COMPARATIVE STUDY OF ENVIRONMENT FACTORS FOR THE EMERGENCE OF DENGUE IN THE CITIES OF DOUALA, GAROUA AND YAOUNDE IN CAMEROON

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Abstract. Dengue is nowadays the most spread arbovirose in tropical environment. Despite the fact that Cameroon does not seem much affected, both the virus and the vector are present and this situation favours the spread of the disease within a short period of time. This leads to the necessity to interrogate on the geographical factors which contribute to its emergence and spread in the country. In order to answer this question, socio geographic, serologic, entomologic, epidemiologic and demographic investigations have been carried out in three cameroonian cities situated in different geographical contexts. The exploitation of these data on topographic maps and satellite images through spatial statistic tools and geomatics, has revealed that all intermediary conditions are set up for the emergence of Dengue in Cameroon and the relief seems to be the most determinant factor. The prevalence in cities (Garoua and Douala) is more important than that on hilly sites such as Yaounde; the absence of slopes here favours the stagnation of water and the positioning of rain water collectors such as, old tins, old car tires.

Key Words. GIS, Logistic regression, Geomatic, Dengue, Geography of health, Epidemiology, Cameroon.

Résumé. La Dengue est actuellement l'arbovirose la plus répandue en milieu tropical. Même si le Cameroun semble ne pas être touché, le virus et le vecteur y sont présents, situation qui offre des conditions favorables à une émergence de la maladie, à très court terme, d'où la nécessité de s'interroger sur les facteurs géographique de son émergence et de sa propagation dans le pays. Pour entre autres réponses à cette question, des enquêtes socio-géographiques, sérologiques, entomologiques, épidémiologiques et démographiques ont été menées dans trois villes camerounaises situées dans des contextes géographiques différents. L'exploitation de ces données basée sur des cartes topographiques et des images satellitaires à l'aide des outils de la statistique spatiale et de la géomatique, a révélé que toutes les conditions du milieu sont réunies pour qu'il y ait émergence de la Dengue au Cameroun. Le facteur relief semble se dégager comme étant le plus déterminant. La prévalence dans les villes à site plat (Garoua et Douala) étant plus importante que dans celles à site collinaire comme Yaoundé ; l'absence de pentes favorisant la stagnation des eaux et la mise en position de collecteurs des eaux de pluies les potentiels gîtes (boîtes de conserves, vieux pneus de voitures).

Mots clés. SIG, Régression Logistique, Géomatique, Dengue, Géographie de la Santé, Epidémiologie, Cameroun.

Introduction

Dengue is an emerging disease (Toma et Thiery, 2003) connected to the physical and socioeconomic environment. The vectors involve in transmission are domestic and para domestic, thus maintaining a very narrow relationship with human beings. Environment (anthropologic, ecologic, hydrologic, etc) are several factors which seem to act on its development (Blateau et al., 1999). Armed with these consideration, a team of researchers; epidemiologists, entomologists, virologists, socio demographers and geographers, have assigned themselves the objective of studying the disease in the mutative environments of Bolivia and Cameroon within the framework of the project N° 0011905 entitled: "The Dengue's emergence in mutative environments (EPI- Dengue)" sponsored by the ANR.

Geography such as it is practised within the framework of that project is part of an original approach. That of georeference, with a spatial and temporal scale, spaces with a risk of introduction (potential spaces), movement/transmission (functional spaces) of the Dengue's diffusion.

An expanding disease, the Dengue is at the moment the most expanded arbivorose in the world, with about 2.5 billion people exposed to it in about a hundred countries in the tropical zone with an incidence approaching 80 millions cases annually. The world map of the countries affected by that disease shows that in Africa, patients have been identified and recorded in the eastern and western parts of the continent. Cameroon does not seem to be affected (Fig.1)

