# EPIDEMIOLOGICAL TRANSITION ANALYSIS IN VULNERABLE AREAS IN HAITI, IN DEFERENCE TO HYDROMETEOROLOGICAL DISASTERS

# EPIDEMIOLOGIQUE DANS LES ZONES VULNÉRABLES EN HAÏTI, EN DIFFERENCE DES CATASTROPHES METEOROLOGIQUES HYDRO

# ANALISIS DE LA TRANSICIÓN EPIDEMIOLÓGICA EN ZONAS VULNERABLES DE HAITÍ, ANTE DESASTRES HIDROMETEOROLÓGICOS

**Gabriela Bravo-Orduña[1]; Alfonso Gutiérrez-López[2]**

## Abstract

It presents the description of the medical services and the Ministry of Health in Haiti, with different levels of organization. The epidemiological transition of the main diseases that have been presented by Departments in the last years is analyzed. In addition, the hydrometeorological information is shown in the form of intensity, duration and period of return of extreme rains, in order to characterize the pluviometric regime of the country. Using this information, a *Meteo-Epidemiological Vulnerability Index (MEVI)* is proposed. This index uses infectious-contagious disease data, the capacity and distribution of medical infrastructure, physiographic conditions of the country, and rainfall data (expressed in intensities, durations and frequency). The results show how mortality and morbidity rates are influenced mainly by communicable diseases in different risk areas. It is concluded that the territorial vulnerability exposed to hydrometeorological phenomena increases in the West and South Departments, where there is a high prevalence of diseases that exceeds the capacity of medical attention.
**Keywords:** Medical services**,** hydrometeorological conditions, epidemic, cholera, malaria, vulnerability by zones.

## Resumen

Se presenta la descripción de los servicios médicos y del Ministerio de Salud en Haití, con sus diferentes niveles de organización. Se analiza la transición epidemiológica de las principales enfermedades que se han presentado por Departamentos en los últimos años. Adicionalmente, se muestra la información hidrometeorológica en forma de intensidad, duración y periodo de retorno de lluvias extremas, con el objeto de caracterizar el régimen pluviométrico del país. Empleando esta información se propone un Índice de Vulnerabilidad *Meteo-Epidemiológico (MEVI).* Este índice utiliza datos de enfermedades infecto-contagiosas, la capacidad y distribución de la infraestructura médica, las condiciones fisiográficas del país, y los datos del régimen de precipitaciones (expresados en intensidades, duraciones y períodos de retorno). Los resultados permiten conocer cómo influyen las tasas de mortalidad y morbilidad principalmente por enfermedades transmisibles en las diferentes zonas de riesgo. Se concluye que la vulnerabilidad territorial expuesta a fenómenos hidrometeorológicos aumenta en los Departamentos Oeste y Sur, en donde existe gran prevalencia de enfermedades que sobrepasa la capacidad de atención médica.
**Palabras clave**: Servicios médicos, condiciones hidrometeorológicas, epidemia, cólera, malaria, vulnerabilidad

## Résumé

La description des services médicaux et le ministère de la Santé en Haïti, avec ses différents niveaux d'organisation est présentée. On analyse la transition épidémiologique des principales maladies qui ont été soumises par les ministères au cours des dernières années. Autant, les informations hydrométéorologiques sont utiliser en forme d'intensité de pluies extrêmes, aussi sa la durée et sa période de retour, afin de caractériser le régime des précipitations dans le pays. En utilisant cette information on propose un *Indicateur de Vulnérabilité Meteo-Epidémiologique (MEVI).* Cet indice utilise les données de maladies infectieuses, de la capacité et de la distribution de l'infrastructure médicale, les conditions physiographiques du pays, et les données des précipitations (exprimée en intensités, durées et périodes de retour). Les résultats permettent de mieux comprendre comment influer sur les taux de mortalité et de morbidité due aux maladies transmissibles, principalement dans les différentes zones de risque. On conclu que la vulnérabilité territoriale exposée à des phénomènes hydrométéorologiques augmente dans les départements de l'Ouest et du Sud, où il y a une forte prévalence des maladies au-delà de la capacité des soins de santé.
**Keywords:** Services médicaux**,** Conditions hydrométéorologiques, épidémie, choléra, paludisme, Vulnérabilité par zones.

1 Universidad Autónoma de Querétaro. *gabybravomoon@gmail.com*
2 Universidad Autónoma de Querétaro. Centro de Investigaciones del Agua, CIAQ, Facultad de Ingeniería alfonso.gutierrez@uaq.mx

*Recibido: 28/08/2016*
*Aceptado: 13/04/2017*

## INTRODUCTION

The ministry of public health and the population is the institution in charge of the health system in Haiti. The microsystems of community health units constitute the basic level of care in the country, which in turn is divided into two orders: the first order is composed of health centers, clinics and private centers where it is attended on an outpatient basis. Second order are hospitals centers of concentration where first order referrals are made; they include pediatrics, gynecology-obstetrics, surgery and internal medicine; In Haiti there is an approximate coverage for a population of 150,000 to 200,000; these hospitals are responsible for more specialized care and hospitalization service. Missing specialty services such as urology, ophthalmology, orthopedics and cancerology are made up of departmental hospitals, thus forming the last level of care (PAHO, 2004).

The Health Council is the entity in charge of the management of services of first order, the communication between this and the second order organizations is based on a medical appointment and a view of medical appointment. Approximately 35% of the care centers are made up of the public sector, private practice constitutes 32% and about 31% are made up of mixed institutions along with non-governmental and non-profit institutions. By contrast, about 80% of the population uses traditional practices, most of which live in rural areas and more than 15 km away from medical care (MPHP, 2013).

Even prior to the earthquake, Haiti had the highest indicators of maternal and child mortality, malnutrition, Tuberculosis and HIV/AIDS, with a low life expectancy and, together with the loss of much infrastructure and health services workers, The situation of the country was seriously compromised, so that diseases prevalent on the island and non-prevalent suffered a change in the course of the months prior to the earthquake and hydrometeorological events that affected vulnerable population (IFCR, 2010).

One of the main problems that afflict the country and involve the various strata of society is communicable diseases, notably influenced by the various natural disasters that have afflicted it in recent years. The prevalence of these diseases increased considerably after the earthquake in 2010 with the Cholera epidemic as one of its major health consequences. Due to the precarious hygienic conditions of health, climatic conditions and low resources, the predisposition to vector-borne diseases increased. In addition to these problems is the disadvantage of the country's vulnerability to extreme hydrometeorological phenomena. The territory of Haiti is especially vulnerable to hurricanes and tropical storms, as well as to geological phenomena such as earthquakes. It is for the above that this work proposes to combine the health aspects with the hydrometeorological aspects expressed in a *Meteo-Epidemiological Vulnerability Index (MEVI)*.This index uses quantitative variables formed by infectious-contagious disease data, the capacity and distribution of the medical infrastructure, the physiographic conditions of the country and the precipitation regime data (expressed in intensities, durations and return periods). The calculation of the *MEVI* is done through a Multivariate Analysis by an Empirical Orthogonal Function (EOF) in which allows hierarchizing and correlating the variables and being able to identify which areas or Departments are most affected. Similar studies with multivariate techniques have been carried out with climatological data (Rao, *et al.,* 1991; Gottschalk, *et al.,* 2015; Kima, *et al.,* 2015). However, few studies have been carried out using health variables with climatological variables.

## OBJECTS AND MATERIALS

The main objective is report about the preconditions of Haiti's health services and the situation of these services after natural phenomena, such as hurricanes. Show the relationship between hydrometeorological conditions as a cause of epidemics and the response of health services according to their capacity by Departments. Use a empirical orthogonal function (EOF) analysis to reduce a data set containing a large number of variables to a data set containing many fewer variables, but that still represents a large fraction of the variability contained in the original data set (Vargas, *et al.,* 2009; Busch, *et al.,* 2012). Using this information, a Meteo-Epidemiological Vulnerability Index (MEVI) is proposed. This index uses infectious-contagious disease data, the capacity and distribution of medical infrastructure, physiographic conditions of the country, and rainfall data (expressed in intensities, durations and frequency).

