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Spatial analysis of the physical deterioration of long-lasting insecticide-treated mosquito nets and risk factors in Benin, West Africa

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Abstract

The objectives of this study are to assess the geo-variability of the physical deterioration of LLINs and to map the risk of tearing them in two districts in southern Benin, Kessounou and Allada, and two others located further north at about 750 km, Kandi and Malanville, in order to analyse the spatial distribution of the physical deterioration of impregnated nets and their risk factors. In each of the 4 study sites, 500 nets were randomly selected. Only nets that are actually used in households and suspended in bed are selected. Each selected net was doubly marked with paint and a label with an identification number. The geographical coordinates of the household are then taken with a GPS. The integrity of nets has been assessed using the new methods described by WHO. The observed holes were counted and categorized according to their diameter and we are interested in data processing.

It appears that one year after distribution, 62% to 87% of LLINs found in households are found at the different sites studied. And 24 months after distribution, 76% to 94% of LLINs found in households are found at the different sites studied. This situation is explained by factors that cause them to tear.

The spatial distribution of PHI in Malanville is characterized by a trend towards a concentration of tear frequencies in the northeast and central parts of the site and that of Kessounou is characterized by a more or less homogeneous distribution of aggregates along the river. Since Moran's autocorrelation index is close to 0, there is spatial independence for this realization of the regionalised random variable. There are then spatial aggregates expressing the local existence of spatial autocorrelation.

LLINs distributed and used in areas with high wash pressure are subject to a significantly higher risk of deterioration of their physical integrity than LLINs in areas with low wash pressure. The frequency of washing and appearance (dirty or clean), frequency of use of LLINs, number of net users, energy and location of the kitchen and distance of the area from a river are very important prognostic factors in the loss of physical integrity of LLINs.

Keywords: malaria, llins, sustainability, anopheles, man

1. Introduction

African region is paying a heavy toll on vector-borne diseases (VBD) due to favorable climatic and environmental conditions for vector multiplication. These vectors transmit mainly onchocerciasis, lymphatic filariasis, human African trypanosomiasis, schistosomiasis, dracunculiasis and malaria. Given the importance of these diseases in public health, most African countries have implemented specific programs to combat each one of them (WHO, 2010) [1].

Unfortunately, these programs have not always given vector control the place it should be. Barriers to the implementation of vector control programs are their relatively high costs and insufficient human resources (WHO, 2009). As the first global parasitic disease, malaria is a real public health problem in Africa that threatens more than one billion people in the poverty belt (Rouy, 2010). According to estimates of the World Health Organization, malaria is the first Endemic disease for which humanity pays a heavy price (WHO 2013).

In Benin, this disease accounts for 39.7% of the causes of Medical consultationand is at the forefront of the main diseases affecting communities. Faced with this situation, Benin has implemented a National Control Program (NMCP) since 1992. This Program has carried out several malaria control activities through various strategies and approaches (MS, 2012). The fight against this disease, stimulated by the "Roll Back Malaria" initiative, aims to significantly reduce the morbidity and mortality associated with this pathology as well as the economic losses it causes (WHO, 2008). Among the various methods promoted in the fight against malaria, vector control occupies a prominent place. The use of long-lasting insecticide-treated bednets (LLINs) as a complementary method of preventing malaria is Themost preferred among thestrategies already implemented by national malaria control programs. Several studies conducted since 1988 to date have highlighted the effectiveness of Impregnated mosquito netsin the fight against malaria, particularly in Cameroon, Democratic Republic of Congo, Kenya, Ghana and Benin (Karch, 1993) [5]. Furthermore, an increase in the washing of these LLINs is possible, especially in areas of high anopheles density where their use is high (Akogbeto *et al*., 2014) [8]. An investigation in Benin in a riparian area revealed that LLINs are almost washed monthly, about 36 times in 3 years (Akogbeto *et al*.,). However, the lifespan of a LLIN is estimated at 3 years or 20 washes according to WHOPES

(WHO, 2006). It is for this reason that we initiated this study to assess the variations of the LLINtears and their risk factors to fight against the resistant populations of malaria vectorsin regions where the frequency of washes is high.

2. Framework of study

Four sites were selected on the north-south transect of Benin (two sites in the South and two sites in the North) for the implementation of this study. Two of the sites, Kessounou and Allada, are located in southern Benin (Figure 1) while the other two, Kandi and Malanville, are located further north about 750 km. The inhabitants of Kessounou, located along the Ouémé River, have easy access to water to wash their mosquito nets. On the other hand, the inhabitants of Allada who want to wash their mosquito net, have to carry water about 5 km. Similar criteria (short distance from water for washing LLINs compared to long distance) were applied to sites in the north. Malanville, located near the Niger River (water for washing mosquito nets easily accessible) and Kandi (where residents have to carry water to wash LLNs from distant place were chosen.