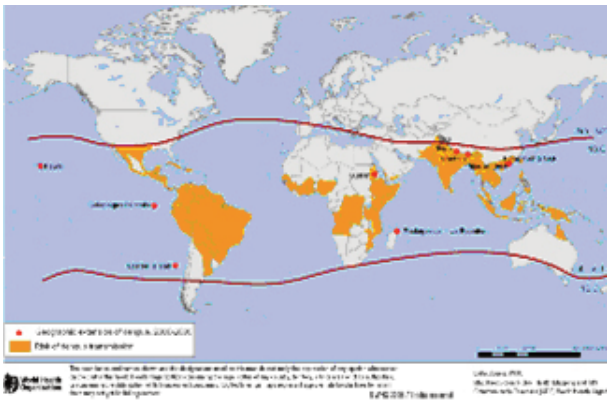

Figure 1. Countries or Areas which present a risk of transmission, 2006
Source:http://gamapserver.who.int/mapLibrary/Files/Maps/WorldDengueTransmission_2006_10%20November.png, may 24 2007

Although both the virus and its vector are present in the tropical zone, the situation offers favourable conditions for the emergence of the disease in a very short term. Its transmission which is particularly ensured by mosquitoes of the Aedes specie, or precisely, the Cosmo tropical Ae-aegyti, but also the Ae-albopictus, is directly related to physical, climatic, and socio-economic environments, themselves affected by demographic and ecologic modifications caused by Man (Hubert, 2001).

Appearing in all four serotypes (Den-1 to Den-4) which circulate independently, the Dengue which originates from Asia where it has become endemic, (permanent circulation of all the serotypes) affected the Caribbean and Central and South America in the 80's and since then, has been classified as an epidemic. In Africa, it is already affecting the eastern part of the continent, but also the Central and Western parts where the virus and its vector have been detected. A situation which offers favourable conditions for the emergence of the disease within a very short period (Blateau et al., 1999).

A study of Dengue's real situation has been carried out in Cameroon in the cities of Douala, Garoua and Yaoundé (Fig. 2). These cities were chosen because they belong to the main climatic regions of the country. The tropical climate (Garoua), the sub tropical climate and the equatorial climate in Yaoundé and Douala respectively. This study aims to bring out the natural morphologic factors essential for the emergence of Dengue by analysing the results obtained in relation with the landform of those three cities. We shall first present the geographic settings, then the methodology used and finally the results which were obtained.

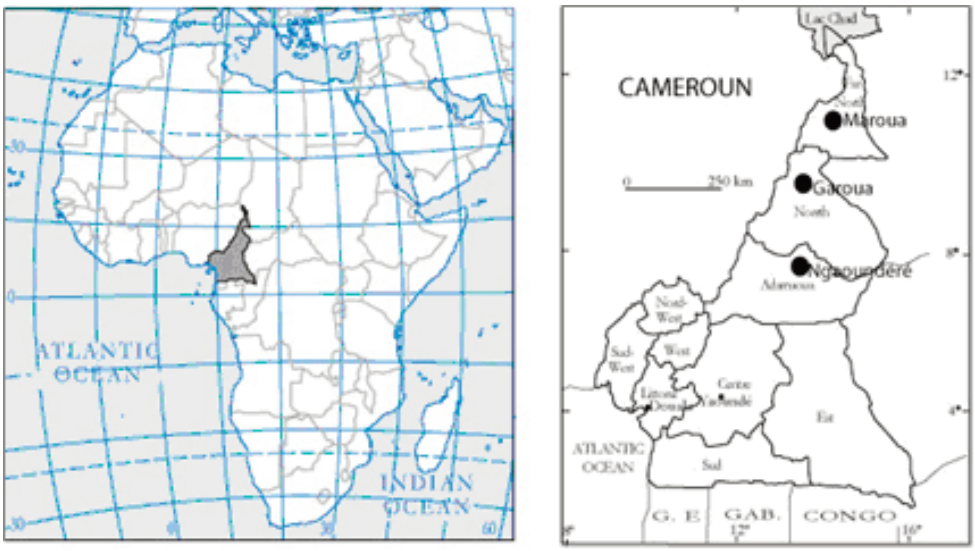

Figure 2. Localisation of survey cities

CONCEPTUAL AND GEOGRAPHIC SETTINGS

Through Geographical Information System, Geography brings out the multi-scale and multi-chronic information understood here as, the sum of semantic and geometric characteristics of the objects in a given space. The semantics describes the entity/name of the neighbourhood, the street, the building ...) and the geometry gives the location in coordinates, x, y, z (georeferencing). Conceived as such, the geographic information system integrates the spatial technology and constitutes a helpful tool for the follow up and comprehension of the mutating environments, planning and development. The advantage presented by such computerisation is that, the data are rapidly updated and can be object of synthesis within the optic of the construction of examples, of simulation in order to verify hypothesis and comparisons of scenario for the anticipation of impacts, and produce the necessary information for decision making. A part from the tested blood of patients, the geographer is interested in by the relationship between Man and his environment, the usage and exploitations of the environment which can be responsible for the emergence of Dengue. He is also preoccupied by the characterisation of the home surroundings (topography, types of dwelling units, the architectural type, how the spaces in compounds are used, the surface, the distances from the neighbouring houses, the water and rubbish management in the compound, and the vege-