## DEVELOPMENT

At the beginning of the last decade, Cholera was not part of the morbidity and mortality statistics despite having a high prevalence of acute diarrheal diseases, but by 2010, as the incidence of watery bowel movements increased in some vulnerable areas and subsequent to investigations carried out by the Cuban medical brigade, it was determined that the origin of the outbreak was due to the microorganism Vibrio Cholerae O1 serotype Ogawa, causing 442 deaths in November of that year of a total of 6,742 hospitalized patients. The first case arose in the Department of Artibonite, an area with minimal earthquake damage, so it is believed that its spread to the various Departments was indirectly due to secondary conditions (IFCR, 2010). The rapid spread of the outbreak by the Departments triggered measures for their attention and containment, however unfavorable conditions such as the mass concentration of the population in some areas such as Port-au-Prince caused 143,036 cases of Cholera with a case fatality rate of 0.7 compared with The high lethality rates in the Southeast with 4.3 and Grand Anse with 4.1 and a total of 8,090 and 22,107 cases respectively (see figure 1), where it is assumed that the lack of medical centers for health care contributed as one of the main reasons of mortality.

Of vector-borne diseases, Malaria is endemic in some coastal areas, especially where the height (altitudes) less than 300 m above sea level, in other regions the outbreaks are seasonal, influenced by climatic factors, with a high prevalence after Hurricanes triggering increased activity of the mosquito transmitter, increased exposure of the population due to destruction of their homes and exposure to the environment, rainwater stalls, inefficiency of drainage systems, excreta and lack of potable water. Because it is believed that the total number of the population affected by Malaria was undervalued by the lack of notification of cases prior to the year 2010, it is not clear if it was an outbreak in the area (PAHO, 2012). According to data obtained from the National Malaria Control Program by the Ministry of Health of 2011, the highest incidence rate was reported in the Central Department with 264 cases in 2009, to 26,563 cases by 2010 (see figure 2).

Because reproduction of the Anopheles mosquito is inversely proportional to the height (altitude), coastal areas are more vulnerable to the spread of Malaria; at a height above 2,500 m above sea level the mosquito does not survive. With this we observe that much of the country is in the ideal conditions of temperature and humidity for the dissemination (see figure 3). The outbreak that originated in the Center during 2010 could have been triggered by the factors mentioned above and with the already mentioned factors triggered by the earthquake.

As mentioned above, Tuberculosis is a disease of high incidence in the country, by 2010 the prevalence was 230 cases per 100,000 inhabitants (PAHO, 2012), after this period was detected especially in the cases of displaced persons camps (see figure 4) and of 1,165/100,000 inhabitants until the year 2013, considering between these periods the affectations caused by the Hurricans Ernesto and Issac in August of 2012 and Sandy in October of the same year (Koenig *et al*., 2015).

Another hurricanes that has left considerable damage in Haiti, were Ike in 2008 (Bozza *et al*., 2016) and Tomas in 2010 (Shamir, *et al*., 2013), in those occasions was able to calculate some flow rates, and however was not associated with damage to health.