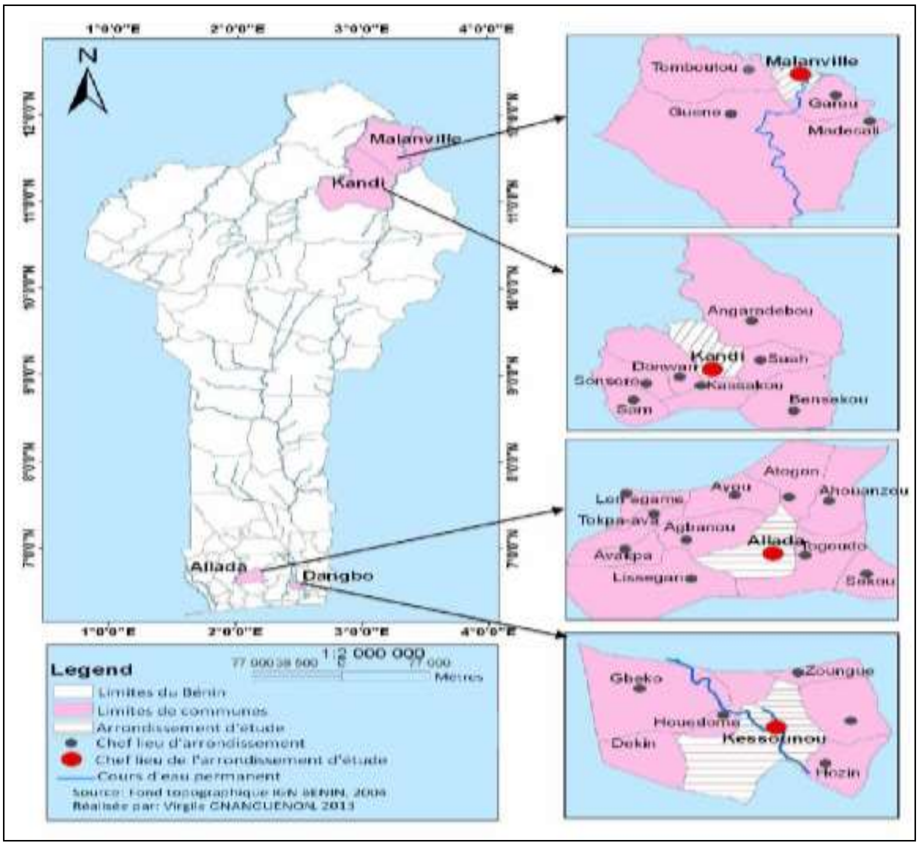

Fig 1: Map of Benin showing the four study sites

3. Methodological approach

Data collection

Household selection and data collection

All of the four study sites were explored. A total of 500 mosquito nets were randomly selected in each study site. Only bednets in actual use in households and hung are selected. Each selected mosquito net was doubly marked with paint and a label with an identification number (Figure 2 and 3). The geographical coordinates of the household are then taken with a GPS (Figure 4).

Information about the net is collected from the household head using a questionnaire developed according to the WHO evaluation guide (WHO, 2011). All this information is collected via tablets used as data terminals and sent to a cloud server. At the end of the survey, the data is retrieved from the remote server and analyzed.

Fig 2: Labeling of the Net

Fig 3: Double Indelible Ink Marking

Fig 4: GPS coordinates registration

Spatial scanning statistics established with a computer equipped with map processing software (Arc-Gis 10.1.) is used to identify the presence of aggregates in space) in time or in space-time. It provides a list of plausible aggregates as well as their location. These were ranked in order of p-value (statistical significance). In addition, we obtain for each a relative risk, which represents the ratio of the number of cases observed to the number of expected cases.

Durability of mosquito nets

Lossof mosquito nets

After 12 months and 24 months of use, each of the 500 households in which the nets were tagged was visited, in order to verify whether the tagged net is still in the household. When a mosquito net has not been found, an interview is conducted to find out why the net is not present in the household. This allowed to estimate the rate of loss of mosquito nets which was defined in two categories of loss:

The rate of loss related to tears (mosquito nets torn and thrown or destroyed) =

$$\frac{\text{Mosquito nets missing from households due to holes or tears}}{\text{Total number of LLINs selected at t0}} \times 100$$

Loss rate related to other

$$\frac{\text{Mosquito nets given away, stolen, sold or used elsewhere, or used for other activities}}{\text{Total number of LLINs selected at t0}} \times 100$$

Physical integrity of mosquito nets

Mosquito net integrity were assessed according to WHO guidelines (WHO, 2011) and those of Albert Kilian (Kilian, 2012). The holes observed were counted and categorized according to their diameter (Figure 5): - category 1: "< thumb (0.5-2 cm)" (can not insert thumb); - category 2: ">thumb<fist (2-10 cm)" (possible to insert the thumb but not thefist); - category 3: "> fist <head <(10-25 cm)" (possible to insert the fist but not the head); - category 4: "> head (> 25 cm)" (possible to insert the head).

5a: Hole of category 1

5b: Hole of category 2

5c: Hole of category 3

5d: Hole of category 4

Fig 5: The different categories of holes

The results are then calculated using the formula of the PHI (Proportionate Holes Index) which makes it possible to quantify the holes per mosquito net. The PHI is therefore calculated by adding the sum of:

Number of holes of category 1 × 1
Number of holes of category 2 × 23
Number of holes of category 3 × 196

Number of holes of category 4 × 576
This makes it possible to estimate the approximate value of the surface of the holes. The PHI formula then looks like this:
PHI = 1 × # C1 + 23 × # C2 + 196 × # C3 + 576 × # C4 (# C = number of holes in the category)
The thresholds suggested by Kilian (Kilian, 2012) to be applied to the data are:
PHI <64: mosquito net in good condition
PHI> 64 and <663: mosquito net still in use
PHI> 663: mosquito net to be replaced
The causes of the holes (tears, burns, rats, sewing defects) were also identified to assess the contribution of each of them in the physical deterioration of the net.

4. Results

Mapping of households surveyed by geographical unit

The objective of this part of the work is to establish the spatial distribution of households surveyed with nets labeled according to the borough (geographical unit) in the study area.