merely observating, filming, coordinating and talking in direct collaboration with the entomologists. He also analyses the dynamics between men and properties at the macro level (seaports, airports, car parks) and at micro level too (working place, markets...).

Situated in the equatorial zone, between 3°45' and 3°59' North; 10°94' and 11°58' East, Yaounde is scattered in its North-West and Western parts with rocky hills, the heights of which vary between 900 and 1300 m. These hills dominate the Eastern part of the town, a piedmont plateau shaped in interference by the Mfoundi and the Ako'o rivers. The subtract is mainly made of gneiss, its alteration here and there is at the origin of thick layers of ferric soils. The converse slopes and the abruptness of the sides which in general form an angle of above 15% gives an impression of steep sided valleys. They are, as says (Franqueville, 1984 in Tchotsoua, 1994) a site wholly made of hills and extended valleys.

The climate is the equatorial type, with four seasons, two rainy and two dry seasons. The rainy seasons are of unequal lengths, and are characterised by heavy rains often concentrated in time. Yaoundé belongs to the half – deciduous forestry zone deeply affected by man. The demographic growth due to both immigration and natural growth is very high there. The total population is estimated to bout 2.000.000 inhabitants.

Situated alongside the Guinean golf, between parallel 3° and 5° latitude North, Douala stretches over a coastal sedimentary basin. Essentially made of mangroves in their coastal border, the plains covered with littoral atlantic forests is composed of Lophiera alata and Saccoglolli gabonensis and at the Wouri estuary by the Biafran forest with Cesalpiniacca. The soils are of the Ferralitic type on the emerged parts and of the dromorphe type along the coastal border.

The Douala region is submitted to the equatorial type of "Cameroonian" climate, mainly to the coastal sub-type with two seasons: a rainy season from March to November, and a dry season from December to February. Due to the proximity of the coast, and to the orographic effect of Mt Cameroon, the rains are abundant there and almost year round. On average, the rainfall reaches a height of 4079 mm per annum (Nguendo Yongsi, 2006).

The zone belongs to the hot and wet climates and the temperatures vary from 23 to 30.6° C. The yearly average temperature is, 26.8°C and the divernal difference is about 8°C. The relative humidity is high in Douala, varying between 80% from January to March, and 90% in August, with an annual average of 84% (Nguendo Yongsi, op cit).

The basin is run-over by many rivers such as the Wouri, the Dibamba, the Mungo, the Nyong, the Sanaga and the Lobe. Its population is now evaluated at about 2.500.000 inhabitants. Contrarily to Yaoundé, the Douala site is essentially flat. What about Garoua?

Garoua is a pre-colonial town which was created on the Benoue-Lobe. Until the construction of the Lagdo dam, it was a very active fluvial port. It stretches on the northern border of the river on a relatively flat terrain. Its present population roughly about 800.000 inhabitants.

The climate in the Garoua region is characterised by two strongly contrasted seasons. The dry season stretches 7 to 8 months (November to April),

whereas, the wet season covers only 4 to 5 months (May to September). The alternance is regulated by the simultaneous and opposed actions of the Saint Helène anticyclone (wet air) and the air masses. The tress found there can be classified into four types of forests: gallery forests, clear forests, swampy forests and wooded savannah. Nonetheless, field observations in 2004 reveal that, the vegetation has been deeply transformed for agricultural reasons and because of the need for firewood. Only a few bands of savannah planted with the same type of trees (*Mytragina imermis or Acacia siberiana*). In the different sectors, the natural vegetation presents a stratification running from grassy savannahs to wooded savannahs, the average heights of which trees vary between 2.5m and 5 m.

