Design of a Unified Scale for the Characterization of Seismic Activity

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Abstract:- Generally, the characterization of a seismic zone is based on the calculation of several parameters including, the b-value, the maximum magnitude, the seismic moment, the frequency of the earthquakes, the recurrence period, the energy released, etc. The objective pursued during this research is to find a way to bring together or group together all these parameters within a single quantity called "unified scale of characterization".

To do this, our work collected the seismic data of events in the DRC and surroundings with geographical coordinates of 10°E-35°E of longitude and 14°S-6°N of latitude, covering the period from 1910 to 2013. The unification of the parameters, passing through the notion of "seismic species" led to the design of the Unified Scale subdivided into two parts:

- **The first part consists of the scale linked to the assessment of the seismic hazard. It is noted $X_{123456789}$.**
- **The second part, noted $X_{(123)(456)}$, relates to the assessment of the vulnerability factor of the area; it is subdivided into two parts: $X_{(123)}$ and $X_{(456)}$. X is an environment-related deform factor. It indicates whether or not there is a volcano, nuclear power plant, lake (ocean), or a combination of these in the area.). the final vulnerability scale will be the product of $I_{(123)}$ and $X_{(456)}$: $X_{(123).(456)} = I_{(123)} .X_{(456)}$ to which a final numerical value will correspond for each zone. X and the indices create degeneration, because they can take the values according to the characteristics of the targeted parameters.**

The design of this scale offers several advantages for the characterization of a seismic zone; it allows in particular:

- **A better description of the seismic activity (and geodynamics) of an area over time, thanks to the invention of a device called an acti-seismometer,**
- **A better assessment of the seismic hazard and the vulnerability factor and, therefore, of the seismic risk,**
- **Better characterization** of the internal structure of an area (seismic tomography).

Used judiciously, this model would make it possible to characterize the seismic activity on our planet for better monitoring, with the possibility of its use for geological prospecting. An improved so-called "quantum" model will soon see the day when it will be a question of representing a seismic zone as an atom and the invention of the Periodic Table called "geo-seismic". We invite you to read our article entitled "application of the unified scale to characterize the seismic activity of the Democratic Republic of the Congo and its surroundings (Comparative study to the Africa, Indonesia and Pacific Coast zones of Central America)" (Mukange, 2021b).

Keywords:- *Unified Scale, Characterization, Seismic Species, Seismic Coordinates, Seismic Level, Modulus, Acti-Seismometer, RDC.*

I. INTRODUCTION

The seismic activity recorded here and there and the extent of the zones it affects reveal the need for its characterization with a view to assessing the seismic risk potentia (Dominique P., 1999) ; Hawell B., 1969). This assessment must be constantly and regularly updated with new data and translated into a seismic zoning map.

In view of the above, our objective is therefore firstly to develop a model which systematically and uniquely characterizes the seismicity of an area through the development of a scale including various seismic parameters (Zana, 1977; Mavonga, 2009). This scale must be able to assign a unique value to each zone, reflecting its seismic activity. Then we need to find a way to use this scale for monitoring seismic activity in a specific area. The various parameters that make up this scale were essentially calculated using the classical approach. In addition, it will be necessary to develop a scale in view of the seismic risk; this requires the design of a vulnerability factor assessment scale, including the environmental parameters and the infrastructure and structure of the region, without forgetting the density of the population.

II. DATA AND METHODS (SCALE DESIGN)

2.1. Calculated methods and parameters

Data are collected through various sources (www.usgs.org and www.isc.ac.uk) which contain the basic parameters (Table 1.1)

Table 1.1: Fundamental parameters of a seismic focus

Year	Moth	Day	Hour	Minute	Second	Latitude	Longitude	Depth	magnitude	Type of magnitude
1995	1	5	22	46	34,8	1,45	30,744	155,5	3,8	mbGS
1996	1	5	16	14	48,5	0,011	32,536	115,3	3,8	mbGS
1999	10	11	5	22	47,9	-8,619	32,761	113,5	3,8	mbGS
2000	3	25	1	24	12,6	-9,001	33,5	179,6	3,8	mbGS

The characteristics of the seismicity are deduced from the statistical analysis of the classical parameters evaluated for each zone and sub-zone and for a given period. Although universal in nature, the scale design process is inspired by data from the Democratic Republic of Congo (DRC), (Mukange, 2016).

In each of these areas, as it is also valid for so many other areas, we calculate the following parameters (Mukange, 2021 ; Lay T., 1995;Gacôgne et al.,1990 ;Carlierc C. et Al.,2007 ;Boleau N.,1986)).:

- m_{bo}: maximum magnitude observed in the area concerned,
- $m_{bc}1$: maximum magnitude calculated on the basis of the b-value (m_b-logN),
- logMoc: logarithm of the calculated characteristic seismic moment, Moc,
- logMo: logarithm of the maximum seismic moment observed in the Mo zone,
- b: the b-value obtained on the basis of (log N- m_b) in figure (2.15), (Aki K. et al.,1980),
- $\lambda_{b\text{-value}}$ obtained on the basis of the exponential line (Figure 2.16),
- c: the c-value calculated on the basis of logMo-m_b,
- Ix: the intercept of the least squares line (N (%) - m_b) on the x-axis,
- NT: total number (N) of earthquakes recorded in the area,
- The seismic energy released,
- f: frequency of earthquakes; this is the number of earthquakes recorded for a given period,
- T: the recurrence period, inverse of the frequency,
- A: the area of the study area, in degrees squared,
- D: the frequency density; frequency per unit area of the area,
- A.S.A: the annual seismic activity.

For a better comparison, we prefer to convert the cumulative number of earthquakes per magnitude range as a percentage of the total number of earthquakes recorded in an area. The exponential curve of figure (1.1) obtained from (mb-% Number of earthquakes) leads to a constant called λb-value that we can relate to the b-value. Likewise, the regression line intersects the x-axis at a point called the intercept Ix which we can also relate to the maximum calculated magnitude obtained from the b-value.

In our case, $\lambda_b = 2.28$ and $Ix = 137.1 / 20.99 = 6.532$ **(1.1)**

Starting from figure (1.1), we define the parameters λb-value and the intercept Ix as expressed by relations (1.2) and (1.3):

$$Y = N_0 \, Exp(-\lambda_b . x) \qquad (1.2)$$

In our case, $\lambda_b = 2.28$

And,

$$Y = ax+b \text{ and } Ix = -b/a \qquad (1.3)$$

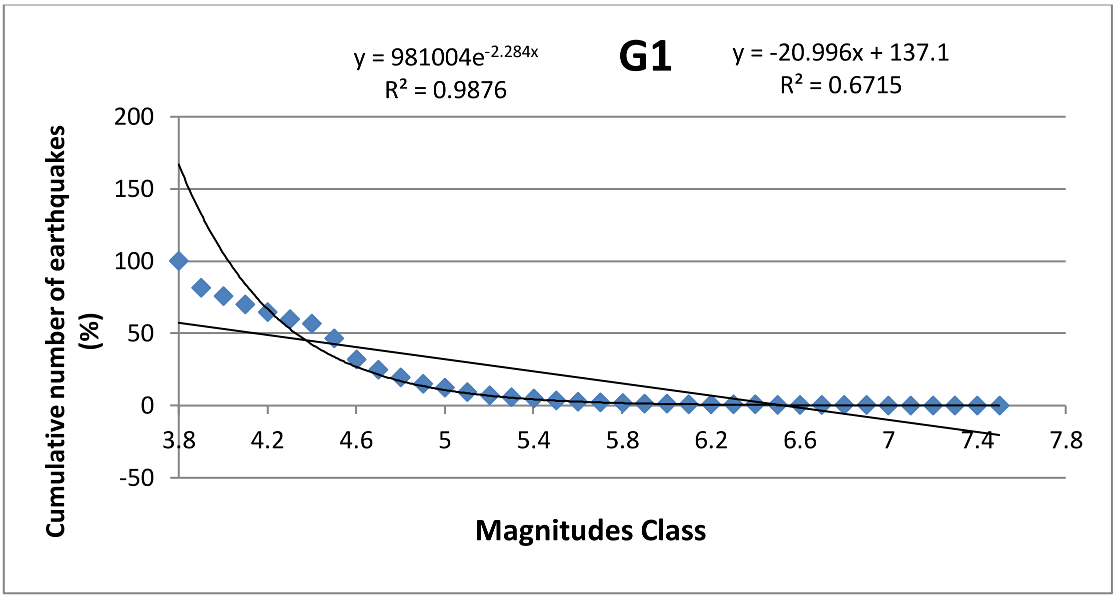


Fig.1.1: Earthquake statistics in the DRC, deduction of the $\lambda_{\text{b-value}}$ parameters and intercept.