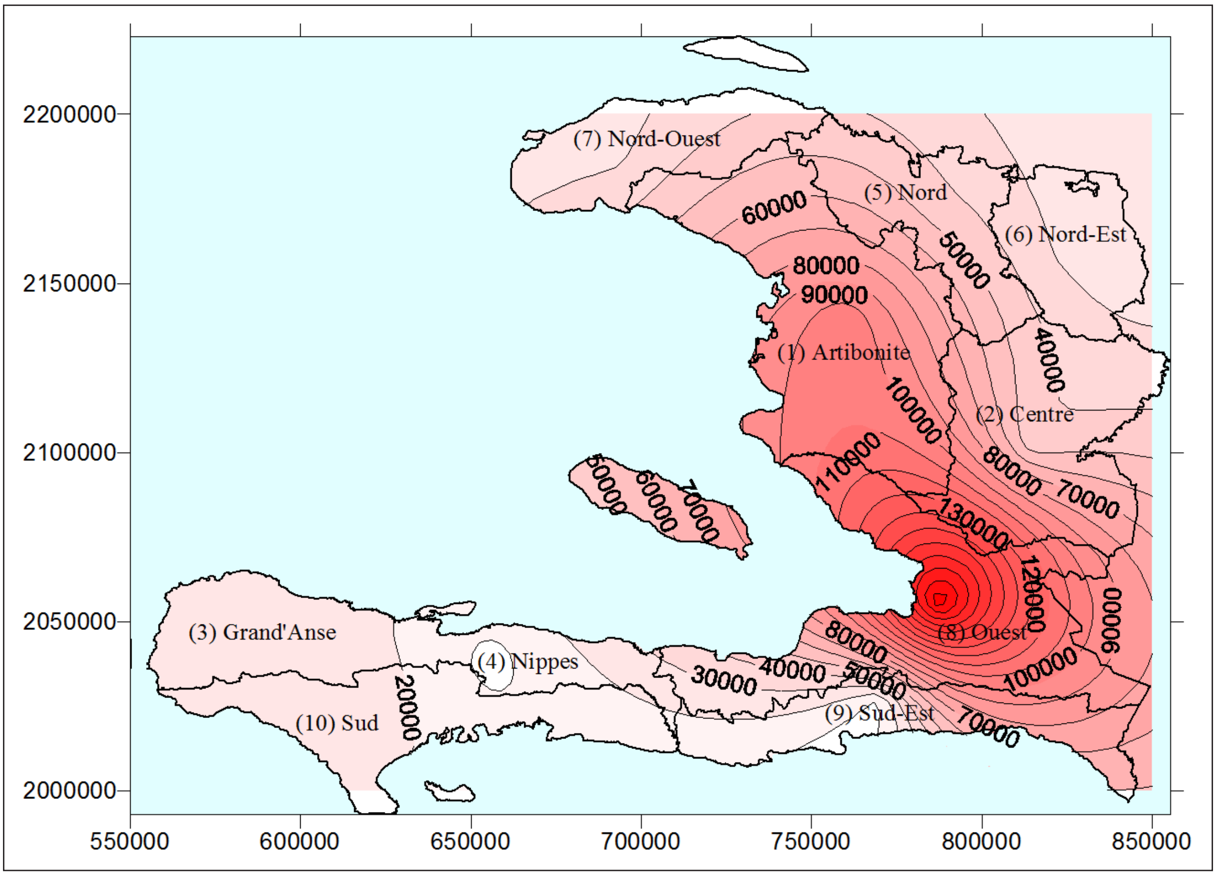



**Figure 1.** Number of Cholera cases presented in the period 2010-2012. Adapted from WHO, 2010

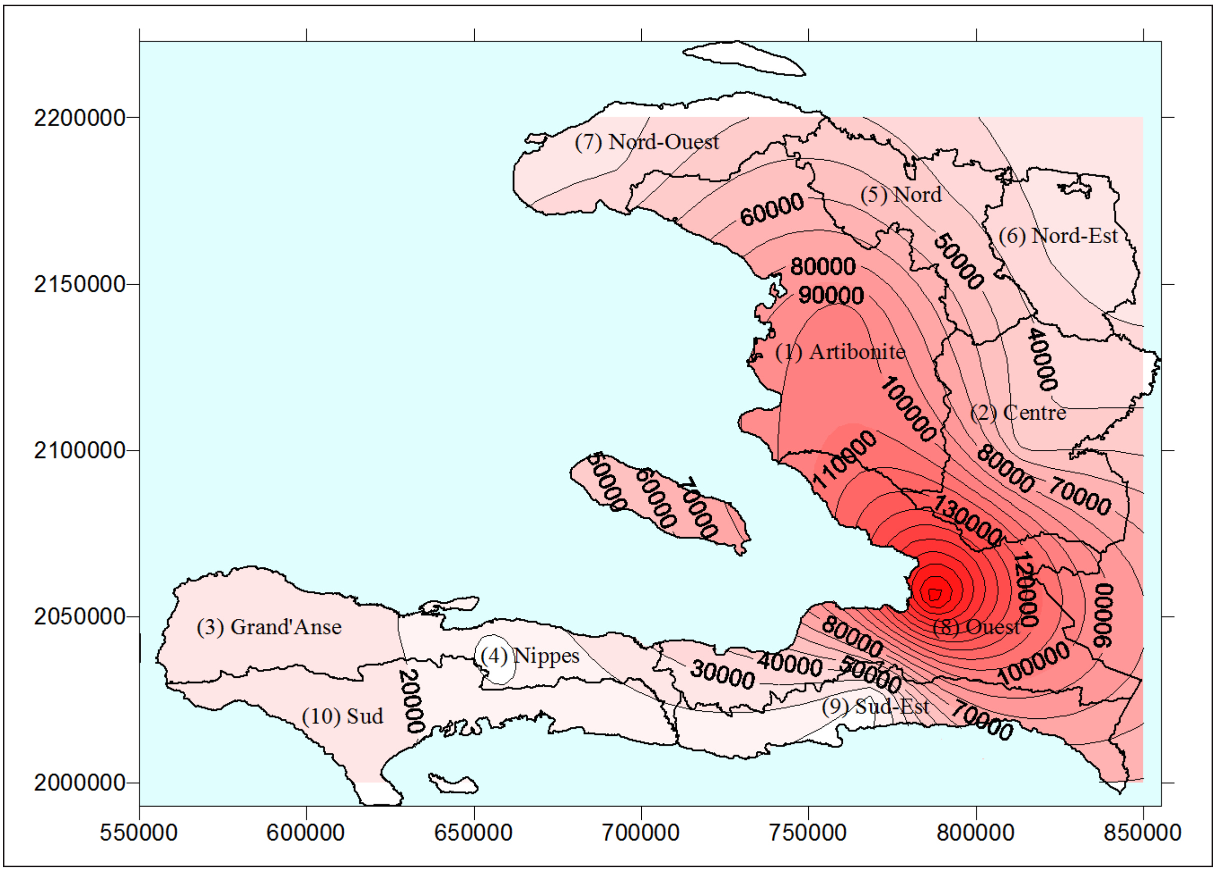



**Figure 2.** Number of Malaria cases presented in year 2010. Adapted from WHO, 2010

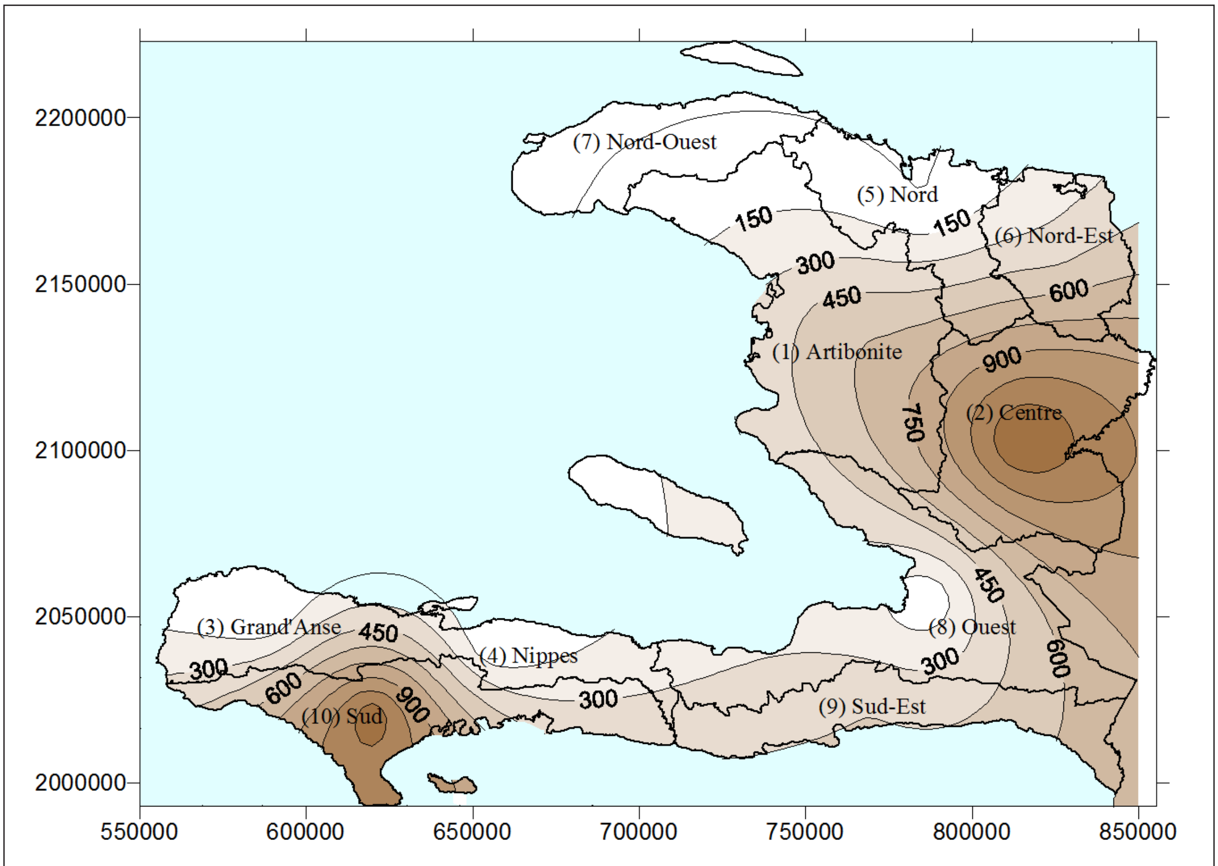



**Figure 3.** Topography of Haiti, altitude of zones in meters

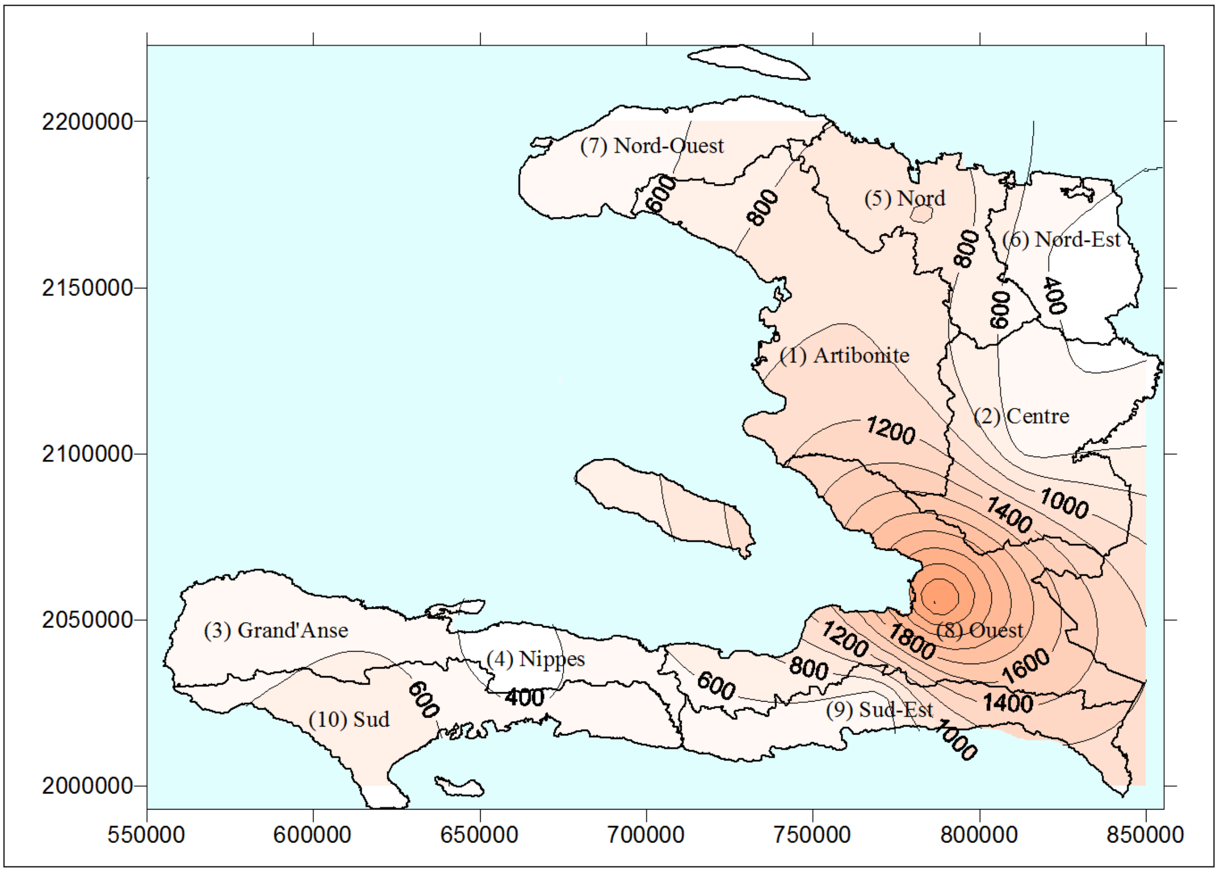



**Figure 4.** Number of new cases of positive bacilloscopy in 2010. Adapted from WHO, 2010

According to the Central Intelligence Agency of the United States, the proportion of beds in Haiti in 2007 was 1.3/1,000 inhabitants, ranking 137th in the world (Mexico 1.5/1,000 inhabitants) and also Haiti had 0.25 doctors per 1000 inhabitants with place 142, who establishes a minimum threshold of 2.3 physicians per 1,000 inhabitants (CIA, 2007). Considering these statistics and that 2.3 million people were left homeless with a displacement of approximately 1.4 million to makeshift camps, without the minimum optimal conditions of hygiene and sanitation, the capacity of the medical services were exceeded and with this raising the incidences of infectious-contagious diseases (IACHR, 2011).