For a prospective study on the sustainability of mosquito nets, the selection of mosquito nets in households in each district took into account five villages. For example, for the district of Kessounou (Kodonou, Kessounou, Gléhoué, Hétin-Sota and Glahounsa), the district of Allada (Alomey-Ahito, Gbowele-Dodomey, Dogoudo-Gbegamey, Donou-Togoh, TokpotaZebou) for Kandi district (Damadi, Gansosso, Keferi, Pede, Gandokossikana) and finally the district of Malanville (Wouro-yesso, Kochi, Kochi2, Haro-banda, Galiel), so as to ensure a representative sampling of the site. For the evaluation of the 500 mosquito nets, approximately 100 nets were randomly selected in each of the four villages. (Figures 6, 7, 8, 9).

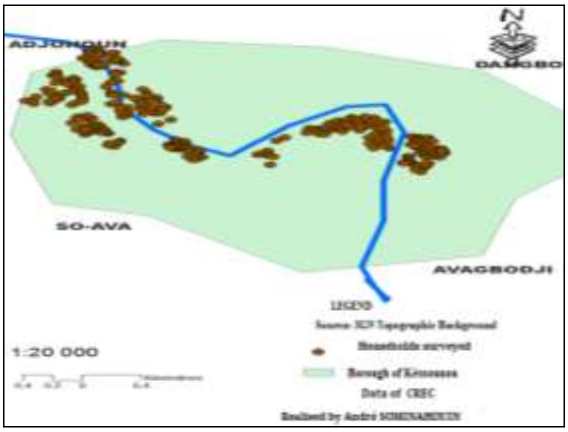

Fig 6: Map of the district of Kessounou showing the households surveyed

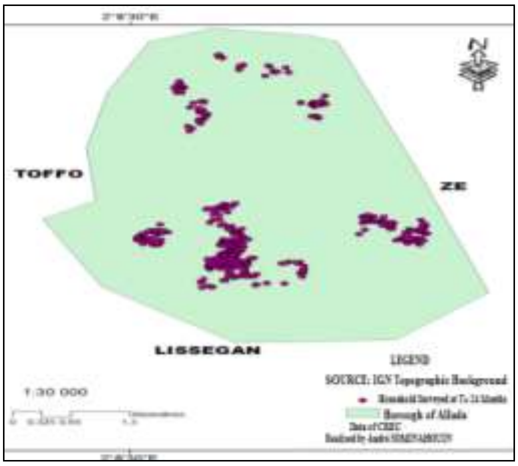

Fig 7: Map of the district of Allada showing the households surveyed

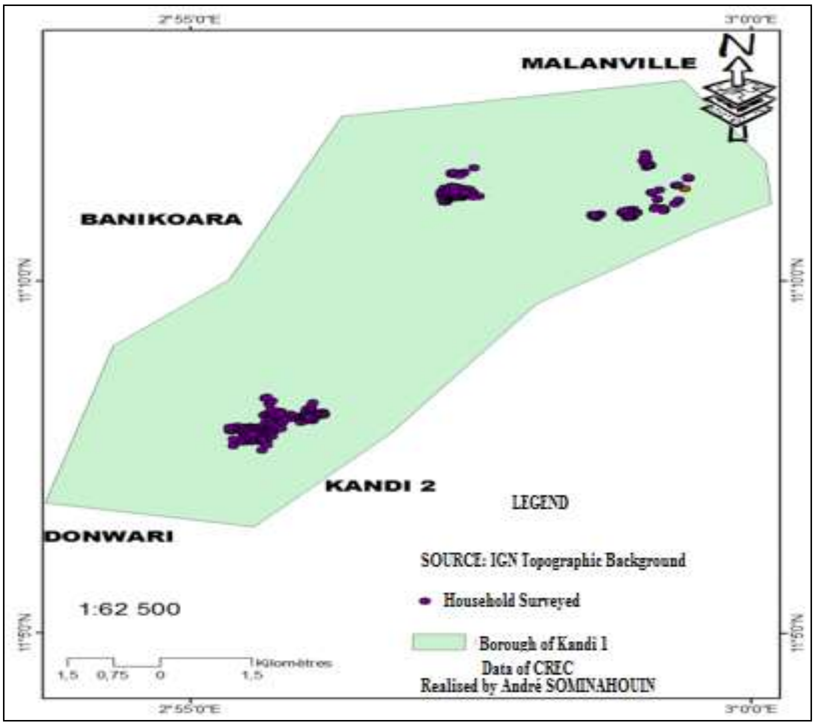

Fig 8: Kandi 1 district map showing the spatial distribution of household respondents

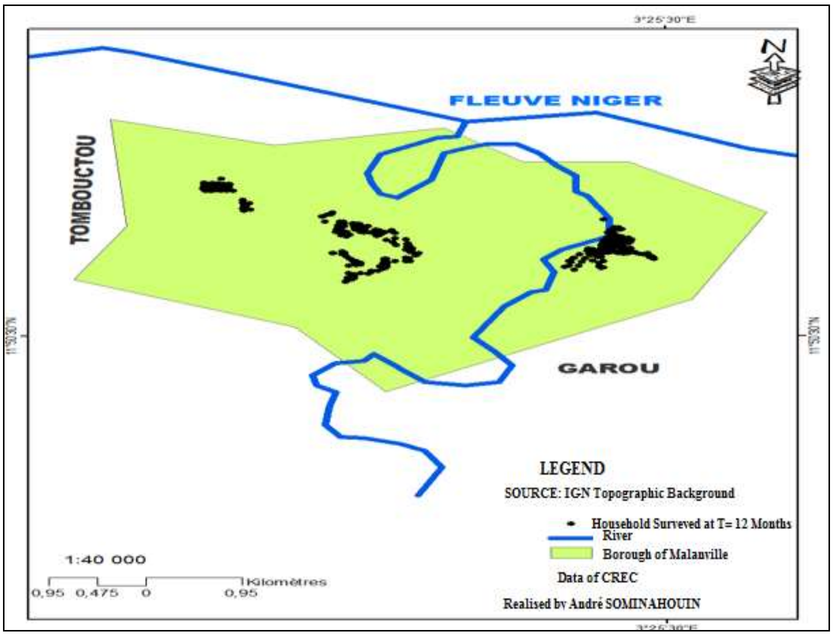

Fig 9: Map of Malanville borough showing the spatial distribution of household respondents