Because of the pedoclimatic constraints and human pressure, the natural vegetation is not only less diversified in terms of family groups, but it is also deeply transformed. Here, we are facing vegetation which from now on integrates anthropic species. The most representatives are: *Mangifera indica, Adansonia digitata, Balanites aegytiaca, Ziziphus mucromata, Tamarindius indica, Phoenix dactylifera, Hyphaena thebaica, Borrossus aethiopum, Theruetia nerifolia, Calotropis procera, Anacardium occidentale, Comiphora kerstingii, Psidium guajava, Corica papaya, Tatropha gossipifolia, Citrus*... These trees are planted to make up the food deficit and restore the familial economy during bridge periods. Some of them are grouped in orchards, the most extended of which are found around urban centres. The same thing happens with hectares of *Eucalyptus calmaldulensis* groves planted by communities or by peasants CIG's in the Pitoa and Kokoumi-Dargala vicinities in order to satisfy the urban needs in terms of timber and firewood.

Species such as, Parkia biglobosa, Adansonia digitata Ziziphus mauritina, Comiphora kerstenguii, Eucalyptus camaldulensis, Piliostigma thonmingii, Parcka biglobosa, Senna siarmea, Azadirachta indica, Terminalia mantalis, Ficus platyphilla are planted or simply preserved in "Sarés" for the protection of the inhabitants, shade, architecture, feeding and compound embellishment or for therapeutic treatments such as malaria, amoebic dysentery, influenza, etc...

METHODOLOGY

Here, we are concerned with a study essentially based on geometrics to conduct a comparative analysis of Dengue's emergence in mutating environments necessitates the collection of an important number of complex data. The management of those complex data collected in changing milieu, constantly shaped by actors who are often indiscernible and versatile cannot be objectively done these days without resorting to Geomatics which, as a discipline has as objective the optimisation of the management of data with spatial references. The treatment and analysis, the management, the set up, storage and diffusion of geographic information with the aim of giving decision makers the possibility to make the best choice possible.

The data in this work originates from different sources;

? Topographic maps,

? ASTER, SPOT and QUICKBIRD satellite images,

? GPS points characteristic of Clusters,

? Socio-geographic, serologic, entomologic, epidemiologic and demographic data (Fig. 3)

The information extracted from images and those collected on the field are grouped in GIS's under the form of layers of objects on which have being linked alphanumeric data.

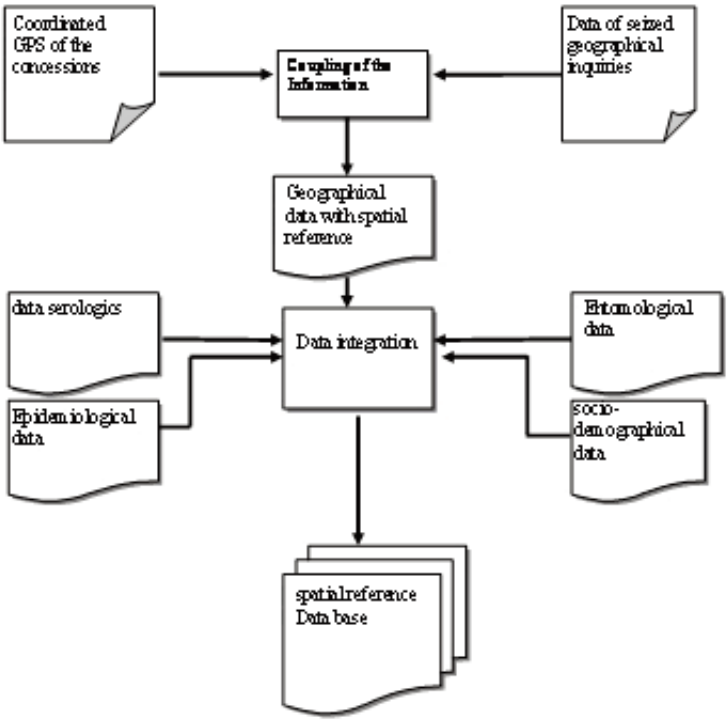

Figure 3. Process of Integration of Distributed Data.

