Mapping of Hazard of Slope Movement Application of the Municipality of Bensekrane, Algeria

F. Benzenine

Master Assisting, Civil Engineering Department, University of Sidi Bel Abbes, Algeria; EOLE Laboratory, University of Tlemcen, Algeria
failab@yahoo.fr

M. A. Allal

Professor, Civil Engineering Department, University of Tlemcen, Algeria

ABSTRACT

The cartography of the natural hazard became the firs step in the prevention of the risks of movements of slope. It is essential for the town planning and the territory development.After having reviewed the different methods evaluation of hazard of the movements of the slopes, we will realise the map of this hazard of the municipality of Bensekrane (wilaya of Tlemcen, Algeria).
At this first time, we shall expose the main families of movement of slopes as well as the factors, permanent and time-varying, which favor the release of these phenomena. Of course the determination of the hazard depends on the type of movement and on the factors which engender this instability. Afterward, we will present and describe the various valuation methods of the hazard of the movements of slope, which were or which can be introduced into the geotechnical file of town planning.
The main elements of this work is to propose a method personalized for the determination of the hazard, which makes the synthesis of the methods of Farès, Anbalagan and the calculation of stability.This step is apprehended with considerable initiative and risk-taking.
Finally, maps of hazard of the movements of slopes of the municipality of Bensekrane will be realized by the software FLAC, by the method of Farès and by the personalized method. In these maps, we made a zoning of the territory according to the intensity, to the gravity and to the probability of appearance of the dreaded movements of slope. So, to reduce the effects of the possible landslides and avoid their damage, it is imperative to consider these maps as soon as possible in the town planning and the territory development.

KEYWORDS: Mapping, hazard, movement of slope, town planning.

INTRODUCTION

Natural disasters are particularly frightening because they cannot be avoided. The most spectacular which affect directly the human beings are the floods, the volcanoes, the earthquakes and the movements of slope. They have a big repercussion on the environment, on the human lives, and the tangible assets. To reduce their effects; tools of prevention are set up such as the geotechnical files of town planning and zoning maps.

THE MOVEMENTS OF SLOPE

The movements of slope are the manifestation of gravitating displacement lots of the masses of ground destabilized under the effect of natural requests (snowmelt, abnormally strong pluviometry, earthquake, etc.) or human beings behavior (earthwork, vibration, deforestation, exploitation of materials and aquifer).

There is more than hundred years that the specialists have tried to define, to distinguish and to classify the movements of slope. There are numerous classifications due to the diversity of factors responsible for movements of slope, proposed by geologists, geotechnical engineers or mechanics.

There is a resemblance between some movements; some can evolve and give rise to another type of movement For this reason, it’s more coherent to work with the varieties of the movements of slope than J.C. FLAGEOLLET adopted, treating the descriptive aspect rather than the mechanical aspect (Figure 1).

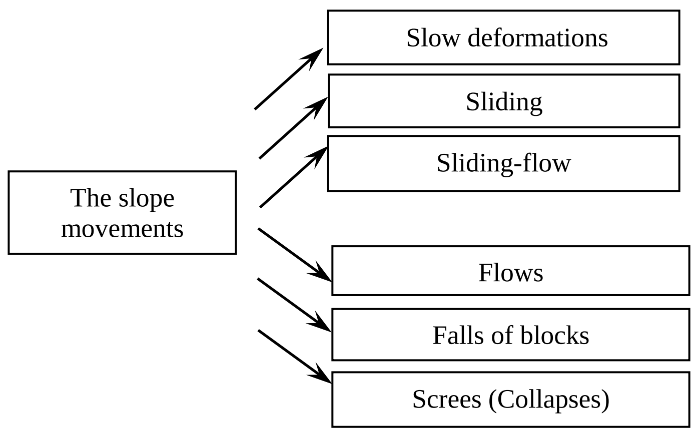

Figure 1: The main movements of slope.