The highest concentration of hospitals for the year 2008 lies in two main areas: Port-au-Prince and the Northern Department with coverage of 35,000 to 45,000 people and <35,000 inhabitants per hospital respectively; with less coverage in the central area of Grand Anse, the South Department and especially in the Southeast with more than 65,000 inhabitants/hospital (see figure 5). Regarding hospital coverage, it is observed that the approximate number of hospitals per zone, has a greater tendency towards the capital of the country with gradual decrease in peripheral form, and with a smaller amount in the Department of Southeast (see figure 6).

Like the distribution of hospitals, the first level centers are in greater concentration near the capital (see figure 7). The importance of these figures is that many of the specialized hospitals and health centers were seriously affected or totally destroyed by the earthquake and the subsequent Hurricanes Ernesto, Issac and Sandy in 2012, reason why many of the centers that were maintained had to be used as centers of mass attention for the victims affected in those disasters.

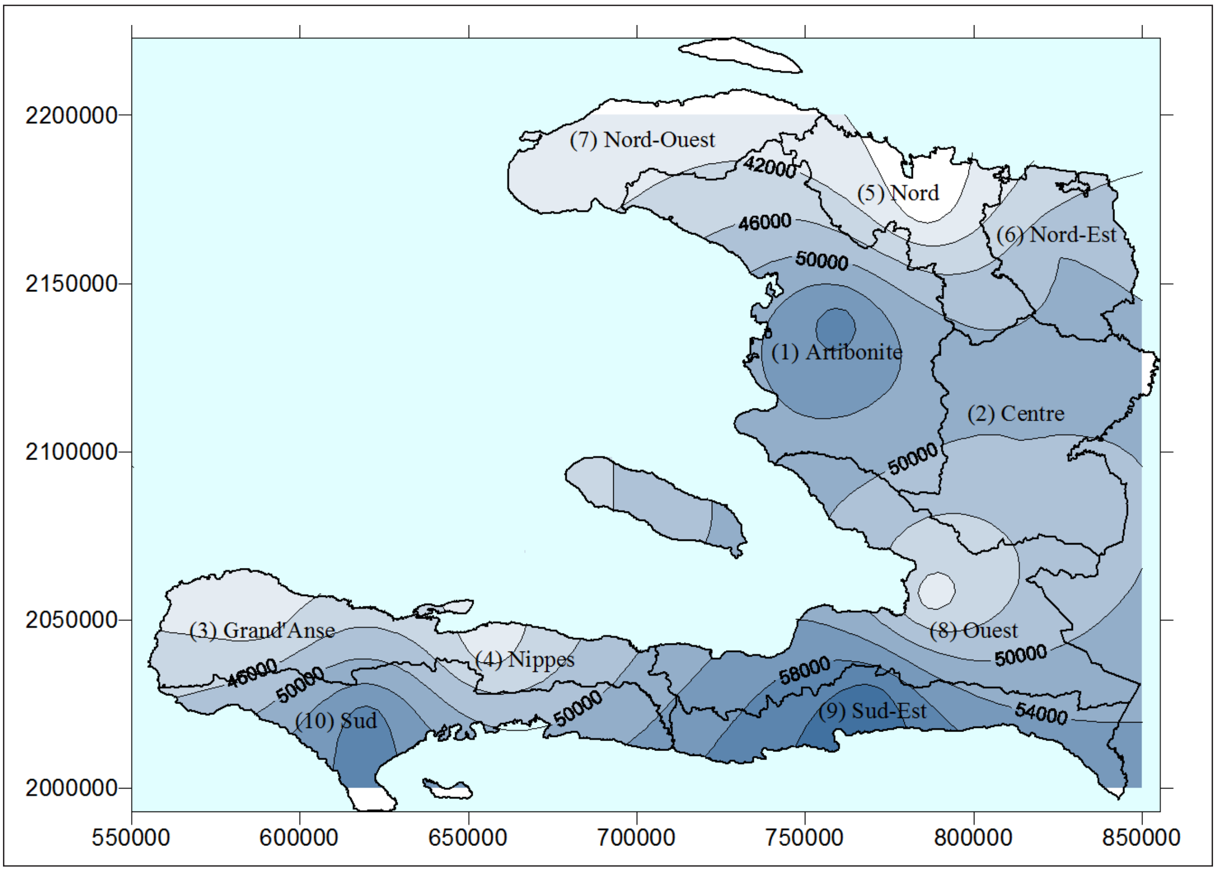



**Figure 5.** Number of inhabitants per Hospital, 2008. Adapted from WHO, 2010

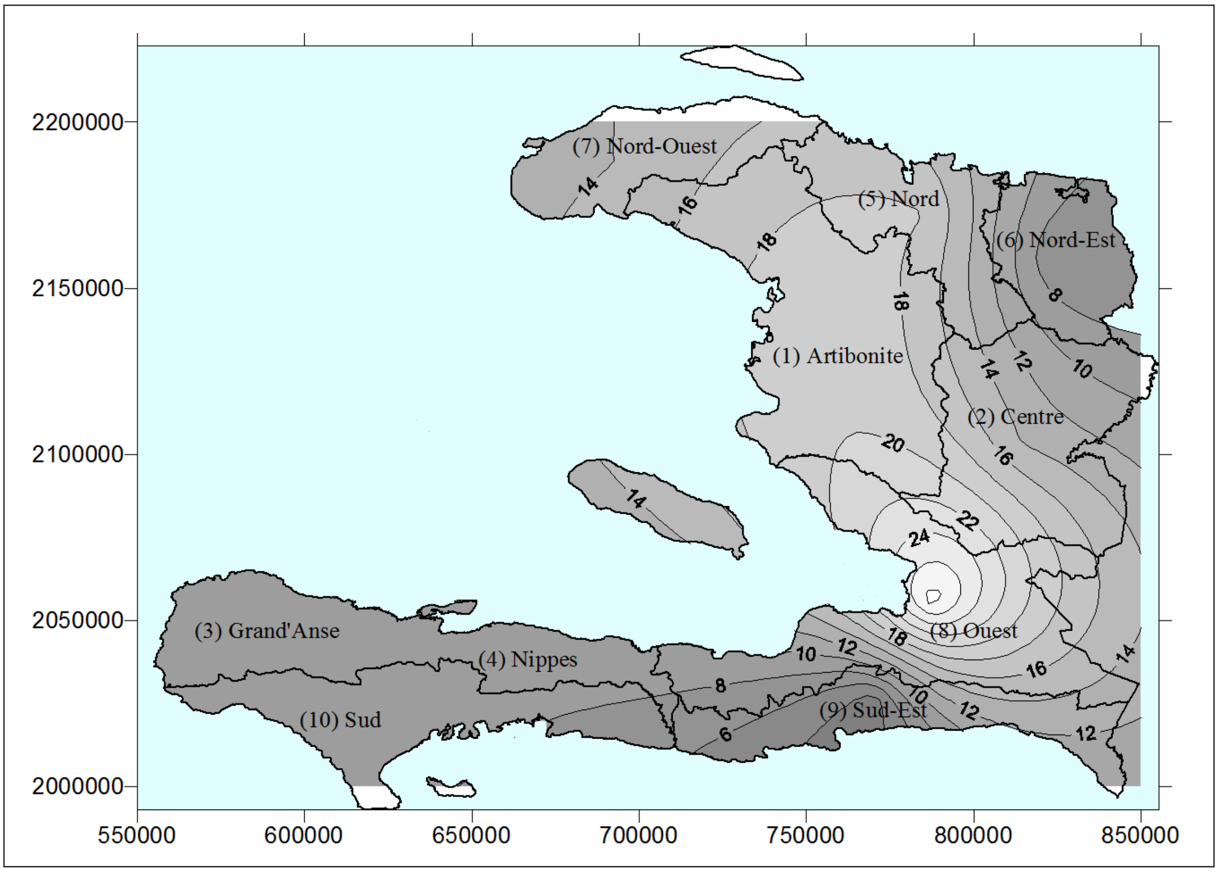



**Figure 6.** Number of Hospitals by zone 2010. Adapted from WHO, 2010

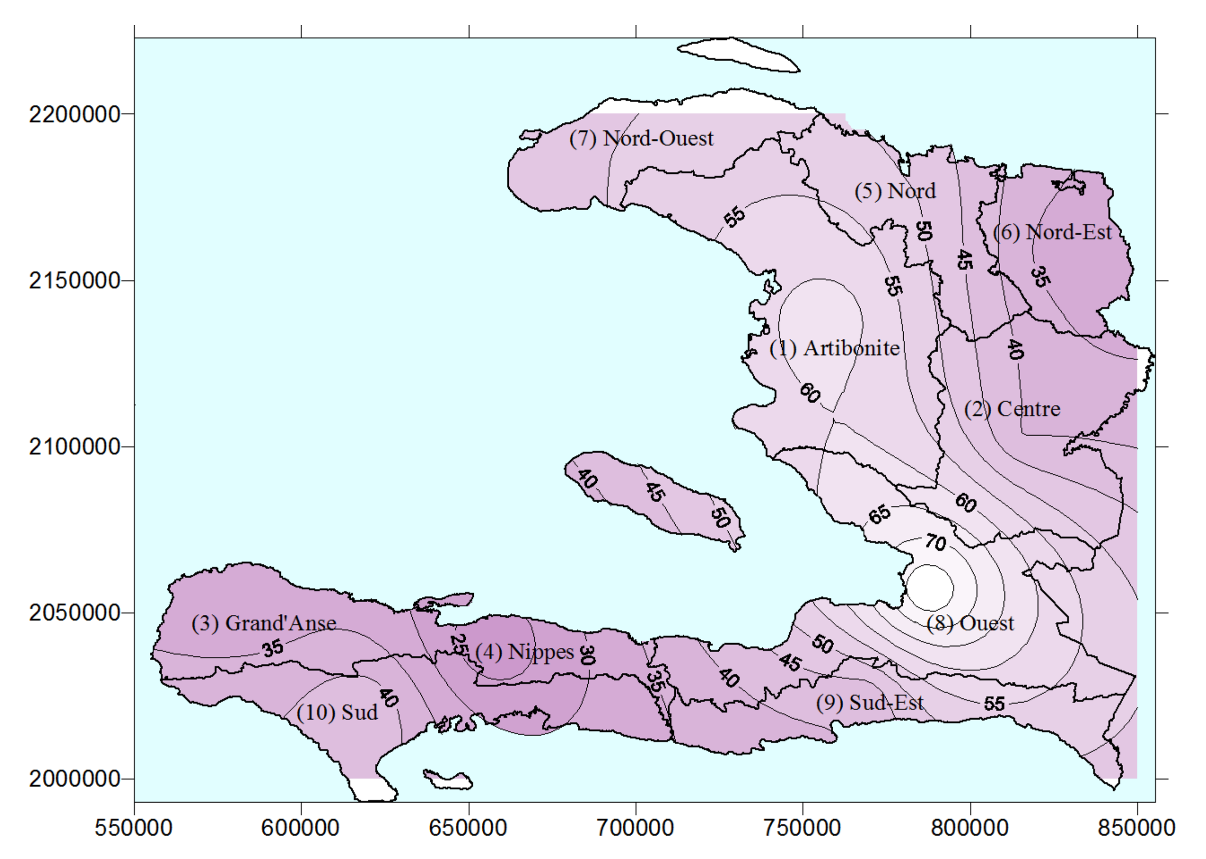



**Figure 7.** Number of Health Centers by area, 2010. Adapted from WHO, 2010

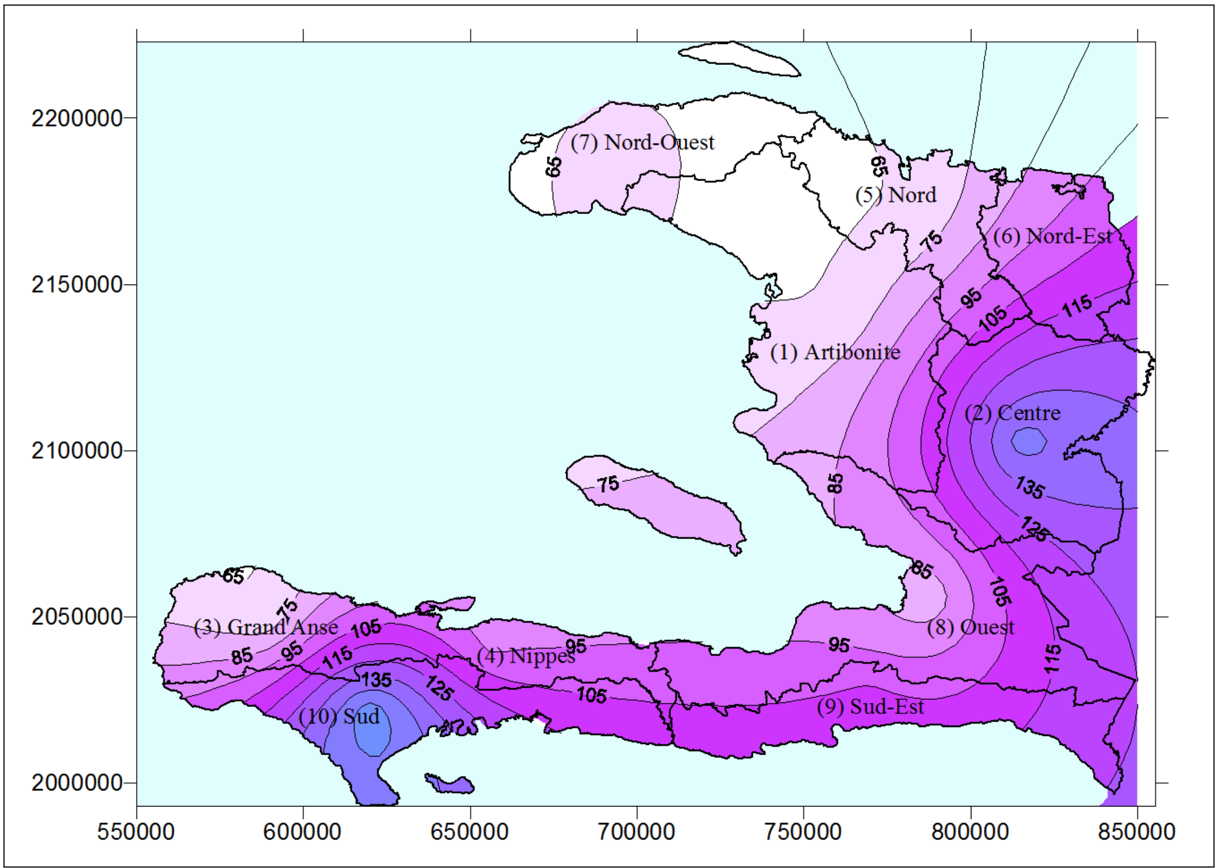



**Figure 8.** Intensity of rainfall 10 years return period and one hour duration storm

## DEVELOPMENT

A Meteo-Epidemiological Vulnerability Index (MEVI) is the product of each one of the principal component $|\Omega_i|$ multiplied by the infectious-contagious disease data, the capacity and distribution of medical infrastructure, physiographic conditions of the country, and rainfall data (figure 8), as follow.

$$(\mathrm{MEVI}_j) = \sum_{j}^{n} Z_j \left| \sum_{i}^{k} \Omega_{i,j} \right|$$

where

$Z_j$ are the proposed central standardized values of the health and medical characteristics estimated by

$$Z_i = (X_i - \mu_x)/\sigma_x$$

$\Omega_i$ i-*th* principal component of each site (Department).