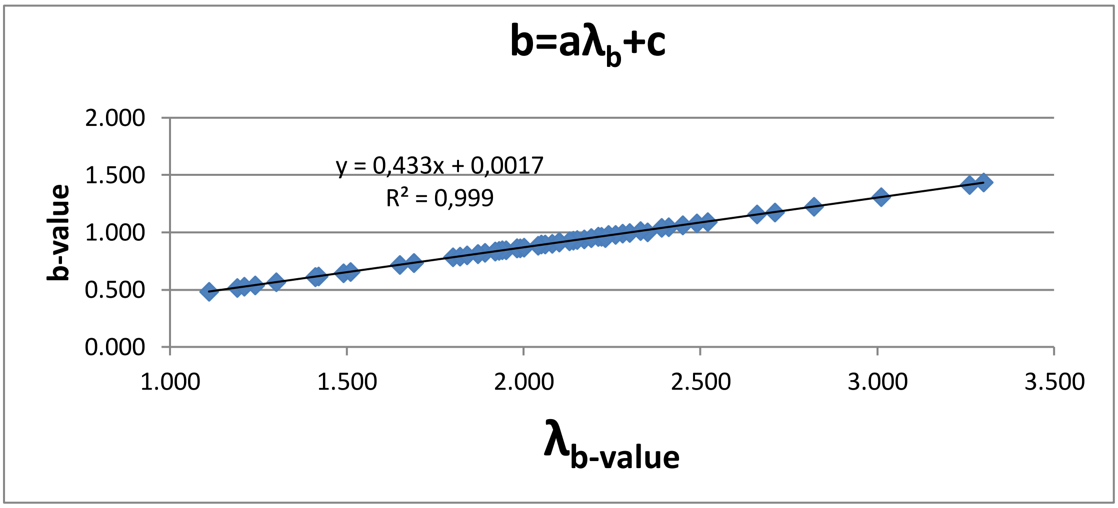


Fig. 1.2: Linear relation between the λb-value and the b-value for the whole DRC.

In DRC, b-value is related to λb-value by the relation:

$$b = 0.433 \quad \lambda_b \quad + \quad 0.001 \qquad (1.4a)$$

The study we have just extended to other areas of the globe, notably the Pacific-North side of the American continent and Indonesia, shows that this relationship is almost identical and therefore universal; she wants :

$$\lambda_{\text{b-value}} \approx 2{,}304 \quad b \qquad (1.4b)$$

This is therefore a new parameter that has just emerged in seismology.

2.2. Design of the characterization scale

2.2.1. Introduction

Seismic risk being defined as the combination between the hazard on the one hand, and the vulnerability of the issues exposed on the other hand, its assessment requires studying not only the probability of facing an earthquake of a certain magnitude at a given location (hazard assessment), but also to take into account potentially exposed elements and assess how they would behave in the event of an earthquake (assessment of the vulnerability of buildings to earthquakes in particular).

The main goal pursued in this section is to define our characterization scale, in particular by explaining the process that led to its development. The calculation of the above-mentioned parameters, treated statistically and combined in a logical manner, will lead to the development of a single reasonable scale which makes it possible to better characterize the seismic activity of various zones across the globe, in particular, the 'development of seismic zoning maps(Dubois J. et al. 2011).

2.2.2. Ladder design

This scale has two sub-components: one relates to the assessment of the seismic hazard, called the seismic hazard scale; the other is to assess the vulnerability factor of the area, we call it the vulnerability factor scale **(Dominique P.,**

1999). Combined together, these two scales are likely to better assess the seismic risk in an area.

2.2.2.1. Seismic hazard scale design

The seismic hazard characterization scale consists of ten parameters classified in decreasing order of importance from left to right. This unified scale is written as follows:

$$X_{123456789} \qquad (2.1)$$

Where :

X is the "form factor" which can take the value O, I, II, III, IV or V, with:

- 0 if the zone is seismic,
- I if the maximum recorded magnitude is between $3,8 \leq m_b \leq 4,9$
- II if the maximum recorded magnitude is between $5 \leq m_b \leq 5,9$
- III if the maximum recorded magnitude is between $6 \leq m_b \leq 6,9$
- IV if the maximum recorded magnitude is between $7 \leq m_b \leq 7,9$
- V if the maximum recorded magnitude is between $8 \leq m_b \leq 8,9$

The subscript group of numbers (1; 2; 3; 4; 5; 6; 7; 8; 9) constitutes the "structure factor", defined as follows:

- The number 1 is relative to the percentage of the seismic energy released by the zone compared to the whole: if the seismic energy released is ≥50%, then the number 1 takes the index b, otherwise the index a ,

- The number 2 relates to the number or percentage of earthquakes of magnitude mb≥5 recorded in an area: if this percentage is ≥15%, then the number 1 becomes b, otherwise a,

- The number 3 refers to the frequency density parameter (D): if this parameter is ≥ 0.5, then it takes the index b, otherwise the index a,

- The number 4 refers to the annual seismic activity (A.S.A) of the area: if this activity is ≥ 50%, then the index 4 becomes b, otherwise a,

- The number 5 refers to the b-value (b): if it is ≥ 0.5, then it takes the index b, otherwise the index a,

- The number 6 relates to the λb-value: if the λb-value is ≥ 2, then it takes the index b, otherwise the index a,

- The number 7 refers to the c-value: if the c-value is ≥ 1.3, then it takes the index b, otherwise the index,

- The index 8 relates to the focal mechanism: the letter "a" corresponds to the normal fault, "b" to the reverse fault and "c" if the fault is stalled,

- The index 9 concerns the depth of the focal points: the letter "a" corresponds to surface earthquakes, "b" to earthquakes with intermediate focal points and "c" to earthquakes with deep focal points.

For a local study, especially in the case of the DRC, we drop these last two parameters because all the earthquakes that occur in the western branch are mainly characterized by normal faults and are generally superficial, that is to say depth not exceeding 60 km.

2.2.2.2. Design of the vulnerability scale

This unified scale is written as follows:

$X_{(123)(4567)}$,

where:

X is an environmentally related form factor. It indicates the presence or absence of a volcano, nuclear power plant, lake (or ocean), or a combination of these in the area(Muswema,2015 ; Zana,1977 ;Zana,1981,Zana,2010 ;

Wafula,1999 ;Wafula,2011). To do this, the form factor can take the following values:

- X takes the value or level I, in the absence of the three elements mentioned above, that is to say neither lake, nor volcano, nor nuclear power plant,
- X takes the value or level II if there is a lake,
- X takes the value or level III in the event of the presence of a volcano,
- X takes the value or level IV in the event of the presence of a nuclear power plant,
- X takes the value or level V in the presence of a lake and a volcano (V=II+III),
- X takes the value or level VI in the event of the presence of a lake and a nuclear power plant (VI=II+IV),
- X takes the value or level VII in the event of the presence of a volcano and a nuclear power plant (VII=III+IV),
- X takes the value or level VIII in the event of the presence of a lake, a volcano and a nuclear power station (VIII =II+III +IV),

The group of indices (1234567), called the structure factor, operates a degeneration on the form factor X. Thus, we have:

a) ***In the absence of all these three elements*** (neither lake, nor volcano, nor nuclear power plant), we have $\mathbf{I_{123}}$, where:

Index 1 relates to the population density in the region where the seismic risk is assessed, this index can take one of three letters "a", "b" or "c":

- "a", if the density, d, is less than 100 inhabitants / km2,
- "b", if 100 <d <500,
- "c", if d>500

Index 2 relates to the level of industrialization (infrastructure and structures) of the region where the seismic risk is assessed; this index can take one of the three letters "a", "b" or "c":
- "a", if the structures are mostly masonry,
- "b", if the structures are mainly made of reinforced concrete or wood,
- "c", if they are predominantly made of steel.