Data bases thus posses 2 groups of information coming from;

- Land occupation, (neighbourhoods, orchards, road networks, bare spaces, and /or water proofed) extracted from satellite images completed by GPS statements and field inquiries.
- The physical milieu (relief, hydrographical networks, ponds and zones liable to flooding) extracts from topographic maps completed by GPS statements

. In this global methodological diagram, cartography as a tool for knowledge, resources management and means of prescription and information for actors is favoured. This approach equally constitutes a more efficient framework which integrates economic, social, and ecologic dimensions of the evaluation options, through projects cycles of planning and achievement.

For this reason, the elaborated methodological approach takes into consideration physical data but also human data and whose spatial representations by the actors whose up stream have contributed consciously or un consciously to their shaping and whose downstream structures the observation of the subject. Field observations, aerial and oblique photo discussions are exploited.

For this study, it must be noticed that in their representations, same as in their elements urban spaces are products. They can be observed either directly when the surfaces considered are sufficiently big with regards to the observation means or indirectly. They are decomposed into two large: built and exploi-

The second set in its turn decomposed into homogeneous sub units which can be identified on satellite images. Thus, the wooded savannahs, groves and forest galleries have been distinguished from farmlands and pastures (shrubby or grassy savannahs), and from inhabited spaces on satellite images.

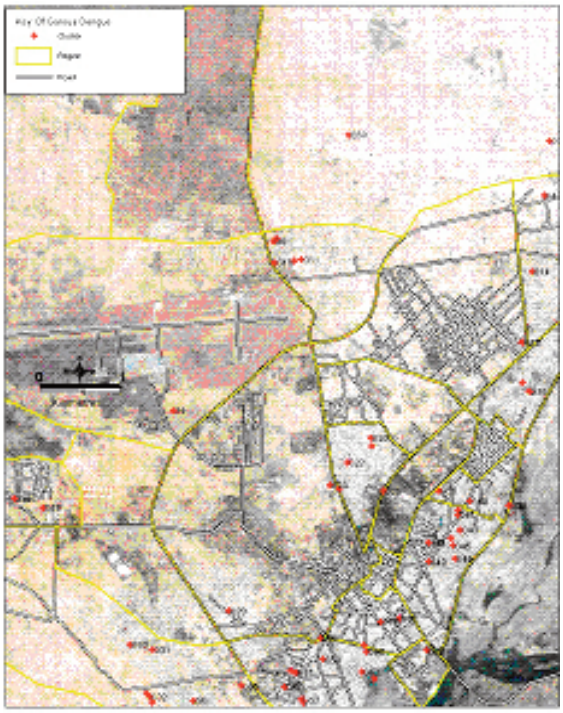

Figure 4. Inquired compounds in the Garoua city (Source: Epidengue investigations, in September, 2006).

A protocol was set up to carry out the inquiries in those three cities. To put into practice the protocol, many drawings of clusters were done; 75 per town in all. A cluster is a couple of GPS coordinates which refers to the surface of the town, the starting point of the enquiries.

In one cluster, 4 compounds at least are looked for north of the cluster, in order to carry out inquiries. The study being pluri-disciplinal (geography,epidemiology,entomology,demography, etc), the inquiry questionnaire was sub divided according to disciplines. The enquiry took place according to a very specific order. To start, the participants had to accept an extraction 10 ml blood from their bodies. The blood was used to research for anti bodies left by the illness. After the participants agreed, the order in which the questionnaire was going to be administered was: Socio- demographer, epidemiologist, entomologist and geographer. It is important to notice that, certain disciplines (geography, entomology) apart from the interviews came under information related to the immediate environment of the interviewed persons: characteristics of the habitat and characteristics of the mosquitoes' homes. The geographic coordinates of all the inquired compounds during the study were drawn up by the GPS (Fig. 4).

At the end of the inquiries, each discipline has recovered its part of the questionnaire and has proceeded to the type of information collected. After respectively typing, it was necessary to integrate the whole distributed data.

The coupling of information consisted of establishing a relationship between the geographic coordinates produced by the GPS and the descriptive information contained in Enquiry files. The result of that operation is a data file with spatial reference. Each discipline thus possesses its own information file. For analysis purposes, all those files must be integrated to form a data base which can be used by different disciplines. This is why it was necessary to proceed to the integration of the data. Each disciplines' inquiry file possess means which could help couple them together. Data integration has then consisted in joining

those files while excluding duplications and other redundant information. During that phase, a control advanced integrity of the data basis was affected. At the end of the process, the data were ready for the beginning of the analysis.