Variations in Loss Rates for LLIN Ruptures by zone

After two years of use, 1120 LLINs were lost out of the 2002 LLINs initially selected. Of the 1120 LLINs lost, 417 LLINs were lost in the first year versus 703 LLINs in the second year. Losses due to physical deterioration of LLINs are 7% after one year (Table I). They vary from one locality to another and appear to be higher in areas near watercourses (5 to 18%) than in areas far from water sources (2 to 4%). After two years of use, losses due totears tripled with a rate of 22%.

We found a significant difference in the rates of loss of impregnated mosquito nets, which varies according to the geographical positions of the sites (North versus South) ($p < 0.05$).

After 12 months, loss rates due to the physical integrity of LLINs in the South are 11% [95% CI: 8.87-12.80] and are higher than in the North (3% [95%: 2.06 to 4.30]). There is therefore a significant difference between the North and South loss rates. After 24 months, these loss rates related to the physical integrity of LLINs in the South are 27% [95% CI: 24.26-29.85] and are higher than in the North (17% [95%: 14.36- 19.06]). There is therefore a significant difference between the North and South loss rates.

Variation in the physical integrity of mosquito nets according to the area

Table 1: Loss Rates Related to Physical Degradation of LLINs, One to Two Years After distribution

		Kessounou (South)	Malanville (North)	Allada (south)	Kandi (North)	Total
Distance to the watercourse		<0,05 km	<0,05 km	>5,0 km	>5,0 km	
Basic data (T_0)	Selected households	501	501	500	500	2002
After 12 months (T_{12})	Eligible households	452	470	454	479	1855
	Visited / Open households	393	411	396	442	1642
	LLINs tagged found	253	338	286	348	1225
	(LLINslost T0 at T12)	(140)	(73)	(110)	(94)	(417)
	Loss rate related to rips % (n)	18 (n=89)	05 (n=22)	04 (n=18)	02 (n=8)	07 (n=137)
	CI_{95} (%)	14,67-21-35	02,92-06,56	02,29-05,62	00,81-03,13	05,82-08,03
	Loss rate related to other factors % (n)	10 (n=51)	10 (n=51)	18 (n=92)	17(86)	14(n=280)
After 24 months (T_{24})	Eligible households	246	326	254	323	1149
	Visited / Open households	229	295	211	243	978
	LLINs tagged found	173	231	120	187	711
	(LLINslost T0 at T24)	311	239	337	233	1120
	Loss rate related to rips % (n)	34(n=172)	20(n=100)	19(n=98)	13(n=66)	22(n=436)
	CI_{95} (%)	30,31-38,59	16,69-23,68	16,36-23,31	10,51-16,45	20,03-23,64
	Loss rate related to other factors % (n)	28(n=139)	28(n=139)	48(n=239)	33(n=167)	34 (n=684)

One year after distribution, 62% to 87% of LLINs found in households are holed at the different study sites. The proportion of holed mosquito nets was significantly higher ($p < 0.05$) in areas of high wash pressure than in areas of low wash pressure (Table II).

The averages of the Proportional Hole Index (PHI) for all four sites studied are between 398.1 and 798.7 (Table II). These averages are 691.2 to 798.7 in areas of high wash pressure versus 398.1 to 510.4 in areas of low wash pressure. In areas with high washing pressure, 50% of the LLINs in Kessounou have a PHI <290. In Malanville, 50% of the mosquito nets have a PHI <243.In areas with low washing pressure, 50% of the LLINs in Allada have a PHI <46. In Kandi, half of the mosquito nets have a PHI<85.5 and the other half has a pHI> 85.5.

24 months after distribution, 76% to 94% of LLINs found in households are Holed at the various sites studied. The average proportional hole index (PHI) in communities near

water is 1140 to 1200, compared to 573 to 1012 in communities far from water sources. Median values of PHIs for communities with easy access to water range from 312 to 706, and are higher than those observed in communities far from water sources (96 to 105).

Table 2: Physical conditions of LLINs after 12 and 24 months

		Kessounou	Malanville	Allada	Kandi
After 12 months	LLINs found	253	338	286	348
	LLINs holes	219 (87)	294 (87)	178 (62)	241 (69)
	CI 95 (%)	81,73-90,51	82,92-90,38	56,34-67,88	64,11-74,06
	PHI Moyen	799	691	398	510
After 24 months	LLINs found	173	231	120	187
	LLINs holes	159 (92)	217 (94)	91 (76)	153 (82)
	CI 95 (%)	86.79-95.51	90.04-96.65	67.17-83.18	75.53-87.07
	PHI Moyen	1205	1139	1012	573

Kessounou, Malanville and Kandi mark the increase in PHI (tears) from the periphery to the center. On the other hand, in Allada, the rounded shape of the ellipse shows a concentration of the PHI in the center. At Allada, there is a shift in the middle center of the PHI from North to South between T12 and T124 (Figure 10). At Kessounou, the displacement of the middle center of tears is towards the West. But in Kandi and Malanville, the movement of the middle center of PHI is from south to north between T12 and T24 (Figure 12). The approximation of PHI directional distributions at 12 months and at 24 months shows the permanent availability of the watercourse, which is much more conducive to the physical deterioration of impregnated mosquito nets.