Index 3 relates to the management of the seismic risk (level of intervention, ability to treat the injured, emergency plan, level of seismic monitoring, etc.). This index can take the letter:
- "c", if the management (g) is low <40%,
- "b", if 40 <g <70%,
- "a", if g>70%

b) *If there is a lake or ocean, we have scale $II_{(123)(456)}$*

The first group of clues, (123), keeps the same meaning as before and in the rest of the work; it remains to give a meaning to the second group **(456), which gives the subscale $X_{(456)}$:**

Index 4 relates to the presence of harmful gas in the lake. He can take the letter:
- "a", in the absence of harmful gases or the presence of gas heading out of town,
- "b", yes, the gas exists, but not very harmful, towards the city,
- "c", if the gas is dangerously harmful heading towards the city.

Index 5 relates to the distance (d) lake-city, the direction of the wind, as well as the dimensions of the lake (water volume, V); thus, the clue takes the letter:
- "a", if 10^7 m^3, and V <500 km^2,
- "b", if 5 <d <10 km and 500 <V <800 km^3,
- "c", if d <5 km and V>800 km^3

Index 6 relates to the presence of faults in or around the lake. He takes :
- "a", if there are no faults,
- "b", presence of minor faults,
- "c", presence of major faults.

c) *Case of the presence of a volcano, scale $III_{(123)(456)}$*

The first group of clues, (123), keeps the same meaning as before and in the rest of the work; it remains to give a meaning to the second group (456):

Index 4 relates to the direction of the lava flow in relation to the city. We have :
- "a", if the flow is not in the direction of the city,
- "b", if the flow is partially heading towards the city,
- "c", if the flow is directly towards the city.

Index 5 relates to the speed of the flow, in terms of the time it will take to reach the city. We can therefore have:
- "a", if the time (t) is greater than ten hours, (t> 10h),
- "b", if 2 <t <10 h
- "c", if t <2h

Index 6 concerns the volume of the magma chamber or the quantity of lava that can reach the city. Thus, we can have the letter:
- "a", if the volume (V) is less than 107 m^3,
- "b", if 107 <V <2.107 m^3
- "c", if V> 2.107 m^3

d) *Case of the presence of a nuclear power plant, scale $IV_{(123)(456)}$*

In this case, the indices (456) look like this:

Index 4 relates to the usual wind direction and speed. We can therefore have:
- "a", direction out of town,
- "b", direction partially towards the city,
- "c", direction towards the city.

Index 5 refers to the speed of the wind, in terms of the time that irradiated nuclear particles can take to reach the city. We have :
- "a", if the time (t) is greater than 10 hours (t> 10h),
- "b", if 2 <t <10 h
- "c", if t <2h

Index 6 relates to the characteristics of the nuclear power plant, including power.

We can therefore have:
- "a", if the power is low,
- "b", if the power is medium,
- "c", if the power is high.

e) *Case of the presence of a lake (ocean) and a volcano, scale $V_{(123)(456)=II+III}$*

In this case, the indices (456) look like this:

Index 4 relates to the direction of the lava, the wind and the presence of harmful gases. So we have:
- "a", if the direction of the lava and the wind is outside the city or if the lake does not contain harmful gases,
- "b", if the direction of the lava is partially oriented towards the city and the lake contains not very toxic gases directed partially or not towards the city,
- "c", if the flow of lava and the wind driving the toxic gases are directed towards the city.

However, we can find intermediate cases; the researcher to assess his level.

Index 5 relates to the wind speed and the lava flow; can we have :
- "a" if the time (t) of the lava flow and / or the wind to reach the city is greater than ten hours,
- "b" if the time (t) of the lava flow or the wind taken to reach the city is such that if 2 <t <10 h,
- "c" if the time (t) of the lava flow and the wind taken to reach the city is less than two hours (t <2 h),

Index 6 relates to the volume of lava and the lake; the clue will be:

- "a", if the volume (V1) of the lavas and (V2) of the lake are respectively $V1 < 10^7 m^3$ and / or $V2 < 500 km^3$,
- "b", if $107 < V1 < 2.107 m^3$ and / or $500 < V2 < 800\ km^3$,
- "c", if $V1 > 2.107 m^3$ and / or $V2 > 800\ km^3$.

f) Case of the presence of a lake and a nuclear power plant and a lake, scale $VI_{(123)(456)=II+IV}$

In this case, the indices (456) appear as follows:

Index 4 refers to the direction of the wind carrying the particles generated by the power station and that of the harmful gases from the lake; thus, we have:

- "a", if all these two directions are directed outside the city,
- "b", if only the direction of the wind carrying harmful gas is towards the city and partially for that carrying the particles coming from the power station,
- "c", the reverse of "b",
- "d" if both directions point to the city.

Index 5 relates to the average wind speed in terms of the average city-central-lake-central distance; from where, we have:

- "a", if the average time taken by these winds to reach the city is greater than ten hours ($t > 10h$),
- "b", if $2 < t < 10$ h
- "c", if $t < 2h$

Index 6 concerns the characteristics of the power plant and the lake; can we have :

- "a", if the volume (V) of the lake is less than $500 km^3$ and the power of the plant is low,
- "b", if the volume of the lake, $500 < V < 800\ km^3$, with the presence of medium faults and an average power of the nuclear power plant,
- "c", if the volume of the lake, $500 < V < 800\ km^3$, with the presence of medium faults and a high power of the nuclear power plant
- "d", if the volume of the lake, $V > 800\ km^3$ with large faults and high power plant.

This situation reminds us of the disaster that occurred in Japan during the earthquake of March 11, 2011, which generated a Tsunami and the explosion of the Fukushima nuclear power plant. About 32 million people, or a quarter of the country's population, were affected by the radioactivity emitted by this accident.

g) Case of the presence of a nuclear power station and a volcano, scale $VII_{(123)(456)=III+IV}$

The indices (456) are presented as follows:

Index 4 looks at the directions of the lava and the wind in the lake in relation to the city; thus we will have:

- "a", if no direction goes towards the city,
- "b", if only the direction of the lava flow is towards the city is partially that of the wind from the lake,
- "c", the reverse of" b ",
- "d", if both directions go towards the city.

Index 5 assesses the average distance between the central volcano and the city; we'll have :

- "a", if the average time (t) city-central and volcano is greater than ten hours,
- "b", if $2 < t < 10$ h,
- "c", if $t < 2h$.

Index 6 relates to the characteristics of the volcano and the nuclear power plant; which can give:

- "a", if the volume (V) of the lava is $V < 107 m^3$ and a low power of the plant,
- "b", if the volume of lava $107 < V1 < 2.107 m^3$ and an average power of the plant,
- "c", if the volume of lava $107 < V1 < 2.107 m^3$ and a high power of the plant,
- "d", the volume of lava $V > 107 m^3$ and a high power of the nuclear power plant.

h) Case of the presence of a lake, a volcano and a nuclear power station, scale $VIII_{(123)(45678)=II+III+IV}$

The indices (45678) look like this:

Index 4 concerns the wind direction for the power plant and that of the lava flow. Can we have :

- "a", if no direction is directed towards the city,
- "b", if only the direction of the lava flow is oriented towards the city is partially that of the wind from the lake,
- "c", the reverse of "b",
- "d", if both directions go towards the city

Index 5 concerns the wind direction of the gas in the lake and that of the particles emitted by the power plant. Can we have :

- "a", if all these two directions are directed outside the city,
- "b", if only the direction of the wind causing harmful gas points towards the city and partially for that causing the particles coming from the power station,
- "c", the reverse of "b",
- "d" if both directions point to the city.