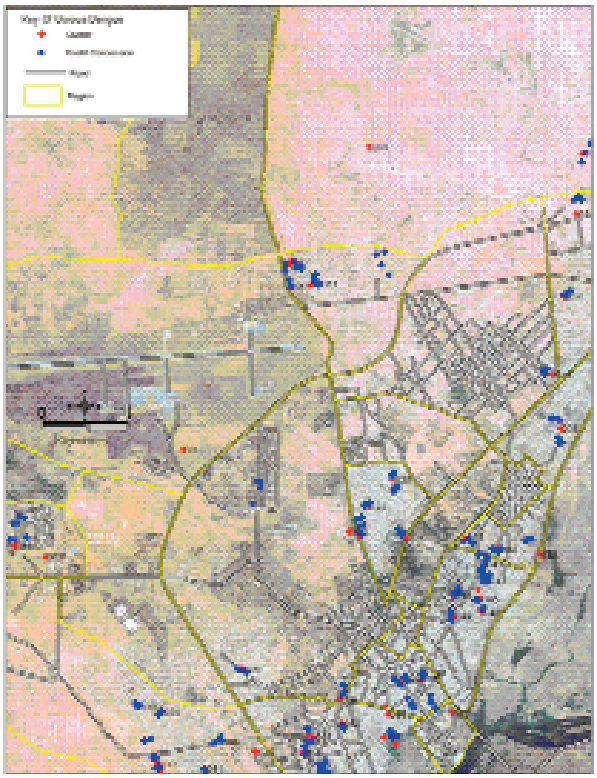

Figure 5. Compounds with results of positive blood analysis in Garoua
(Source: Epidengue investigations, in September, 2006).

DATA ANALYSIS

This study aims at obtaining a spatial characterisation of its emergence in those three environments.

At the end of joining between the geographic table containing the results of all the inquired compounds and the serologic table which contains the value of the presence or not of the anti bodies per individual, a differentiation map between positive and negative compounds was established (Fig. 5).

We were then able to draw the following table.

It is understood by compounds showing positive results to the analysis that, compounds in which at least a case of positive traces of antibodies were found in an occupant. This table shows that, the illness's tendencies present a big gap between the cities of Douala and Garoua on one side, and that of Yaounde on the other. In order to explain such a gap, we shall proceed by characterising of Dengue's emergence in those three cities.

Table 1. Summary data on the survey. (Source, Epidengue survey, September 2006).

Towns	Investigated compound	Number of Positive compound	Percentage
Garoua	259	142	54,82%
Douala	299	233	77,92%
Yaounde	237	31	10,80%

We shall begin with an adopted statistical sample to explain the phenomenon. The indicated sample is that of logistic regression. The logistic regression is applied to the phenomena which are marked by variations whose abundances are diversified. It has as principle the connection of occurrence of

not, starting from its co-variables (Afssa Essafi, 2003 ; Leblanc et al., 2000).

Here, we are concerned with an analysis of the data in order to extract statistical dependencies among co-variables. The variable to be explained (Y) corresponds to the presence of traces of antibodies left by the illness; the variable is positive or negative. The trace of antibodies simply means that at one moment or another, the individual suffered from the disease but is no longer ill. The explanatory variables are a sub-set of descriptive variables on the geographical survey sheet. Those which particularly interests us are; the setting of the compound (Q1), the type of dwelling unit (Q2), the architectural type of building (Q3) (Legrand, 2005).

The different modalities of these variables are presented in the tables below:

Table 2. Variable Q1 modalities.

Q1: Site of the compound	**Codes**
Flat Terrain	1
Thalweg with river 2	2
Swamped thalweg 3	3
Small slope 4	4
Stiped slope 5	5
Top of the hill 6	6

Table 3. Variable Q2 modalities

Q2: what is the type of the living unit?	**Codes**
lindividual	1
Many families	2
Building	3
House of season workers	4
Other (To be precise)	5

Table 4. Variable Q3 modalities.

Q3: Architectural type	**Codes**
isolated	1
continuous	2
backed on wall	3

RESULTS

During the exploitation of the logistic regression method, we shall be interested by the statistic independence or dependence among variables. The threshold confidence which we will consider is 11%. According to the test, there is statistical dependence when the Wald value is inferior to 11%, that is, when (Pr>Khi2)<0.11 (Kleinbaum, 1994).