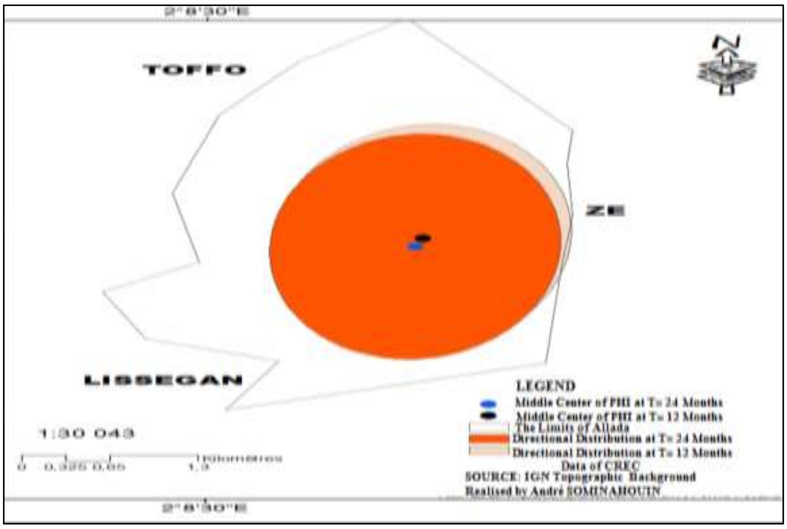

Fig 10: Allada District Map showing the directional distributions of PHI at T = 12 months and at T = 24 months.

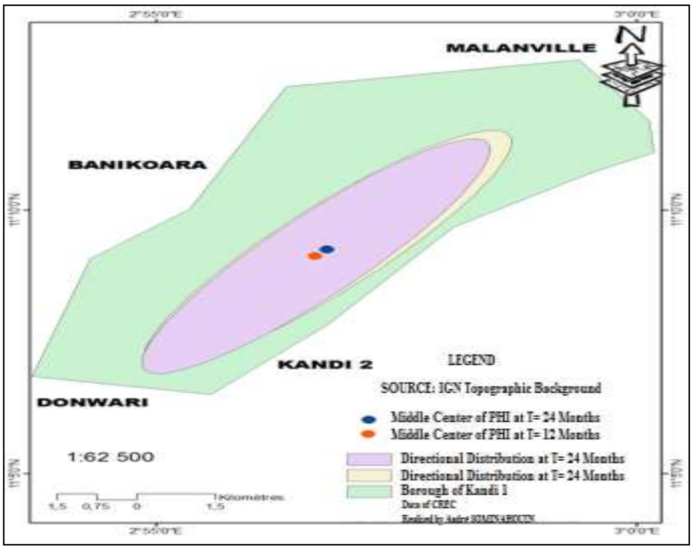

Fig 11: Kandi borough Map showing the directional distributions of PHI at T = 12 months and at T = 24 months.

The p-values are respectively 0.001 and 0.05, both less than 5% (test threshold). We can therefore consider its distribution as random. We also note that the medians and the respective averages of the mortality rate and the coverage in LLIN are close to the maximum values. The following figure summarizes the values of the probabilistic index and p-value test statistic, representing the risk of physical deterioration of the nets.

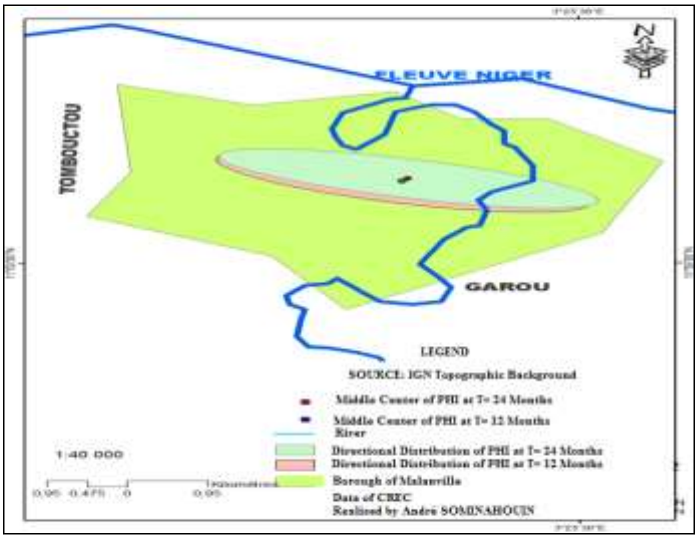

Fig 12: District map of Malanville showing the directional distributions of PHI at T = 12 months and at T =

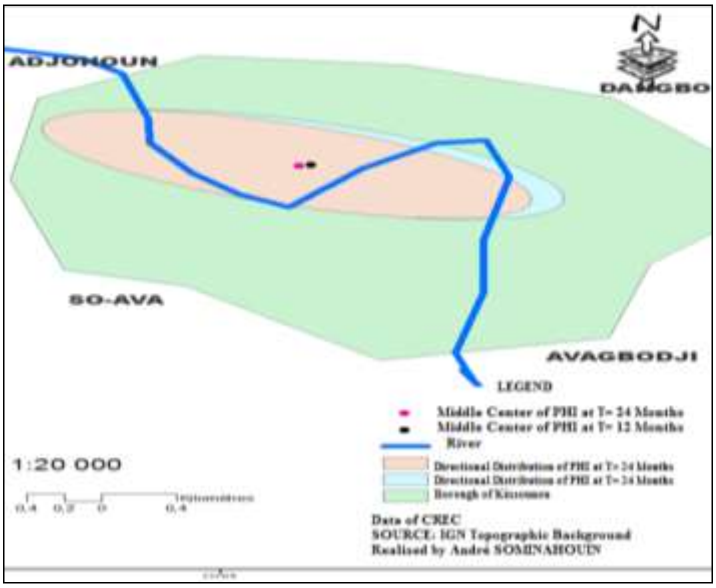

Fig 13: Kessounnou District Map showing the directional distributions of PHI at T = 12 months and at T = 24 months.