Index 6 concerns the average distance between the center-volcano-lake and the city. We'll have :

- "a", if the average time (t) city - central - lake - volcano is greater than ten hours,
- "b", if $2 < t < 10$ h,
- "c", if $t < 2h$.

Index 7 concerns the characteristics of the power plant and the lake; can we have :

- "a", if the volume (V) of the lake is less than $500 km^3$ and the power of the plant is low,
- "b", if the volume of the lake $500 < V < 800\ km^3$, with the presence of medium faults and an average power of the nuclear power plant,

- "c", if the volume of the lake 500 <V <800 km^3, with the presence of medium faults and a high power of the nuclear power plant
- "d", if the volume of Lake V> 800 km^3 with large faults and high power plant power.

Index 8 relates to the characteristics of the volcano and the nuclear power plant; which can give:

- "a", if the volume (V) of the lava is V <107m^3 and a low power of the plant,
- "b", if the volume of lava 10^7 <V1 <2.107m^3 and an average power of the plant,
- "c", if the volume of lava 10^7 <V1 <2.107m^3 and a high power of the plant,
- "d", the volume of lava V >107m^3 and a high power of the nuclear power plant.

Let's say that the final vulnerability scale will be the product of $\mathbf{I_{(123)}}$ and $\mathbf{X_{(4567)}}$ **:**

$\mathbf{X_{(123)(4567)} = I_{(123)}.X_{(4567)}}$, where X takes the value II, III, IV, V, VI, VII or VIII.

2.2.2. Seismic species

The combination of these various parameters affects a unified scale unique to each zone; we call it ***"seismic species"*** related to the seismic hazard (Table 2.1).

Note that we will have two categories of seismic species, one relative to the scale of hazard, the other to that of vulnerability. In what follows, we focus on the first category.

Strictly speaking, by **species** we mean **the structural factors** composed only of the indices (a, b or c) constituting the scale; but in the broad sense they include the **X form factor**.

AREAS	LIMITS OF AREAS STUDIED	MAXIMUM MAGNITUDE ACHIEVED (m_{bo}) AND CALCULED (m_{bc}),INTERCEPTED (I_x), Area(A)					ENERGY (E_T), NUMBER(N_T) DES EARTHQUAKES RELEASED		SEISMIC ACTIVITY(%), FREQUENCY(f), ,DENSITY(D)		CLASS (MAGNITUDE)								LADDER AND SEISMIC SPACE
											I: 4≤m_{bo}≤ 4,9		II: 5≤m_{bo} ≤5,9		III: 6≤m_{bo} ≤6,9		IV : 7≤m_{bo} ≤8		
	Longitude	$m_{bobservée}$	m_{bc1}	Log Mo	A	I_x	N_T	E_T	Ann.	f	N	T(an)	N	T	N	T	N	T	Level zoning in Arabic numerals
	Latitude	Log Moc	B	c	λ_b		Rate (%)	Rate (%)	Moth.	D	Rate (%)		Rate (%)		Rate (%)		Rate (%)		
G2 P.EASTEN	25°E-31,3°E	6,9	6,8	26,3	42	6,153	594	312 E+20	98%	9,9	514	0,12	72	0,83	5	20,8	0	-	**IIIabababb** **25**
	0,7°S-6°N	26,22	0,981	1,31	2,26		17%	3,4%		0,24	**87**		**12**		**1**	**1,31**	0		
G3 P .KIVU	25°E-31,3°E	6,5	6,8	25,8	27	6,00	678	130 E+20	98%	11,3	600	0,1	70	0,86	7	14,9	0	-	**IIIaaabbbb** **14**
	0,7°S-6°N	26,482	1,023	0,86	2,35		19%	1,4%		0,42	**88,6**	**27**	**10,3**		**1**	**1,34**	0	-	
G4 P.KATAN	22°E-31,3°E	7,5	7,3	26,5	83	6,523	884	636 E+21	98%	14,73	786	0,08	81	0,74	9	11,6	2	52	**IVbaabaaa** **43**
	5,1°E-14°S	26,833	0,861	1,25	1,98		25%	70%		0,18	**89,5**		**9,2**		**1**		0,23		
G5 P.KASAI	20°E-25°E	6,1	6,1	25,3	32	5,628	73	43 E+19	50%	1,22	68	0,9	3	20	2	52	0	-	**IIIaaabab-** **11**
	0,7°S-7°S		0,903	-	2,08		2,1%	0,05%		0,04	**93**	**32**	**4**		**3**		0	-	
G6 P.BDD-BC	12°E-20°E	0	0	0			0	0	0%	0	0		0		0		0		**0**
	0,7°S-7°S	0					0%	0%		0	**0**		**0**		**0**		0		
G7 **EQT**	17°E-25°E	5,9	6,6	24,7	42	5,83	41	238 E+18	22%	0,68	28	2,1	12	5	0	-	0	-	**IIabaaaab** **7**
	0,7°S-6°N	24,725	0,617	2,02	1,42		1,2%	0,03%		0,02	70		30		0		0	-	
G13 SOUTH	10°E-35°E	7,5	7,5		300	6,513	2321	784 E+21	100%	38,68	2097	0,03	184	0,33	27	3,9	4	26	**IVbbabab-** **51**
	2°S-6°N		0,931	2,20	2,14		66%	86%		0,13	**87,9**		**10,4**		**3**		0,4		
G14 North	10°E-35°E	7,1	7,4		200	6,310	1205	123 E+21	100%	20,1	1024	0,06	149	0,4	24	4,3	1	104	**IVaaabbab** **34**
	2°S-6°N		0,916	2,5	2,10		34%	14%		0,1	91		6,5		2,1		0,1		
G30 VICTORIA	31,5°E-36°E	7,1	7,3		23	6,27	1125	107 E+21	97%	18,8	1029	0,06	73	0,8	22	4,73	1	104	**IVaabbab38**
	5°S-10°S		0,896		2,06		32%	12%		0,82	91,5		6,5		2		0,1		

Table 2.1. : Seismic parameters calculated and observed for the DRC Zones- Provinces: seismic species of the hazard and characterization scale.

2.2.3. Assignment of the seismic level

This is the seismic level linked to the species generated by the scale of the seismic hazard as well as by those due to the vulnerability factor.

2.2.3.1. Assessment of the level of seismic hazard

Let us classify the species obtained for each zone in ascending order and assign a corresponding number to y, according to the order of arrival (Table 2.2). This figure constitutes the seismic level corresponding to each zone; the value of the figure therefore reflects the degree of aggressiveness of a seismic zone compared to others.

Table 2.2. : Species retained not duplicated and corresponding seismic zoning level (Mukange, 2016)

Species	Seismic Level	Species	Seismic Level	Species	Seismic Level	Species	Seismic Level
IIaaaaab	1	IIIaaabbbb	12	IIIabbbbba	21	Ivababaa	31
IIaaaabb	2	IIIaabaaa	13	IIIbbaaaa	22	Ivbaaaaa	32
IIaaabbb	3	IIIaabbaa	14	IIIbbabab	23	Ivbaabaa	33
IIaabaab	4	IIIaabbaaa	14	IIIbbbaaa	24	Ivbaabaaa	33
IIaabbbb	5	IIIaabbab	15	IIIbbbbab	25	Ivbaabab	34
IIabaaaa	6	IIIaabbbb	16	Ivaaaaaa	26	Ivbaababa	34
IIabaaaab	6	IIIabaaaa	17	Ivaaabaa	27	Ivbaababb	35
IIabaaab	7	IIIabaaaab	17	Ivaaabab	28	IVbaababb	35
IIabbaaa	8	IIIababaa	18	Ivaaabab	29	Ivbabbaa	36
IIIaaaaaa	9	IIIabababaa	18	Ivaaabab	29	Ivbabbaaa	36
IIIaaabab	10	IIIababab	19	Ivaaababb	29	Ivbabbaab	36
IIIaaababb	10	IIIabababb	19	Ivaabbab	30	Ivbbabab	37
IIIaaabbba	11	IIIabbbaa	20	Ivaabbaba	30	Ivbbababa	37

Is it not true that areas with the same seismic species can have the same geological characteristics and thus consider that this scale can be used for geological prospecting?