Table 1, shows the limits of Meteo-Epidemiological Vulnerability Index (MEVI). Table 2 shows the variables of infectious-contagious disease data, the capacity and distribution of medical infrastructure, physiographic conditions of the country and rainfall data. With these values an EOF analysis was carried out. In this analysis, it was found that the first two principal components explain the 67% of the variance of health and medical characteristics. Figure 9 shows the circle of correlation coefficients among the 8 proposed variables (table 2). EOF results show the existence of two groups of variables that define the behavior of the Haiti (figure 9). The first group is formed by the morphologic, hydrometeorological (figure 8) and infrastructure characteristics and Malaria data (Hab/Hospt; Malaria; Altitude, others and T10D60). The second group is composed by the geographic longitude, number of hospitals, Cholera, Tuberculosis, hospitals and health centers. This analysis can offer additionally a prioritization of the characteristics based on the projection of each variable over the axis of the principal components $|\Omega_i|$. This procedure corresponds to the traditional interpretation of an EOF in which it can be observed that the variable with highest importance for the first principal component $|\Omega_1|$ are hospitals and Cholera, and that of highest relevance for the second component $|\Omega_2|$ are the rainfall intensity for 10 years return period and one hour duration and altitude. Likewise, the values of the characteristics shown in table 3 are standardized.

The formed groups check the obvious hydrometeorological and heath condition of Haiti. The concentration of large masses together with the conditions of water shortage and lack of proper disposal of sewage triggers an environment of easy spread of infectious-contagious diseases. We have Cholera as the most important variable. Its means of transmission is by contact with the feces of the sick, as well as food and water contaminated by Vibrio Cholarae. Considering that the hospitals are located in zones of greater population concentration and that these were found to exceed their maximum capacity the contagion was high and with easy propagation. Something similar can be observed with Tuberculosis, which is transmitted by means of “flügge” droplets which are secretions that are sent from an infected person, especially when coughing, measuring from 1 to 5 μm and contain the bacillus responsible for the disease (Mycobacterium Tuberculosis). Taking into account its easy propagation is compressible that in areas of greater concentration and in hospitals that even having the necessary measures for their containment, it spread. In an isolated and opposite way we find Malaria, being a disease transmitted by vector through the Anopheles mosquito, the vulnerability of the affected area will depend only on the conditions that favor the reproduction of the insect. Low altitude zones, with higher rainfall frequency, poor wastewater management are the ones that will be most exposed to this disease. The only human-human transmission of Malaria is by blood transfusions or via maternal-fetal route. So concentrations of the population will not be a risk for its dissemination unless they are in areas of vulnerability. This is why the outbreak occurred in the Central Department in 2010 does not exist such a close relationship with the other variables analyzed; this justifies the opposite occurrence with the opposite variables of latitude and longitude as shown in figure 8. The distribution of hospitals is inversely proportional to greater latitude and, to a lesser extent, to the length of the capital, whereby peripheral areas have fewer hospitals, perhaps influenced by demographic and economic structures.

**Table 1.** Meteo-Epidemiological Vulnerability Index (MEVI) proposed limits

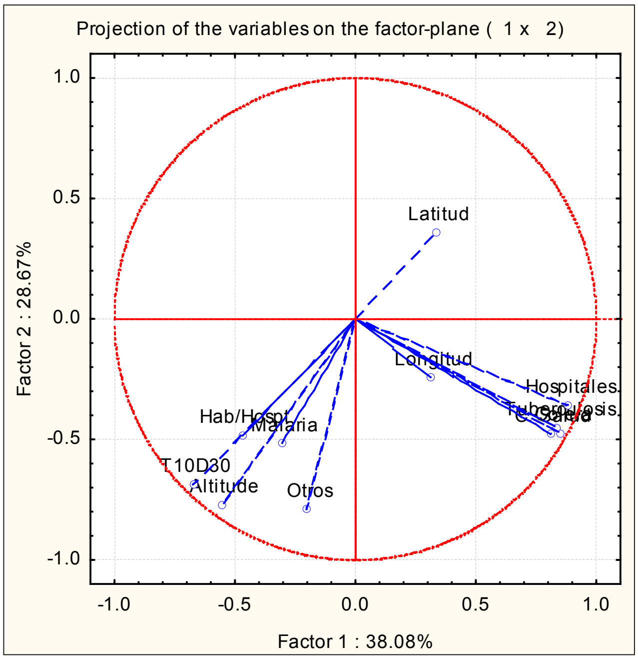
| Minimum value | MEVI condition | Maximum value |
|---|---|---|
| + 10.0 | Extreme vulnerability | > + 20.0 |
| + 5.0 | Average vulnerability | + 9.9 |
| 0.0 | Normal condition | + 4.9 |
| | Safety condition | - 0.1 |

For example, the MEVI index for the Grande Anse Department (3) is, from the figure 10, $\Omega_1 = -0.56251$ and $\Omega_2 = 1.7667$ and $\left| \sum_{i=1}^{k=2} \Omega_{i,j} \right| = 1.20419$ using the standardized variables $\sum_{j=1}^{n=7} Z_j = -3.770$

Finally

$$(MEVI_j) = \sum_j^n Z_j \left| \sum_i^k \Omega_{i,j} \right| = (1.20419) * (-3.770) = -4.5397963$$

This result corresponds to a Safety condition in the Grande Anse Department (3), (see figure 11).



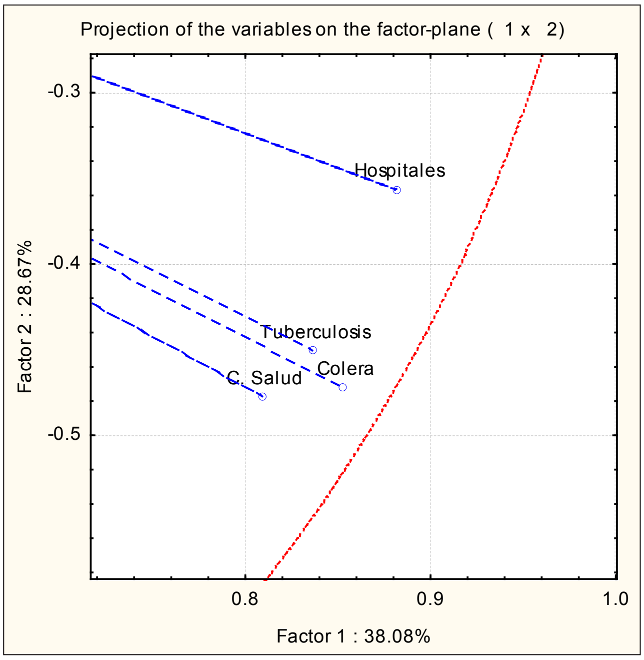




**Figure 9.** EOF results by variables

**Table 2.** Variables of Infectious-contagious disease data, the capacity and distribution of medical infrastructure, physiographic conditions of the country and rainfall data

| | Department | T10D30 (mm/h) | T10D60 (mm/h) | Cholera (# cases) | Tuberculosis (# cases) | Hab/ Hospt | Malaria (# cases) | Hospitals | Health Centers | Others |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Artibonite | 102.5 | 67.3 | 107,924 | 1,000 | 60,000 | 3,157 | 20 | 63 | 4 |
| 2 | Center | 227.3 | 149.2 | 43,129 | 458 | 50,000 | 26,563 | 14 | 40 | 10 |
| 3 | Grande Anse | 102.5 | 67.3 | 22,107 | 488 | 40,000 | 1,808 | 9 | 32 | 4 |
| 4 | Nippes | 142.4 | 93.5 | 7,247 | 282 | 40,000 | 1,904 | 9 | 20 | 4 |
| 5 | North | 102.8 | 67.5 | 45,149 | 1,020 | 35,000 | 597 | 18 | 50 | 2 |
| 7 | Northwest | 102.8 | 67.5 | 28,168 | 490 | 40,000 | 1,038 | 14 | 50 | 3 |
| 6 | Northeast | 153.1 | 100.5 | 27,433 | 335 | 50,000 | 2,551 | 6 | 32 | 3 |
| 8 | West | 118.1 | 77.5 | 208,901 | 2,901 | 40,000 | 3,440 | 29 | 81 | 9 |
| 10 | South | 246.5 | 161.8 | 27,944 | 796 | 60,000 | 1,042 | 10 | 45 | 19 |
| 9 | Southeast | 164.3 | 107.9 | 8,090 | 472 | 65,000 | 7,443 | 3 | 42 | 1 |