Aggregate search

The spatial distribution of PHI at Malanville (Figure 14) is characterized by a tendency to a concentration of tear frequencies in the northeastern and central parts of the site. The evaluation of the Moran autocorrelation index in the site gives the following results: Moran index = 0.097; Expected index = -0.0005; Variance = 0.00023; p <0.0001. Since the Moran autocorrelation index is close to 0, there is spatial independence for this realization of the regionalized random variable. There are then spatial aggregates expressing the local existence of spatial autocorrelation. Four types of aggregates have been identified as shown in Figure 14. The first category of PHI (00-695) includes LLINs that are in good condition or have an acceptable degree of deterioration (which can be repaired). This first category is more concentrated in the center of the district more than 1 km from the river. The other three PHI categories include LLINs with a tear level greater than 695 (greater than 1000cm²). These 3 types of aggregates are found throughout the borough and appear to be much more concentrated in the north-east of the borough at a distance less than 0.5 km from the river.

The spatial distribution of PHI at Kessounou is characterized by a more or less homogeneous distribution of aggregates along the river. The evaluation of the Moran autocorrelation index from PHI to Kessounou gives the following results: Moran index = 0.1466, expected index = -0.000544; Variance = -9.712; p <0.0001. Thus the spatial autocorrelation of the Moran index revealed a spatial correlation (P <0.001). Four types of aggregates were also identified with a predominance of the first three types of aggregates, which are found both in the west, in the center and east of the borough (Figure 15).

The evaluation of the Moran autocorrelation index at Allada gives the following results: Moran index = 0.056; Expected index = -0.0025; Variance = 0.0002; P-value = 0.187. The spatial autocorrelation of the Moran index performed revealed no spatial correlation (P>0.05). There are no spatial aggregates expressing the local existence of spatial autocorrelation.

In Kandi district, the Moran autocorrelation index of PHI showed the following results: Moran Index = 0.0338; Expected index = -0.0238; Variance = 0.00096; P-value = 0.2421. The spatial autocorrelation of the Moran index carried out revealed no spatial correlation (P>0.005).Therefore, there are no spatial aggregates expressing the local existence of spatial autocorrelation.