It is therefore appropriate to carry out research aimed at finding all the world's seismic species and assigning them an appropriate level in a unique (universal) way. To do this, we must set the elementary area and the period covering the data in which the research is to be carried out.

2.2.3.2. Assessment of the level of the vulnerability factor and species

This unified scale is written as follows:

$\mathbf{X}_{(123)(4567)}$, where: X is an environmentally related form factor. It indicates the presence or absence of a volcano, nuclear power plant, lake (or ocean), or a combination of these in the area. In our study X goes from I to VIII; the level (value) corresponding to each factor is' indicated in Table (2.3).

Table 2.3. : Form factor and corresponding level

Form factor (X)	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Level (value) assigned (A)	**1**	**4**	**7**	**10**	**13**	**16**	**19**	**22**

As for the structure factor, the groups of indices **(123)** and **(456),** can be combined as indicated in Table (2.4). Each combination corresponds to a number assigned in ascending order of species.

Table 2.4.a : Structure factor (X = I) and corresponding level.

Structure factor (123) for I = 1	**Level (value) Assigned, N**	**Structure factor (123)**	**Level (value) Assigned, N**	**Structure factor (123)**	**Level (value) Assigned, N**	**Final level of vulnerability NT = I + t, example:**
aaa	**0**	**baa**	**1,0**	**caa**	**2,0**	**Iaaa=1+1,1 =2,1**
aab	**0,1**	**bab**	**1,1**	**cab**	**2,1**	**Icba=1+3,1 =4,1**
aac	**0,2**	**bac**	**1,2**	**cac**	**2,2**	**Ibac=1+2,2=3,2**
aba	**0,3**	**bba**	**1,3**	**cba**	**2,3**	**Iccc=1+3,8=4,8**
abb	**0,4**	**bbb**	**1,4**	**cbb**	**2,4**	**Ibbb=1+2,4 =3,4**
abc	**0,5**	**bbc**	**1,5**	**cbc**	**2,5**	**Iabc=1+1,5 =2,5**
aca	**0,6**	**bca**	**1,6**	**cca**	**2,6**	**Icab=1+3,1 =4,1**
acb	**0,7**	**bcb**	**1,7**	**ccb**	**2,7**	**Icca=1+3,6=4,6**

acc	**0,8**	**bcc**	**1,8**	**ccc**	**2,8**	**Iaaa=1+1,0 =2,0**

Table 2.4.b : Structure factor (X = II, III,… ..VIII) and corresponding level.

Structure factor (456) for I = 1	**Level (value) Assigned, N**	**Structure factor (456)**	**Level (value) Assigned, N**	**Structure factor (456)**	**Level (value) Assigned, N**	**Final level of vulnerability NT = I + t, example:**
aaa	**0**	**baa**	**1,0**	**caa**	**2,0**	**IIaaa=4+0 =4,0**
aab	**0,1**	**bab**	**1,1**	**cab**	**2,1**	**IIccc=4+2, =6,8**
aac	**0,2**	**bac**	**1,2**	**cac**	**2,2**	**IIIbac=7+1, =8,2**
aba	**0,3**	**bba**	**1,3**	**cba**	**2,3**	**IIIccc=7+2, =9,8**
abb	**0,4**	**bbb**	**1,4**	**cbb**	**2,4**	**IVbbb=10+1,4=11,4**
abc	**0,5**	**bbc**	**1,5**	**cbc**	**2,5**	**Vabc=13+0,5=13,5**
aca	**0,6**	**bca**	**1,6**	**cca**	**2,6**	**VIcab=16+2, =18,1**
acb	**0,7**	**bcb**	**1,7**	**ccb**	**2,7**	**VIIcca=19+2,6=21,6**
acc	**0,8**	**bcc**	**1,8**	**ccc**	**2,8**	**VIIIccc=22+2, =24,8**

The final level (VT) of the Vulnerability factor will then be the product of the values taken from scale $\mathbf{I_{(123)}}$ of table (2.4.a), denoted V1, and of $\mathbf{X_{(456)}}$ of table (2.4.b), denoted V2; we can therefore write:

$$\mathbf{V_T = V1 * V2} \qquad \mathbf{(1)}$$

2.2.3.3. Seismic Risk Level Assessment

The total seismic risk (R_T) being the combination of the seismic hazard and the vulnerability factor, we evaluate it by making the product of the level of the seismic hazard (A) in table (2.2) by the total vulnerability factor (V_T) of relation(1):

$$\mathbf{R_T = A * V_T} \qquad \mathbf{(2)}$$

The values resulting from the relation (2) being of times very high, we estimate to convert them in logarithmic scale, noted R_{Tl}, such as:

$$R_{Tl} = 2log(R_T) \qquad \mathbf{(3)}$$

Hence, a scale consisting of six levels is developed with an appropriate color code:

- if $1 < R_{Tl}, \leq 2$, we have level 1, (N1),
- if $2 < R_{Tl}, \leq 3$, we have level 2, (N2),
- if $3 < R_{Tl}, \leq 4$, we have level 3, (N3),
- if $4 < R_{Tl}, \leq 5$, we have level 4, (N4),
- if $5 < R_{Tl}, \leq 6$, we have level 5, (N5),
- if $6 < R_{Tl}, \leq 7$, we have level 6, (N6).

III. DISCUSSION OF THE RESULTS

The discussion of the results focuses on the multiple advantages that this scale offers in characterizing the seismic activity of an area.

This ladder offers the following advantages:

3.1. Comparison of areas using the match rate

The characterization scale makes it possible to compare two or more zones by estimating the rate of resemblance: it suffices to compare the corresponding indices of these two zones. The comparison is best done by exploiting the notion of the Venn diagram.

Let be two zones i and j of seismic level $\mathbf{X_{1i2i3i4i5i6i7i}}$ and $\mathbf{X_{1j2j3j4j5j6j7j}}$ respectively; the evaluation of the similarity rate of these zones respects the following convention:

- if Xi = Xj, then the resemblance has a rate of 50%, if not zero.
- if 1i = 1j, then the resemblance has a rate of 10%, otherwise zero.
- if 2i = 2j, then the resemblance has a rate of 10%, otherwise zero.
- if 3i = 3j, then the resemblance has a rate of 10%, otherwise zero.
- if 4i = 4j, then the resemblance has a rate of 5%, otherwise zero.
- if 5i = 5j, then the resemblance has a rate of 5%, otherwise zero.
- if 6i = 6j, then the resemblance has a rate of 5%, otherwise zero.
- si7i = 7j, then the resemblance has a rate of 5%, otherwise zero.

For two identical zones, the sum of the parameter values must be 100%.

The use of the Venn diagram makes it possible to compare qualitatively and quantitatively two areas; it concerns the detailed characterization of the area. The resemblance consists in having the same threshold “a” or “b” for the respective indices (parameters) of two compared zones; if the indices are equal, then they are placed in the intersection of two sets, otherwise each index or parameter will be placed in the part of its set outside the intersection. The comparison of structures can be done in two ways: between the same zone, but at different times, or between two different zones, but for the same period (Fig.3.1). The value of the similarity rate is obtained by applying the conventions of the previous subsection.