**Table 3.** Standardized Variables of Infectious-contagious disease data, the capacity and distribution of medical infrastructure, physiographic conditions of the country and rainfall data

| | Cholera | Tuberculosis | Hab/Hospt | Malaria | Hospitals | H. Centers | Others | *Sum Z* | Sum EOF | MEVI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.894 | 0.227 | 1.133 | -0.229 | 0.893 | 1.017 | -0.350 | *3.585* | *0.880* | **3.16** |
| 2 | -0.153 | -0.473 | 0.189 | 2.756 | 0.105 | -0.320 | 0.756 | *2.860* | *4.158* | **11.89** |
| 3 | -0.493 | -0.434 | -0.755 | -0.401 | -0.552 | -0.785 | -0.350 | *-3.770* | *1.204* | **-4.54** |
| 4 | -0.733 | -0.700 | -0.755 | -0.389 | -0.552 | -1.482 | -0.350 | *-4.961* | *0.451* | **-2.24** |
| 5 | -0.121 | 0.253 | -1.227 | -0.556 | 0.631 | 0.262 | -0.719 | *-1.478* | *3.022* | **-4.47** |
| 7 | -0.395 | -0.431 | -0.755 | -0.499 | 0.105 | 0.262 | -0.535 | *-2.249* | *2.455* | **-5.52** |
| 6 | -0.407 | -0.632 | 0.189 | -0.307 | -0.946 | -0.785 | -0.535 | *-3.421* | *0.174* | **-0.60** |
| 8 | 2.526 | 2.681 | -0.755 | -0.193 | 2.075 | 2.063 | 0.571 | *8.969* | *2.375* | **21.30** |
| 10 | -0.399 | -0.036 | 1.133 | -0.499 | -0.420 | -0.029 | 2.415 | *2.164* | *4.787* | **10.36** |
| 9 | -0.720 | -0.455 | 1.605 | 0.317 | -1.340 | -0.203 | -0.903 | *-1.699* | *1.617* | **-2.75** |

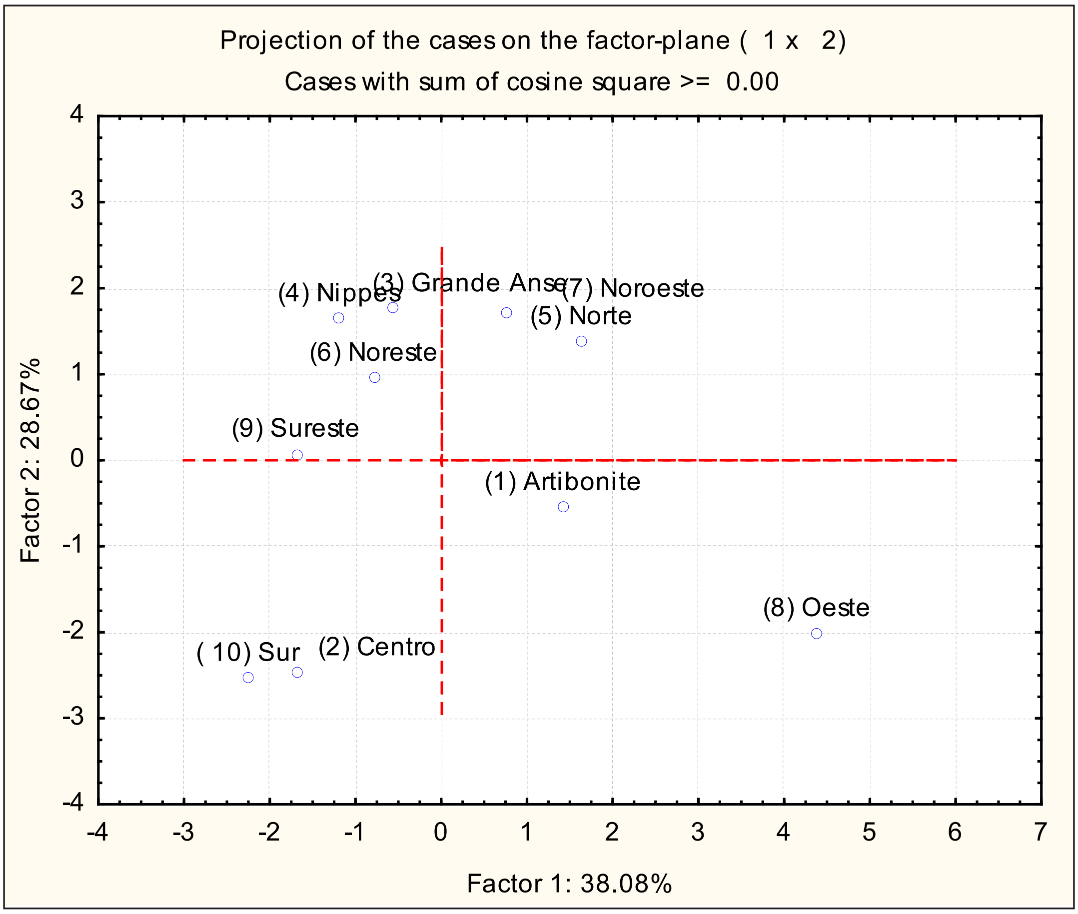



**Figure 10.** EOF results by Departments

The projection in the first Principal EOF Component demonstrates with greater importance Department 8 (see figure 10) influenced by the location here the capital of the country constitutes the economic, judicial and governmental center of the country and the most important port of Haiti and therefore exposed to greater concentration and influx of people who can import and export transmission diseases.

Department 10 is shown in isolation that despite not having enough hospitals for its population, there have been no threats as important as in areas more predisposed to affect public health.

A group is formed with Departments 4, 9, 6 and 3, similar to the northern zone the prevalence of diseases is moderate but with less medical coverage (see figure 10).

A group with Departments 7 and 5 with similar characteristics in their variables is formed, which favorably with their areas of moderate prevalence to the diseases mentioned above and their greater coverage of inhabitants/hospitals (see figure 10).

The Meteo-Epidemiological Vulnerability Index (MEVI) shows that the vulnerability is greater in the Western Department 8, with the maximum risk zone in the capital, starting from the peripheral zone there is a gradual decrease from 4 points to 2 (see figure 11) to the boundaries of the adjoining Departments of Southeast 9, Center 2 and Artibonite1; Leaving from there 2 to 0 and -0.5 in the north borders of Artibonite and Center, part of the Southeast 9, Grand Anse 3 and Nippes 4. In the South 10 we observe in isolation that the highest vulnerability starts from 2.5 to -0.5. The Northeast region has the lowest vulnerability zone with values of -1.5 and -2, similar to the Northern region.