FACTORS TRIGGERING

The movements of slopes are natural demonstrations of the evolution of the relief in action in the earth's surface since millions of years. The permanent factors (conditions of site) and time-varying (precipitation, temperature) favor the release of these phenomena (Table 1).

Table 1: Factors triggering.

AUTHORS	TRIGGERING FACTORS
CLRB Central Laboratory for Roads and Bridges	The gravity The water The morphology The vegetation The climate The earthquake and the volcanism
GUPTA & ANBALAGAN	The lithology The discontinuities The slope The relief The hydrogeology The vegetation
FARES	The lithology The morphology The climate The hydrology The vegetation The man's action

THE EVALUATION OF THE HAZARD

The valuation methods are qualitative or quantitative, direct or indirect. They concern the zoning of the hazard on descriptive terms are subjective; against by the quantitative methods give a numerical estimates (probabilities) for the occurrence of the phenomena in all the zone of hazard. The main methods are grouped as follows:

✓ **Approach and expert's judgment :**

Determine phenomena to be considered;
Estimate the degree of hazard;
Formulation factors selected writing.

✓ **Weighting of factors (Gubta and Ambalagan, on 1997):**

Factors taken into account with notation are:
The lithology (note max: 2,0);
The relation between the orientation of the discontinuities and the slope (note max: 2,0);
The value of the slope (note max: 2,0);
The relief, the local made uneven (note max: 1,0);
The degree of cover of the ground by the vegetation (note max: 2,0).
The degrees of the hazard are distributed as follows:

$S \leq 3,5$ very low hazard;
$3,5 \leq S \leq 5,0$ low hazard;
$5,0 \leq S \leq 6,0$ moderate hazard;
$6,0 \leq S \leq 7,5$ strong hazard;
$S \leq 7,5$ very strong hazard;

✓ **Statistical Study :**

We must follow the following steps:

Establish the degree of causality between every factor and every type of phenomenon;
Define the quantitative criterion to distinguish the stable zones and the unstable zones;
Estimate the hazard in the handled region.

✓ **Systematic Calculations of stability:**

Define the characteristics of slope;

Define the mechanical parameters;
Define the level of the groundwater;
Determine the chance from the safety factor.

✓ **Method of Farès (1994):**

They factors taken in account are :
The slope;
The geology;
The geomorphology.
The risk indices sont: Ip, IL, IG.
The evaluation of the hazard by the arithmetical method: Ip + HE(IT) + IG, the classes of the risk are:
[(3,4,5); (6,7,8); (9,10,11); (12,13,14)];
The evaluation of the hazard by the method probability: Pp ×PL × PG, the classes of the degrees of the risk is: [(0-10 %); (10-30 %); (30-50 %); (50-100 %)];

THE REALIZATION OF THE HAZARD MAP

The elaboration of the hazard map contains concretely two phases:

Analytical Phase: it is dedicated to the inventory and to the work of the information. The collection is made from the existing and archival documents, from the inquiries, from observations on the ground, aerial photos, etc.

Phase of interpretation and synthesis: on the same document, the information collected will be postponed, compared and correlated to obtain an estimated graduation hazard in the studied zone.

The steps are schematized in the following figure:

