such as agricultural and timber, motivated settlements in the districts of Vista Alegre do Abunã and Nova California, which historically have the highest deforestation rates in Porto Velho. Land occupation has moved eastwards and reached the districts of Abunã and Mutum-Paraná, as well as Jaci-Paraná, where the Jirau hydroelectric power plant is located. Thus, deforestation is expected to intensify in this area. In fact, during the construction period, deforestation rates were higher in areas close to and with easy access to the construction sites, including the city centre. In IIA and CA, located east of the city, however, the deforestation rate has been lower.

The analysis of selected indicators allowed the identification of some spatial and temporal patterns of health problem. Regarding AIDS and dengue fever, a growing incidence has been observed in recent years all over the country and cannot be attributed exclusively to the construction of hydroelectric power plants. However, the association between AIDS and dengue fever and migration and urbanization may be a sign of the aggravation of the vulnerability of populations due to the construction works. HIV/AIDS has spread throughout the country and tends to be found among poor people, women, and in rural regions, often following the main migration routes (Barcellos and Bastos, 1996). Data collected in this study reveals that there has been an outbreak of dengue fever, particularly in DIA, characterizing a risk area in the area surrounding the HPP. The area most affected is predominantly occupied by people with a poor educational level and housing conditions. It is impossible to establish a direct correlation between the higher incidence of dengue fever and the construction of hydroelectric power plants, since similar epidemic dynamics have been observed in other regions of the country (Barcellos and Lowe, 2014). However, the intensification of migratory movements, in association with poor housing and sanitation conditions, may facilitate the introduction and spread of pathogens (Vasconcelos et al., 2006; Katsuragawa et al., 2010).

The results of the model for leishmaniosis and its spatial distribution show that the disease is associated with the recent occupation of forest areas by a population that has to cope with poor housing conditions. These factors may be indirectly related to the hydroelectric power plants, since the construction works place susceptible populations in contact with the forest, either through deforestation or by inducing the occupation of areas recently cleared for agricultural purposes.

Historically, endemic diseases such as malaria and leishmaniosis are directly associated with demographic, environmental, socioeconomic, and cultural changes occurred in recent decades, determining a continuous reorganization of territories (Barata, 1995; Tauil, 2011).

Thus, the impact of hydroelectric power plant implementation on the population's health may manifest itself in a direct way, by changing the environment, favouring the transmission of pre-existing diseases, and in an indirect way, by concentrating risk factors among the most vulnerable populations. Moreover, Porto Velho is experiencing an agricultural frontier expansion process, it also has a privileged geographical position, as it is a route to Bolivia and the western Amazon region along rivers and highways, which results in large movements of people and, consequently, the emergence and spread of infectious diseases.

Final remarks

The model developed in this study is a useful tool for analysing the health dynamics of populations affected by large development projects. Epidemiological risk mapping enabled a better understanding to be achieved of the interaction between several factors that influence the spread of diseases. The methodology was also adequate to define a set of demographic, socioeconomic, health, and environmental variables that may act as mediators of the impact of the construction of hydroelectric power plants on health conditions. These impacts are rarely direct and are preceded by processes of change regarding patterns of land use and territorial occupation (Cao et al., 2012).

The construction rationale in this region differs from other hydroelectric power plants. In Porto Velho, the hydroelectric project has strong ties with the local urban area, since the construction work is relatively close, providing more consistent responses to the application of the methodology adopted.

Most of the health problems studied showed a statistically significant association with migration or deforestation, demonstrating an indirect impact of the construction works and the recent occupation of forest areas. Moreover, the spatial distribution of these health problems is associated with the location of the hydroelectric power plants, indicating their possible role in inducing changes in land use.

In fact, the actual and potential disease risks tend to be systematically higher in the surroundings of the Santo Antônio and Jirau construction works, where the growing population has to cope with poor housing and sanitation conditions, thus favouring the exposure to disease vectors. The unemployment of a part of this population after the construction of the hydroelectric power plants, may lead to the displacement of workers and former inhabitants of the area affected to adjacent areas. This process should be monitored, since most of the diseases under analysis were closely associated with migration and urbanization rates.

Therefore, if the implementation of the Madeira Hydroelectric Complex is not followed by the adoption of consistent public policies, especially in order to improve or even completely change the ineffective current disease prevention programs, there is likely to be an increase in diseases and social disturbance associated with these conditions.

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Feature Topics

HEALTH RISK ASSESSMENT ASSOCIATED WITH THE IMPLEMENTATION OF THE MADEIRA HYDROELECTRIC COMPLEX, BRAZILIAN AMAZON

***Abstract*:** This article analyses the health impact of the installation of the Madeira Hydroelectric Complex to the population of Porto Velho county (Amazon, Brazil) between 2001 and 2010. The incidence of a selected list of diseases was evaluated with regard to changes that took place in the human and natural environment, compared to the phase prior to the installation of the hydroelectric power projects. An assessment of environmental responsiveness and the population's vulnerability was carried out based on a matrix of socioeconomic, health, and environmental indicators. Malaria, Aids, leishmaniosis and dengue transmission were differentially affected by the implementation of the hydroelectric power plants in a context of limited government intervention in terms of sanitation and health care infrastructure, deforestation, different forms of land use and cover, in addition to migration processes within the area influenced by the hydroelectric power plants.

***Keywords*:** Hydroelectric construction; health impact assessment; Amazon; Development projects

***Resumo*:** Este artigo analisa o impacto da instalação do Complexo Hidroelétrico da Madeira sobre a saúde da população do município de Porto Velho (Amazônia, Brasil) no período de 2001 a 2010. A incidência de um conjunto de doenças foi avaliada em relação às mudanças ocorridas no ambiente humano e natural, em comparação com a fase anterior à instalação dos empreendimentos hidrelétricos. A avaliação da sensibilidade ambiental e da vulnerabilidade da população foi realizada com base em uma matriz de indicadores socioeconômicos, ambientais e de saúde. A transmissão das doenças: malária, Aids, leishmaniose e dengue - foi afetada de diferentes formas pela implantação das usinas hidrelétricas em um contexto de intervenção governamental limitada em termos de infraestrutura de saneamento e de serviços de saúde, desmatamento, diferentes formas de uso e cobertura do solo, além de processos de migração na área de influência das usinas hidrelétricas.

***Palavras-chave*:** Construção de hidrelétricas; Avaliação de impacto sobre a saúde; Amazônia; Projetos de desenvolvimento

***Resumen*:** Este artículo analiza el impacto de la instalación del Complejo Hidroeléctrico del rio Madeira sobre la salud de la población del municipio de Porto Velho (Amazonía, Brasil) entre 2001 y 2010. Se evaluó la incidencia de algunas enfermedades respecto a los cambios ocurridos en ambiente humano y natural, en comparación con la fase previa a la instalación de los proyectos. Se realizó una evaluación de la respuesta ambiental y de la vulnerabilidad de la población a partir de una matriz de indicadores socioeconómicos, ambientales y sanitarios. La transmisión de malaria, SIDA, leishmaniosis y dengue se vieron afectados de diferentes modos por la implementación de las centrales hidroeléctricas en un contexto de intervención limitada del Estado en materia de infraestructura de saneamiento, servicios de salud y la deforestación, cambios en el uso y cobertura del suelo, además de la migración en el área bajo influencia de las centrales hidroeléctricas.

Palabras clave: Construcción de hidroeléctricas; Evaluación de impacto en la salud; Amazonia; Proyectos de desarrollo

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