We have carried out that test on a set of combinations among explanatory variables and the variable to be explained. The combination which lookes interesting is the one between Q1 and Q3 variables with the variable Y. The following tables summarise the logistic regression test carried out for each of the three cities.

Table 5. The test results for the town of Garoua.

Statistic	DDL	Khi²	Pr > Khi²
-2 Log (likehood)	4	9.010	0.061
Score	4	8.959	0.062
Wald	4	8.654	0.070

Table 6. The Dwelling test results for the town of Douala.

Statistic	DDL	Khi²	Pr > Khi²
-2 Log (likehood)	5	14.958	0.011
Score	5	15.539	0.008
Wald	5	11.618	0.040

Table 7. The Dwelling test results for the town of Yaoundé.

Statistic	DDL	Khi²	Pr > Khi²
-2 Log (likehood)	4	6.843	0.144
Score	4	3.680	0.451
Wald	4	0.202	0.995

DISCUSSION

An interpretation of the results according to the logit test shows that an evaluation of the Pr<Khi2 value for each of the three cities indicates the following;

For the Garoua town, the (Pr > Khi ^{2}) value is equal to 0.07, and is inferior to 0.11. It can then be concluded without any risk of error that, statistic dependence exists among the variables Q1, Q3 and Y. In other words, Y=f(Q1,Q2) for the town of Garoua.

For the city of Douala the (Pr > Khi ^{2}) value is equal to 0.040 and is inferior to 0.11. It can then concluded without and risk of error that, statistic dependence exists among the variables Q1, Q3 and Y. In other words, Y=f(Q1,Q2) for the town of Douala.

On the contrary, for Yaoundé, (Pr > Khi ^{2}) is equal to 0.995 and is superior to 0.11. It can be concluded that no statistic dependence exists between the Q1, Q3 variables and y, which in other words mean that, Y≠ f(Q1, Q2) for the town of Yaoundé.

The above results show that in the towns of Gaoua and Douala, the presence of the Dengue in a compound can be explained by the setting (land which is equally flat), and the architectural type of construction (compound with many families, or blocks of flats) in the compounds. It is not the case for with Yaoundé which is essentially a hilly city.

If we look at the landscape of the towns of Douala and Garoua, they are the same type. They are alluvial plains built on recent deposits. Both of them have an average of 300m of altitude. We can thus deduce that, on flat and low landscapes in spontaneous and generally packed up quarters, Dengue finds a favourable terrain for its emergence and diffusion. The absence of slopes favours stagnant waters and the development of collectors (cans, old cars, etc) which are potential homes for the germs. It is therefore important to mentioned that, these objects, out of carelessly dropping on slopes and is swept away by the water current and constitute water collectors when they do not remain stable. Moreover, in the densely populated areas, the soils are rather shady and make good homes for the germs.

Conclusion

This study aimes at characterising the emergence of Dengue in the cities of Garoua, Douala and Yaoundé. After presenting the approach used and the methodology adopted, we focused our attention on the geographic and statistic study of the phenomenon using the logistic regression method. This method helped us define statistic dependencies in relations to variables which had been chosen before. We thus came to the conclusion that, Dengue's emergence is identical in flat open surroundings in Cameroon no matter the bio climatic conditions. The particularity of this study comes from its pluri-disciplinary nature. For that purpose, the project had to be tackled by using a transverse discipline such as geometrics. Thanks to this discipline, it was possible to conceive and apply the geographic information systems; the methodological approach elaborated took into consideration physical data, but the human data as well,

whose representation in the space by actors whose up streams have contributed consciously to their shaping and whose down streams structure the observation of the subject. Field observations, aerial or oblique photographs, satellite images, maps, interviews and group discussions have been exploited. The contribution of the statistics has permitted to bring out the interactions between explanatory variables and the one explained thanks to the logistic regression method. This rendered possible the analysis of the proportions that, each explanatory variable contributes to the formation of the interest in variable. Populations of the high risk zones can then easily be drawn according to that morphologic parameter. Its combination with other parameters such as the knowledge of factors of Dengue's propagation can help draw more refined maps with the aim of facilitating decision making.

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