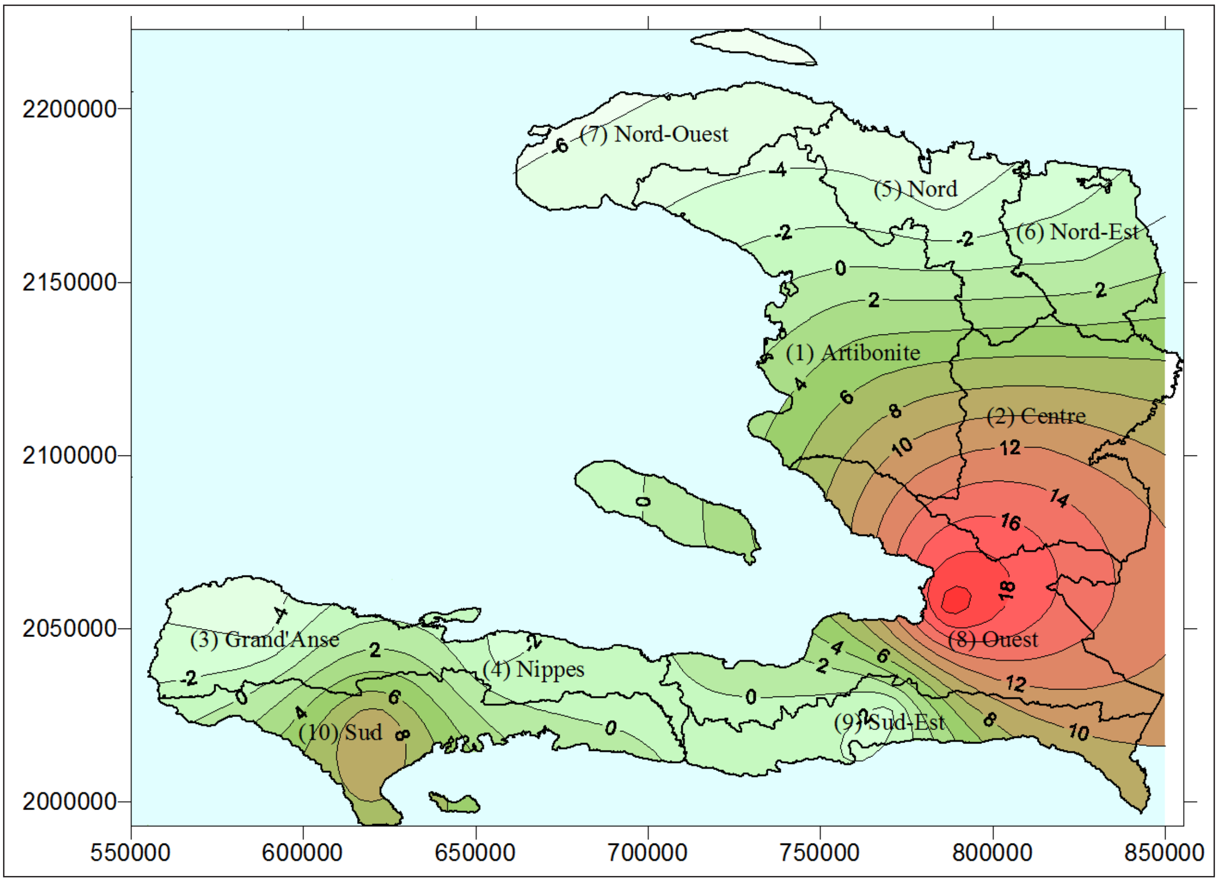



**Figure 11.** Meteo-Epidemiological Vulnerability Index (MEVI)

## CONCLUSIONS

According to the projection of variables in the Empirical Orthogonal Function Analysis (EOF), we observed the conformation of two groups, in a group we counted on Cholera, Tuberculosis and the number of hospitals (see Figure 9). The second group relates malaria and climatological conditions, which means that the EOF analysis allowed a correct analysis of the climatic variables combined with the health variables. The concentration of large masses together with the conditions of water shortage and lack of proper disposal of sewage triggers an environment of easy spread of infectious-contagious diseases.

The topographic distribution of the diseases mentioned is variable but, with a tendency to concentrate in areas of greater population that fortunately are areas of greater number of hospitals only with the exception of cases of Malaria in the Central Department. The post-disaster internal displacement triggers a series of social phenomena that directly affect the health of the population. Lack of shelter, services, hygiene, order and security in a country where previously social situations were already seriously affected represents a public health problem and a challenge not only to national government institutions but also an international effort that despite being rough is still not enough. The vulnerability of Haiti will always represent a latent, especially with seismic and hydrometeorological events, which without any prediction of when the next disaster will occur; the work of all will be aimed at rebuilding the country with stronger foundations and awareness on preventive security. The *Meteo-Epidemiological Vulnerability Index* (*MEVI*) allowed identifying zones or Departments that are most vulnerable to health risks, combined with the hydroclimatological variables that affect the territory of Haiti. It is proposed the systematic calculation of *MEVI* to characterize the vulnerability of areas that are prone to combined phenomena where there is a strong health, epidemiological, hydrometeorological and medical infrastructure component.

It is proposed to update the data used in this study and to perform a new calculation of the *MEVI*. It is worth mentioning that *MEVI* is currently used in some mountainous areas of the Sierra Gorda mountain range of Querétaro, México, where some populations are particularly affected by the scarce infrastructure and the incidence of the changing climatic aspects detected in recent years.

## REFERENCES


Bozza A., Durand A., Confortola G., Soncini A., Allenbach B., and Bocchiola D. (2016). Potential of remote sensing and open street data for flood mapping in poorly gauged areas: a case study in Gonaives, Haiti. Applied Geomatics. Volume 8, Issue 2, pp 117–131.

Busch, Frederick A. , Niemann Jeffrey D. and Coleman Michael. (2012). Evaluation of an empirical orthogonal function–based method to downscale soil moisture patterns based on topographical attributes. Hydrological Processes Volume 26, Issue 18 Pages 2696–2709.

CIA, Central Intelligence Agency U.S:A. (2007) The World Factbook: Haiti. https://www.cia.gov/library/publications/the-world-factbook/geos/ha.html

Gottschalk Lars, Krasovskaia Irina, Dominguez Efrain, Caicedo Fabian and Velasco A. (2015) Interpolation of monthly runoff along rivers applying empirical orthogonal functions: Application to the Upper Magdalena River, Colombia. Journal of Hydrology 528 177–191. Elsevier Science Publishers B.V., Amsterdam.

IACHR, Inter-American Commission on Human Rights (2011). Informe de seguimiento sobre la situación de derechos humanos en Haití. Capítulo V. Pp. 609.

IFRC, Federación Internacional de Federaciones de la Cruz Roja y la Media Luna Roja (2010). Terremoto de Haití 2010 Informe de avance anual 2010. Ginebra, Suiza. Pp.52

Kima Kwang-Yul, Hamlington B., Na Hanna (2015) Theoretical foundation of cyclostationary EOF analysis for geophysical and climatic variables: Concepts and examples. Earth-Science Reviews 150 201–218 Elsevier Science Publishers B.V., Amsterdam.

Koenig S.P., Rouzier V., Vilbrun S.C., Morose W., Collins S.E., Joseph P., Decome D., Ocheretina O., Galbaud S., Hashiguchi L., Pierrot J., and Pape J.W. (2015). Tuberculosis in the aftermath of the 2010 earthquake in Haiti. Bull World Health Organ. Jul 1;93(7):498-502. doi: 10.2471/BLT.14.145649.

MPHP, Ministry of Public Health and Population (2013). National plan for the elimination of cholera in Haiti 2013-2022. National Directorate for Water Supply and Sanitation. Republic of Haiti.

PAHO. Organización Panamericana de la salud. (2004). La tuberculosis en la Región de las Américas. Informe Regional 2011 Epidemiología, control y financiamiento MSPP Ministerio de la Salud Pública y de la Población. Plan estratégico para la reforma del sector de la salud. Washington, DC

PAHO. Organización Panamericana de la salud. (2012). Salud en las Américas, Edición de 2012: Volumen de países: Haití. Publicación Científica y Técnica No. 636 Washington, DC. ISBN 978-92-75-31691-7

Rao A.R. and Hsieh C.H. (1991) Estimation of variables at ungaged locations by empirical orthogonal functions. Journal of Hydrology, 123 (1991) 51-67 51 Elsevier Science Publishers B.V., Amsterdam

Shamir E., Georgakakos K. P., Spencer C., Modrick T. M., Murphy Jr. M. J. and Jubach R. (2013). Evaluation of real-time flash flood forecasts for Haiti during the passage of Hurricane Tomas, November 4–6, 2010. Natural Hazards 67:459–482.

Vargas J., De la Fuente L., Gutiérrez-López A., y Arumi J. (2009) Análisis geoestadístico para describir la Distribución espacial de la precipitación de una cuenca Patagónica. Aqua-LAC. Revista científica del Programa Hidrológico Internacional para América Latina y el Caribe (PHI-LAC) de la Organización de las Naciones Unidas para la Educación la Ciencia y la Cultura (UNESCO). Año 1. No. 1 pp.29-41

WHO, World Health Organization. (2010). Haití maps http://www.who.int/hac/crises/hti/maps/en/