Example:

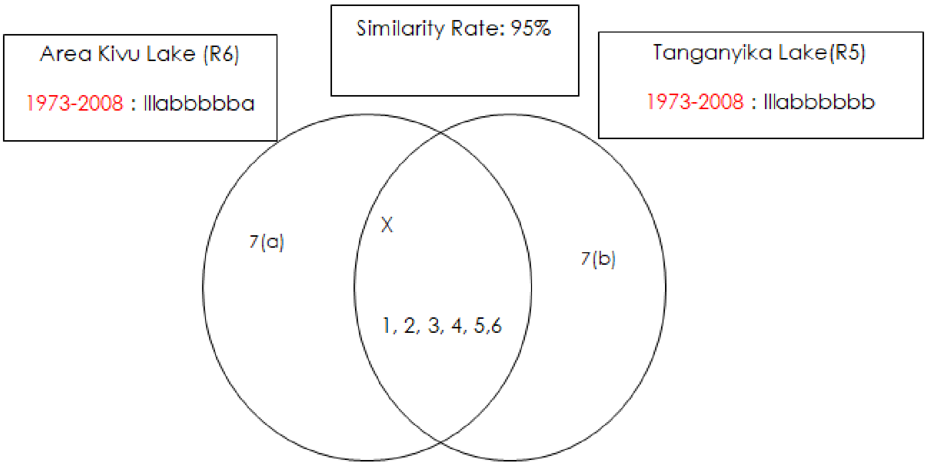


Fig. 3.1.a: Venn diagram between two zones, R5 and R6, from 1973 to 2008; 95% similarity rate.

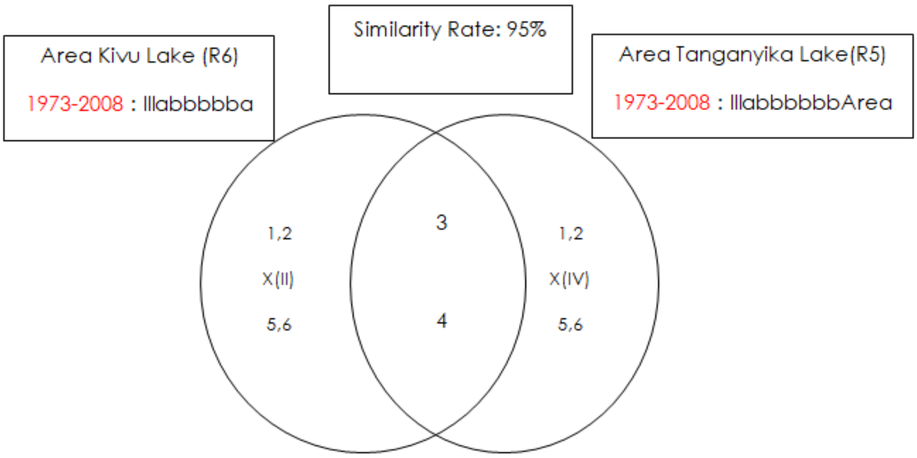


Fig. 3.1.b: Venn diagrams of two zones, R5 and R6, from 1910 to 2013.

3.3.3. Monitoring of seismic activity

The evolution of the level of the scale therefore allows us to follow the geodynamics of an area (Fig.3.2) by making a virtual device called acti-sismometer (Mukange,2021b).

The figure below compares most clearly the seismicity of the areas of the DRC for two periods, namely 1973-2008 and 1910-2013.

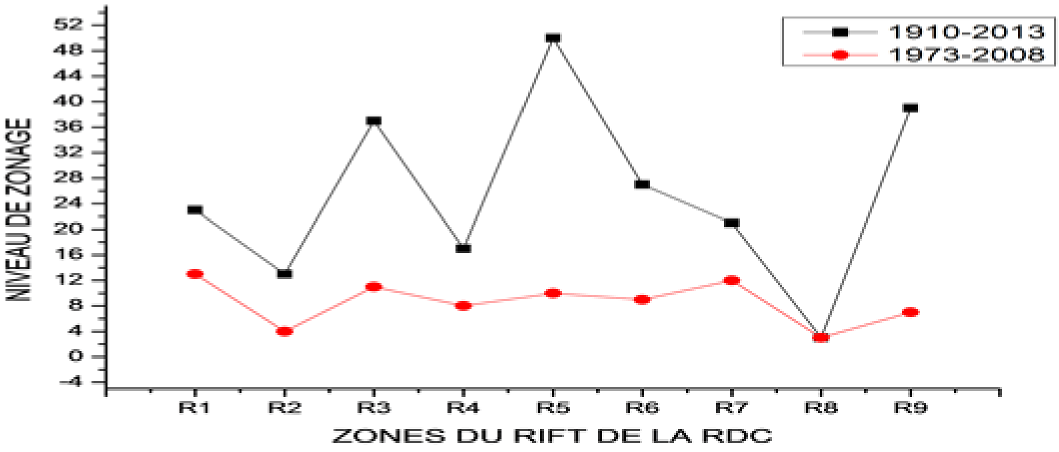


Fig. 3.2: Dynamics of the zoning level of the zones - Rift for two periods in legend

The variation of the seismic species of an area over time to follow its dynamics (Fig.3.3).

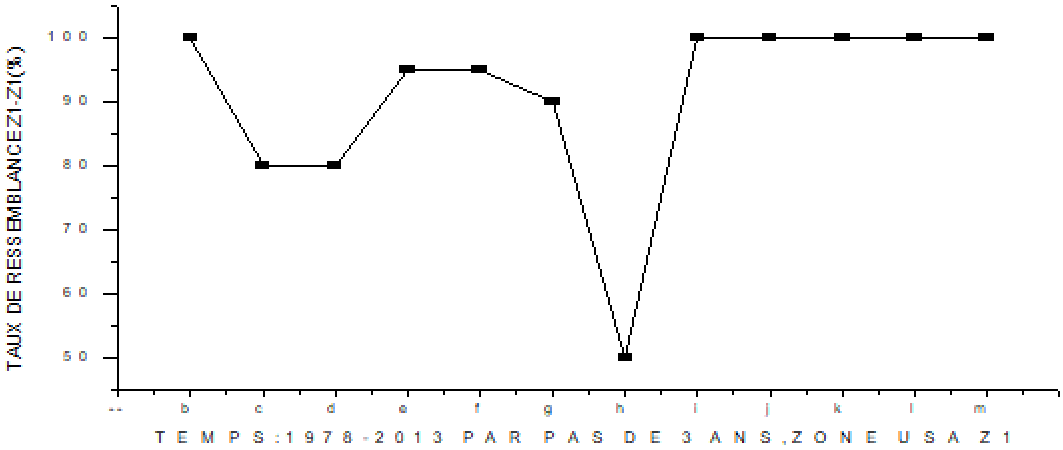


Fig.3.3. : Dynamics of seismic activity in the Pacific Coast-Central America area.

3.3.4. Analytical description of an area based on others

The scale also makes it possible to characterize a R_i zone as being a combination of the parameters of several other zones R_j partially identical to R_i. We assign in front of the R_j zone the partial resemblance rate a_j of R_j with respect to the R_i zone while indicating in parenthesis, after the resemblance parameters. The sum of all a_j is 100%; hence the writing:

$$R_i = \sum_{j=1}^{n} a_j R_j$$
(3.1)

By way of illustration, of the results of table (2.17), for the period 1910-2013, we write:

- 100(%) R4(X,1,2,3,4,5,6.7) = 75(%)R2(X,1,2.7)+25(%)R5(3,4,5,6)
- 100(%) R5(X,1,2,3,4,5,6,7)=75(%)R3(X,1,3.7)+10(%)R7(5.6)+15(%)R2(2.4)

3.3.5. Seismic risk assessment

Seismic risk being defined as the combination between the hazard on the one hand, and the vulnerability of the issues exposed on the other hand, its assessment requires studying not only the probability of facing an earthquake of a certain magnitude at a given location (hazard assessment), but also to take into account potentially exposed elements and assess how they would behave in the event of an earthquake (assessment of the vulnerability of buildings to earthquakes in particular).