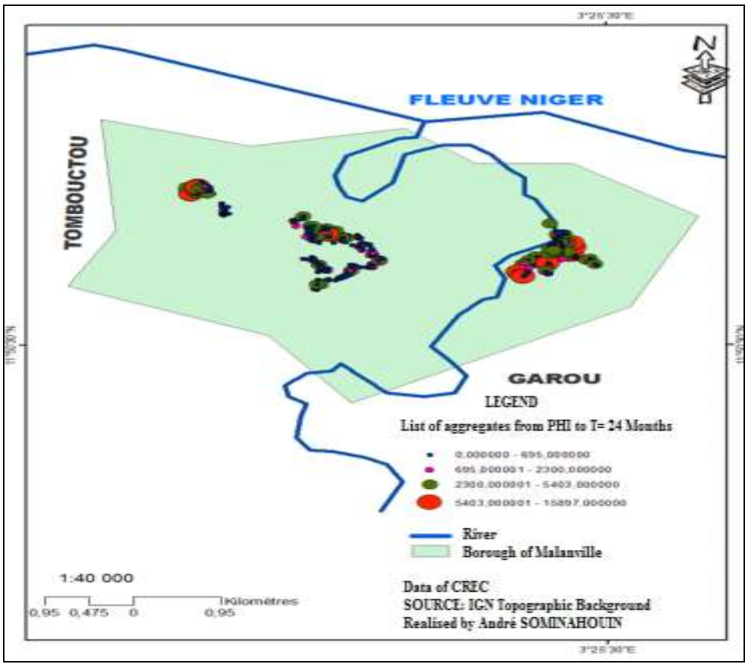

Fig 14: Malanville District MapShowing PHI Aggregates

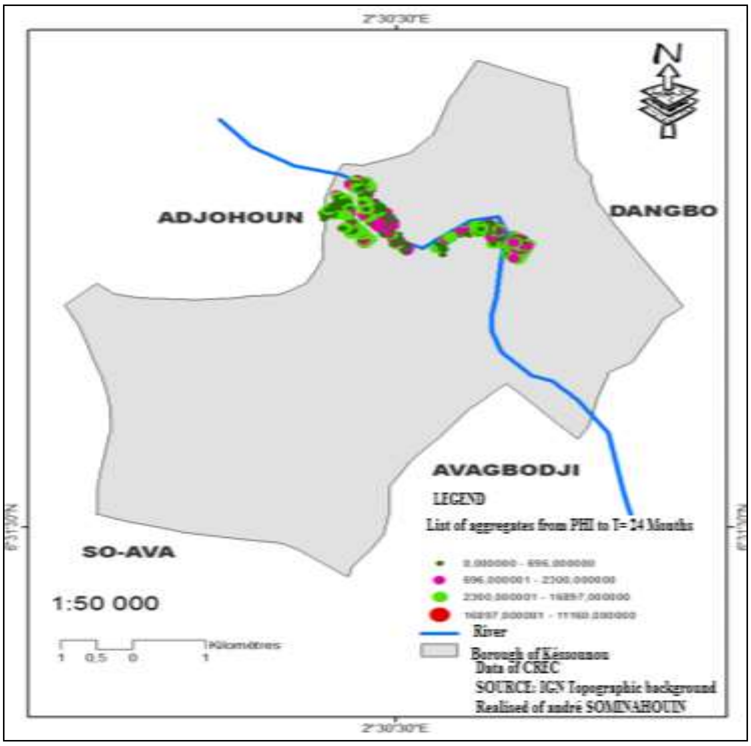

Fig 15: Kessounnou District Map Showing PHI Aggregates

Risk factors

Several variables had effects on the loss of the physical integrity of the LLINs. LLINs distributed and used in areas of high wash pressure are significantly more likely to be physically impaired than LLINs in areas with low wash pressure (Rate Ratio = 1.61) [01,27- 02.05]; p = 0.0001). Frequency of washing and appearance (dirty or clean), frequency of use of LLINs, number of net users, energy and location of the kitchen and distance from the area to a river represent very important prognostic factors in the loss of physical integrity of LLINs (p <0.05) (Table III)

Table 3: Influence of Other Factors on Loss of Integrity Loss Rates Related to Physical Degradation of LLINs

Factors	Modalities	coefficients	Rate Ratio	CI-95%(RR)	P (Wald test)	P (LR-test)
Distance to a river	>5 km	-	1	-	-	0.000106
	<0.5 km	0.48	1.61	[01.27-02.05]	0.000106	
Frequency of washing	None	-	1.00	-	-	<0.0001
	1	1.24	3.45	[01.63-07.29]	0.001225	
	02-05	1.11	3.02	[01.57-05.82]	0.000915	
	06-10	1.75	5.73	[02.92-11.25]	<0.00001	
	10+	2.12	8.36	[04.06-17.21]	<0.00001	
Location of the kitchen	Outside	-	1.00	-	-	0.012664
	Inside	0.51	1,67	[01.11-02.50]	0.0131	
Energyused	Coal	-	1.00	-	-	0.017557
	Wood fire	0.53	1.70	[01.09-02.66]	0.01951	
Maintenance of the mosquito net	Clean	-	1.00	-	-	0.000822
	Dirty	0.49	1.63	[01.22-02.17]	0.00091	
Frequency of use	Not at all	-	1.00	-	-	0.004242
	Often	-1.03	0.36	[00.20-00.65]	0.00077	
	Every night	-0.88	0.42	[00.23-00.74]	0.00269	
Number of users		0.13	1.14	[01.03-01.26]	0.014079	0.01660

5. Discussion

The main purpose of this study was to apply the spatial method to identify the existence of geographical patterns of physical deterioration of long-lasting insecticide-treated mosquito nets (polyethylene) that were distributed in Benin in 2011. Two years after distribution, 76% to 94% of LLINs found in households are holed at the various study sites. Losses due to physical deterioration of LLINs appear to be higher in areas near watercourses (20 to 34%) than in areas far from water sources (13 to 19%). These physical deteriorations tend to aggregate in areas close to rivers where they exhibit a spatial autocorrelation.

The low rate of tear losses in remote areas of rivers is likely due to the permanent unavailability of sreamthat reduces the frequency of LLIN washing. These results are similar to those of Adoha obtained on the efficiency and durability of Olyset nets, after its distribution in Benin in 2012 (Adoha 2012).

Physical integrity is an important and critical element that influences the capacity of LLINs to reduce human-vector contact. The main cause of holes reported by several studies is mechanical damage, followed by holes caused by rodents. The third category of damage is thermal damage (burns or sparks) (Kilian *et al*., 2015, Hakizimana *et al*., 2014). Most LLINs with significant physical damage are found in areas with high wash pressure. Olyset LLINs appear to have less physical damage in low pressure washing locations. This result confirms that obtained by Allan *et al*. (2012) who have shown that Olyset LLINs are less likely to have a high proportional Hole Index than other types of LLINs in semi-arid conditions. This finding was also made by Atieli *et al*. (2010). The use of geo-spatial techniques has shown spatial relation in the tendency of LLINs to deteriorate. Several aggregates have been identified in areas close to water. Their concentrations and amplitudes appear to increase with distance from the stream. This would be related to wash pressures that would increase as the household's proximity to the watercourse increases. This also explains the high concentration of high amplitude aggregates in the northeastern part of Malanville closer to the Sota River compared to the center which is far away from the river. According to DIALLO AbdoulBrahim's studies at the MoughataaM'bout Mauritania in 2012, the frequent washing of the LLINs accelerated their physical deterioration. This observation is confirmed by the washing frequency and the appearance (clean or dirty) of the LLINs that were significantly correlated with the loss of the physical integrity of LLINs. In addition, the pressure exerted during these many washing sessions of these LLINs gradually contributes not only to the loss of physical integrity but also to the loss of the effectiveness of LLINs. This loss of effectiveness of LLINs tends to confirm Kelani's claim that LLINs used in field conditions by populations appear to be ineffective long before the peak of 20 washes prescribed by manufacturers. These results obtained in the three health zones in Benin, confirm those of Doannio *et al*. in Côte d'Ivoire, which also showed the loss of effectiveness of LLINs after soaking and washing of the latter by other soap than that recommended (Marseille soap) by the manufacturer.