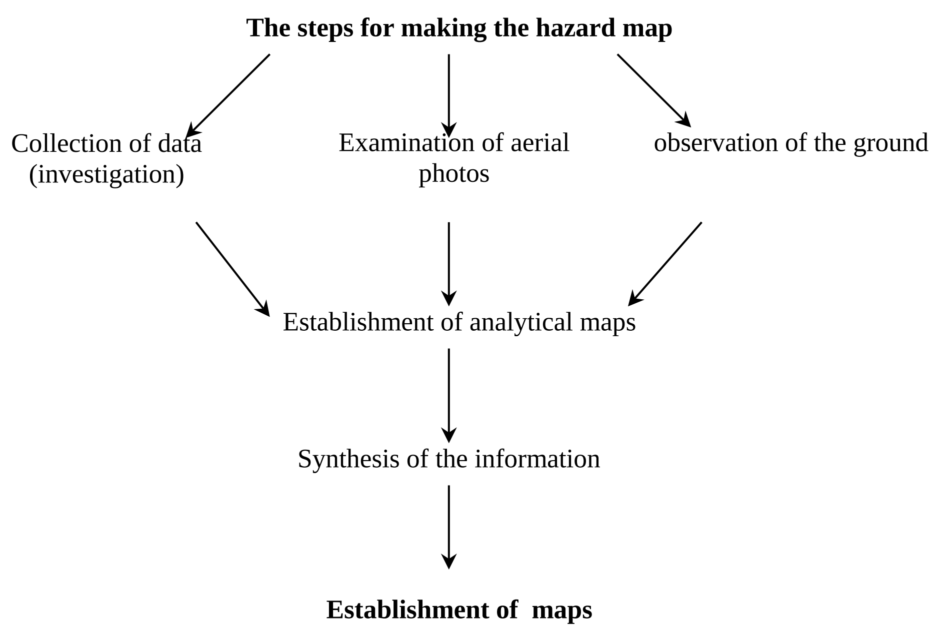

Figure 2: Establishment of the hazard maps.

OBJECTIVES OF THE CARTOGRAPHY OF THE HAZARD

The use of the mapping is frequent; the cause is very simple; the map replaces advantageously the literary mode to express the space perception and the data processing. It also plays a very important role at every level a study, as paper of work, search, information and decision. It is necessary that the author of the map determines his objective; two can be assigned to the mapping of hazard:

- ✓ **To Supply an information completes on the phenomen:** the map is of informative type, it spreads the information about the existence of the hazard. It should lead a behavior responsible for citizens and for decision-makers, who to protect itself from dangers, will avoid high-risk areas. This type of map is conceived to be readable by a general public; the French map ZERMOS was sold in bookshop.

- ✓ **Prepare the realization of a map of statutory type:** the statutory map imposes constraints to the inhabitants and to the candidates for the construction so as to reduce the risk. It is intended for the political authorities, but also for the concerned citizens. Contrary to the maps of hazard, scientific type, the statutory mappings suppose political choices. The plans of risk prevention (PRP) bound the zones in which regulations are imperative upon the new projects (Figure 3).