Assessing the level of risk is therefore a difficult exercise, especially when looking at very large areas. Indeed, the evaluation of the seismic hazard requiring to take into account the local conditions which can in certain cases, called site effects, modify the magnitude of the earthquakes of the ground in a significant way, the characterization of these local effects is more or less precise depending on the influence of the study.

Determining the seismic risk therefore amounts to calculating the probability and the level of damage during a reference period and in a region considered.

The seismic risk chain **R** is the combination of the seismic hazard **A** at a given point and the vulnerability **V** of the issues.

The relationship therefore makes it possible to assess the seismic risk in time and space as clearly as possible (Mukange, 2021b)

3.3.6. Seismic zoning map, notions of Zone-Grids and seismic coordinates

This model opens a new avenue for the characterization of seismic zones. Indeed, the notion of Zone-Grid or Mesh comes from the technique which consists in subdividing a territory into five columns and four lines of width 5 ° each. The intersection of the column and row forms a square with side 5 °, called Zone-Grid or Mesh (Fig.3.4). Each column or row is characterized by its seismic species and therefore by its seismic level. Thus, each zone is between two seismic bands and identified by the symbol Aij, where the index i and j respectively indicate the number of the vertical and horizontal band to which the Grid-Zone belongs.

Therefore, a Grid Zone is composed of two seismic level values, one relating to the vertical band, the other to the horizontal band. These two values constitute the “seismic coordinates”. For example, the Zone-Grid A11 of figure (3.4) has for seismic coordinates (20,40).

The above representation introduces the notion of simplified seismic and geographic coordinates attributable to each zone. Indeed, let for example the zone A11 of geographical coordinates A11[(10°E-15 °E); (6°N-1°N)]; it is therefore a square with side 5 °, including:

- The lower left corner has for coordinates (10°E,1°N),
- The lower right corner has for coordinates (15°E,1°N),
- The upper left corner has coordinates (10°E,6°N), and
- The upper right corner has for coordinates (15°E,6°N).

We call simplified geographic coordinates the fact of representing the area by considering only the coordinates of the lower left corner, the others can easily be reconstituted by adding 5 ° to each coordinate to thus obtain a square of side 5°. In particular, the area A11 has for simplified geographical coordinates **A11(10°E,1°N).**

Let the Akl zone consist of "n" grid zones (Aij) with "k", the number of grid zones along the x-axis and "l" along the y-axis. The area Akl therefore has the area SAkl = n SAij. If Pmn represents the geographic coordinates of the lower-left corner of the Akl area, then the simplified coordinates of the entire study area Akl will be written: $A_{k,l}=[(P_{mn})]_{k,l}$; in the case of the DRC (Fig. 2.4), we will write:

$$\mathbf{A_{5.4} = A[(10°E,14°S)]_{5.4},} \quad \mathbf{(3.2)}$$

This writing is justified by the fact that this zone has five columns and four lines equivalent to five Grid-Zones on the abscissa and four Grid Zones on the y-axis. This means that, starting from 10°E, add five Grid Zones in steps of 5° going to the right on the x-axis and starting from 14°S, add four Grid Zones in steps of 5 ° also, but going up on the y-axis. Note that the 5° step, that is to say a square with side 5 °, has been taken as desired; the main thing is to take a square Grid Zone. We have therefore just introduced and explained the notion of simplified geographical coordinates of a Zone-Grid and of the entire zone made up of the latter. Therefore, the indices k and l, m and n respectively indicate the dimensions and the coordinates at the origin of the whole area (DRC).

Thus, with each Zone-Grid of simplified geographical coordinates, the seismic coordinates are associated or correspond. For example, for area A11, we can write as follows:

- A11(10°E,1°N) → A11(20,40)
- Or quite simply **A11[(10°E,1°N);(20,40)]**
-

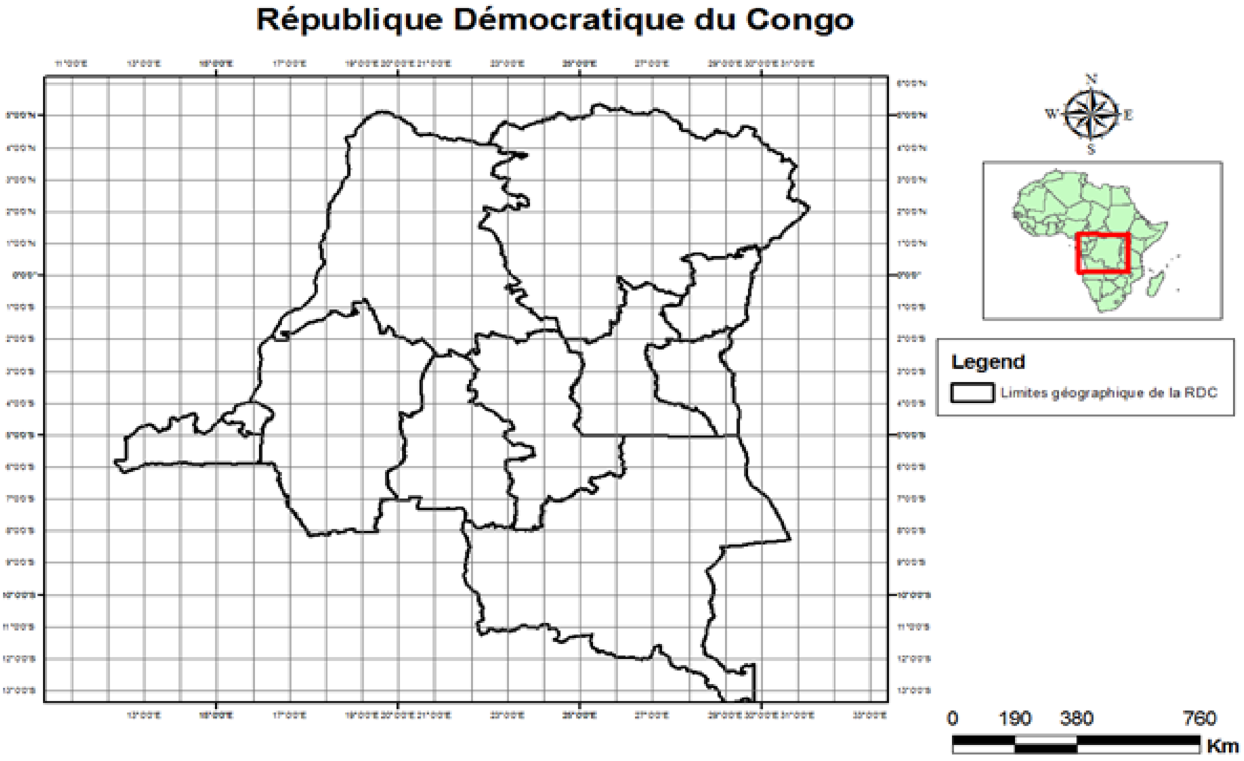


Fig. 3.4: Vertical and horizontal subdivision of the territory of the DRC and concept of Zone-Grids (A_{ij}).

The concept of the vector representation follows from the results obtained in figure (2.4). These results clearly show that each Zone-Grid can be written as a vector $\vec{a}$:

$$\vec{a} = a_x\vec{i} + a_y\vec{j} \quad \mathbf{(3.3)}$$

Where:

$\vec{a}$ Represents the Zone - Grid, Aij (a_x, a_y):

a_x , corresponds to the seismic level of the column (along longitude, that is to say going from West to East, better still along the X axis)

a_y , corresponds to the seismic level along the line (along the latitude going from North to South, therefore along the Y axis).