Several studies have shown that ITNs reduce malaria-related morbidity and mortality in areas of high and moderate epidemics in sub-Saharan Africa and also reduce malaria-related morbidity in various Asian lake regions. However, the PHI averages observed in our study were between 600 and 1200 suggesting that the majority of LLINs were subject to significant physical damage. However, recent studies (Gnanguenon *et al*., 2013, Haji *et al*., 2013 and Ochomo *et al*., 2013) have shown that, despite a relatively low loss of integrity (PHI <300), *An. gambiae*sl succeed to penetrate the impregnated mosquito nets every night in the zone of resistance. A loss of physical integrity of the LLINs two years after their use could therefore contribute to a resurgence of malaria in the third year.

6. Conclusion

This work has shown a geographical variation in the physical deterioration of LLINs which is higher in areas near rivers and low in areas far from water sources. It also showed a correlation between geographically close measurements of the proportional index of holes that tends to aggregate in areas near rivers. The higher the aggregates of PHI, the closer spatial proximity to a river. Six extrinsic factors were identified as promoting the physical deterioration of LLINs.

At the end of this analysis, it should be noted that the recommendation made by the various promoters of LLINs namely the non-use of detergent for the washing is correct. But, it is insufficient and should include the washing frequency, to distinguish the LLINs to be used depending on the areas near or far from watercourses. Similarly, these recommendations should emphasize the wash pressure which should be low, because washing too vigorous (rubbing hard) seems to lead to a faster loss of physical integrity of the LLINs and the insecticidal effect. Thus, one of the best guidelines to give,from the results of this study is to rub the LLIN very gently or to rinse and shake it. The repair of hole and awareness of care and maintenance when using LLINs could increase their operational life.

Without wanting to settle in a mirage of eradication of malaria and immediate control of the culicidian population in the study area, this study wants to bring another look at the questions "environment and health" by illuminating, from a geographical angle, decision-makers and researchers who invest in vector control.

Competing interests

The authors declare that they have no competing interests.

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7. References

1. WHO. World Malaria Report 2010. Geneva: World Health Organization, 2010.
2. Carnevale P, Robert V, Boudin C, Halna JN, Pazart L, Gazin P, *et al*. Parasitologie. La lutte contre le paludisme par des moustiquaires imprégnées de pyréthrinoïdes au Burkina Faso. Bulletin de la Société de pathologie exotique. 1988; 81(5):832–46.
3. Desfontaine M, Gelas H, Cabon H, Goghomou A, Kouka Bemba D, Carnevale P. Evaluation des pratiques et des couts de lutte antivectorielle à l'échelon familial en Afrique Centrale. II. Ville de Douala (Cameroun), juillet 1988. Ann. Soc. belge Méd. trop. [Internet] 1990; 70:137-44. Availablefrom: http://horizon. documentation.ird.fr/exl doc/pleins_textes /pleins_textes_5/b_fdi_23-25/31120.pdf
4. Azondekon R, Gnanguenon V, Oké-Agbo F, Houevoessa S, Green M, Beach R, Akogbeto M: Tracking a long-lasting insecticidal (mousquito) net intervention: coverage, durability and bioefficacy following a 2011 national distribution in Benin. Am J Trop Med Hyg, 2013. Inpress
5. Karch S, Garin B, Asidi N, Manzambi Z, Salaun JJ, Mouchet J. Moustiquaires impregnées contre le paludisme au Zaire. Ann. Soc. belge Méd. trop. [Internet]. 1993; 73:37-53. Availablefrom: http://lib.itg.be/open/ASBMT/1993/1993asbm0037.pdf
6. Nevill CG, Some ES, Mung'ala VO, Muterni W, New L, Marsh K, *et al*. Insecticide-treated bednets reduce mortality and severe morbidity from malaria among children on the Kenyan coast. Tropical Medicine & International Health [Internet] 2007; 1(2):139-46.Available from: http://doi.wiley.com/10.1111/j.13653156.1996.tb00019.x
7. Binka FN, Kubaje A, Adjuik M, Williams LA, Lengeler C, Maude GH, *et al*. Impact of permethrin impregnated bednets on child mortality in Kassena-Nankana district, Ghana: a randomized controlled trial. Tropical Medicine & International Health [Internet] 1996; 1(2):147–54. Availablefrom: http://doi.wiley.com/10.1111/j.1365-3156.1996.tb00020.x
8. Akogbeto M, Nahum A. Impact des moustiquaires imprégnées de deltaméthrine sur la transmission du paludisme dans un milieu côtier lagunaire, Bénin. Bull Soc PatholExot. 1996; 89:291-8.
9. Contrôle de qualité des moustiquaires imprégnées commercialisées ou distribuées au Bénin Mémoire de l'Ecole des Hautes Etudes en *Santé Publique*, 2010, 109.
10. Plan de développement Communal de Kandi, Rayonnement du carrefour de services iso 14001 du nord bénin, 2011-2015, 22.
11. Plan de développement Communal de Malanville Rayonnement du carrefour de services iso 14001 du nord bénin, 2011-2015, 25.
12. Monographie de Dangbo, AFRIQUE CONSEIL, Avril 2006 Lazare A. AKOMAGNI, 38.
13. Plan de développement Communal de Kessounou, Rayonnement du carrefour de services iso 14001 du nord bénin, 2011-2015, 24.
14. PNLP. Plan stratégique de lutte contre le paludisme au Bénin, 2006-2010. Disponible sur: http://www.rollbackmalaria.org/countryaction/nsp/benin.pdf [Consulté le 7 Avril 2014].
15. Gnanguenon V, R Azondekon, F Oke Agbo, A Sovi,y*et al*. Evidence of man-vector contact in torn long-lasting insecticide treated nets. BMC Public Health. 2013; 13:751.
16. PNLP. Evaluation post campagne de la distribution gratuite de MIILDs en, 2011.