"a", represents the modulus which indicates the final seismic level of each Zone-Grid in Figure (3.4). The modulus "a", also called Seismic level, is obtained as follows:

$$\mathbf{a} = \sqrt[2]{a_x^2 + a_y^2} \quad \mathbf{(3.4)}$$

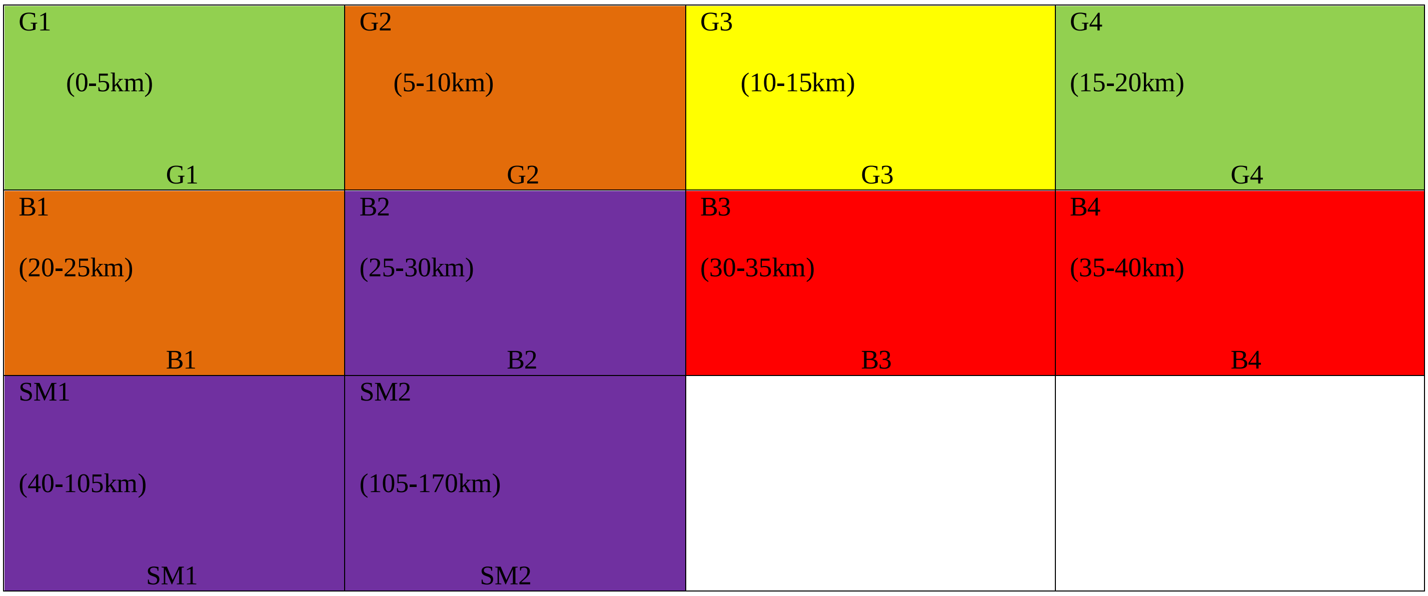
For example, the modulus of Zone A43(46,42) is worth:

$$a = \sqrt[2]{46^2 + 42^2} = 62$$

(3.5)

Zone A43(46,42) corresponds to Zone Tanganyika, the most seismic in the DRC.

Assigning a color to a Grid Zone according to its modulus allows obtaining the seismic hazard zoning map (Fig. 3.5, Table 3.1). This figure illustrates the dynamics of the internal structure of zone A43 as a function of depth; a kind of seismic tomography.



G1 (0-5km) G1	G2 (5-10km) G2	G3 (10-15km) G3	G4 (15-20km) G4
B1 (20-25km) B1	B2 (25-30km) B2	B3 (30-35km) B3	B4 (35-40km) B4
SM1 (40-105km) SM1	SM2 (105-170km) SM2		

Fig. 3.5: Gradient of the seismic activity of the A43 grid zone of the DRC:

G,B and SM to say, respectively, **G**ranitic, **B**asaltic and **U**nder the **M**antle layer.

Table 3.1: Color code relating to the seismic activity of zone A43.

Seismic hazard level	14-18	19-24	25-33	34-44	45-58	59-77
Color code	Purple	Blue	Green	Yellow	Orange	Red

3.7. Comparison of the seismic activities of two zones using an equation

In addition, starting from Figure (3.4) and calculating the modulus in each Grid Zone Aij, we obtain the evolution of the seismic activity of an area: each curve represents a line in Figure (3.4). So, for example, we will have the following equations connecting one curve (area) to the other:

$\boldsymbol{Y_{L3} - Y_{L1} = +2,5}$ **or** $\boldsymbol{Y_{L3} = Y_{L1} + 2,5}$ **(3.6)**

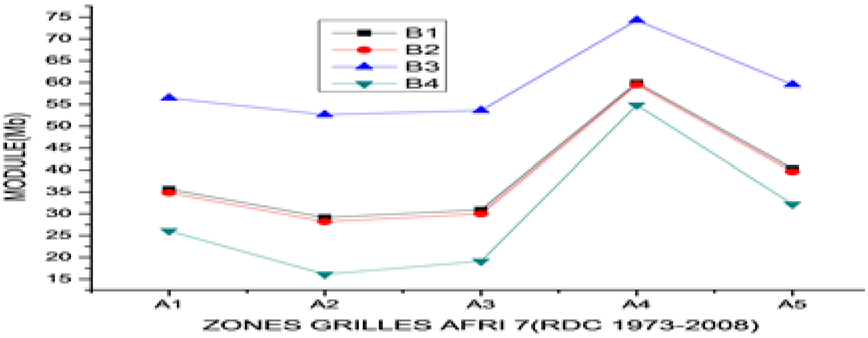


Fig. 2.5: Graphic characterization of the seismicity of the DRC from West to East (OX) and from North to South (OY)

Where Y_{L1} is the value of the zoning level read on the y-axis for the nth horizontal band (line); each horizontal band is symbolized in the legend by Ai1,…, Ai4.

The difference in zoning levels between the two curves, also called Shift, is clearly deduced on the y-axis.

IV. CONCLUSION

The study based on the "design of a unified scale for the characterization of the seismic activity of an area, the case of the DRC and its surroundings" allowed us:

- The highlighting of a new almost universal parameter, called $\boldsymbol{\lambda_{b-value}}$ related to b-value (b) by the relation: $\lambda_{b-value} \approx 2{,}304\, b$,
- The design of a Unified Scale for characterizing seismic activity; this scale is subdivided into two parts: one evaluates the seismic hazard, the other the seismic vulnerability. To do this, said ladder offers the following advantages :
  - The generation of a "seismic species" linked to the seismic activity of each of the zones unambiguously associates a corresponding quantified seismic level,
  - As the seismic level is dynamic, it is possible to describe the seismic activity (and the geodynamics) of an area over time, hence better monitoring of the seismic activity,
  - The generation of a color code assigning a color to each seismic level allows the establishment of seismic zoning maps with the possibility of leading to geological prospecting,
  - The introduction of the notion of "similarity rate" and of the Venn diagram offers, respectively, the opportunity to, quantitatively and qualitatively, compare one area to another,
  - The graphical representation, in the form of curves, of the seismic activity of an area allows the comparison of two areas using a linear mathematical equation,
  - Exploitation of the concepts of algebraic and similarity rate offers a way to write an area as a linear combination of other areas,
  - The flexibility and sensitivity observed during the design of the scale make it possible, on the one hand, to make a reasonable choice in setting the threshold values relating to the parameters constituting the scale and, on the other hand, make it possible to quickly detect anomalies relating to the collection or processing of data,
- The distinct design of the scale partly related to the hazard and the other to the vulnerability factor offers a better way to assess or estimate the seismic risk,
- The presentation of a seismic zone as being a vector allowed the introduction of a new vocabulary in our field: Zone-Grid (or Zone-Mesh), seismic coordinates, simplified geographic coordinates, seismic species $\boldsymbol{\lambda_{b-value}}$, resemblance rate, etc.

Used judiciously, this model would make it possible, unambiguously, to characterize the earthquake activity of the planet for better monitoring, with the possibility of its use for geological prospecting. An improved so-called “quantum” model will soon see the light of day.

For a better understanding of this article, we strongly invite the reader to read the forthcoming article relating to the application of this model to the characterization of the seismic activity of the Democratic Republic of Congo (DRC) as well as to other areas.

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