Synthesis of the steps of the mapping of the PRP

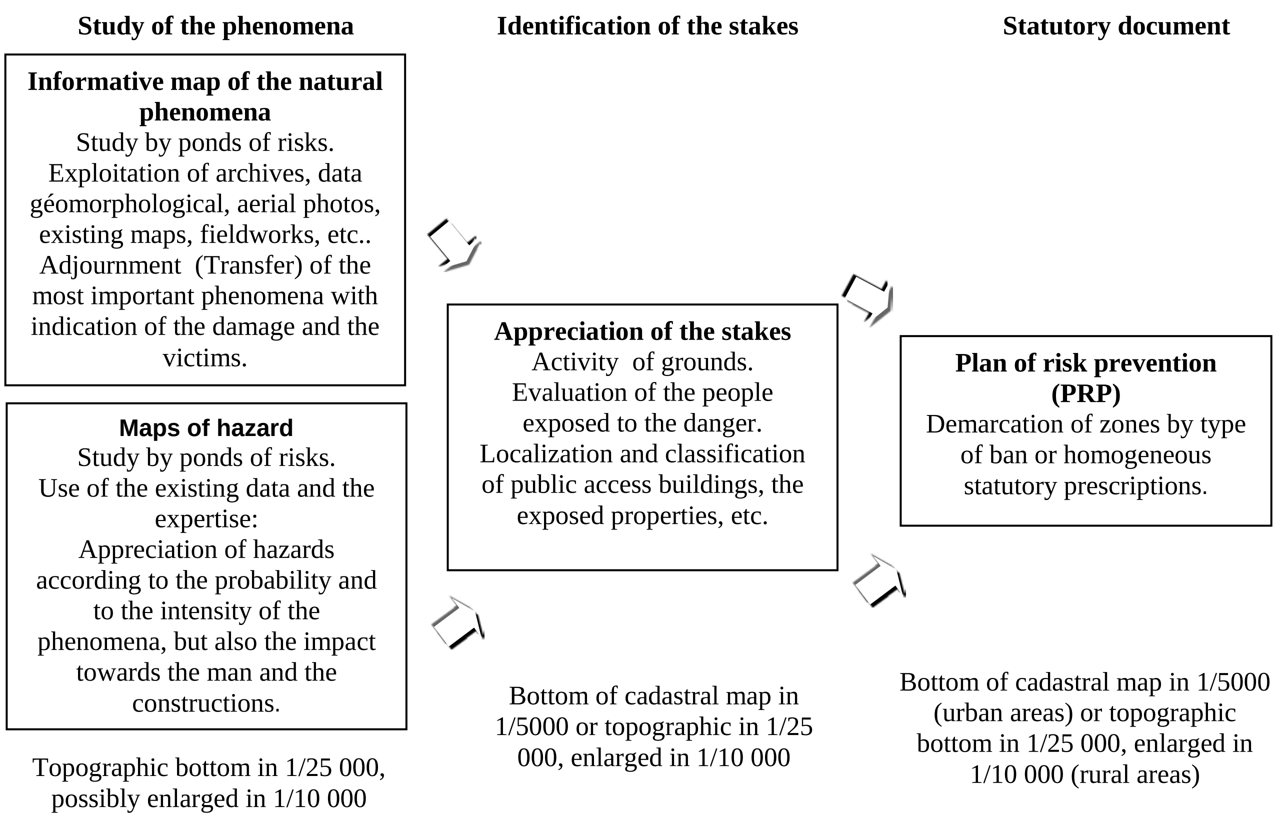

Figure 3: Diagram describing the approach of the Plans of forecasts of the risks (PRP), including the map of hazards and informative map which precedes it (map of report)
(According to a document of the Ministry of the Environment and the town and country planning)

PRESENTATION OF THE ZONE OF STUDY

The zone of study is the municipality of Bensekrane belonging to the wilaya of Tlemcen, situated at the edge of oued Isser, main tributary of Tafna. The municipality is characterized by a little raised but uneven ground (slopes varying from 0 to 30 %). It is hilly and sometimes even breakable with abrupt breaks in the neighborhood of the marble quarry (slopes between 30 and 35 %).

Concerning the geology, it is formed by a thick monotonous coat of stoneware and by clayey marls. We register a presence of travertine mixed by onyx.

From a hydrogeologic point of view the oued Isser is the main stream. On the other hand, it was listed by numerous sources on the territory of the municipality, essentially in the administrative center and at the level of Takbelat, their debits were very variable. At present, a groundwater is individualized in this zone, its piezométric surface is situated between 80m and 200m.

ESTABLISHMENT OF THE MAPS OF HAZARD

The maps of hazard are realized by using the software 2D FALC, the method of Farès and another method than we propose which is the synthesis of various methods.

Calculation of the safety factor by the 2D FLAC software

The FLAC software is a code of two-dimensional numeral calculation of the mechanics using the explicit method of the finished differences. It allows the use of several models which characterize the behavior of grounds. In our work, we used the model of MOHR-COULOMB which rests on the hypothesis of a break by plasticity. This model requires a number of parameters to characterize the ground; who are:

- ✓ The volume weight γh
- ✓ The angle of friction Φ;
- ✓ The cohesion c;
- ✓ The module of volume compressibility K;
- ✓ Shear modulus G.

We took the most unfavorable case for c and F (the most low) and? The highest volume weight γh , that of a talus of slope equal to 35 % (figure 4).

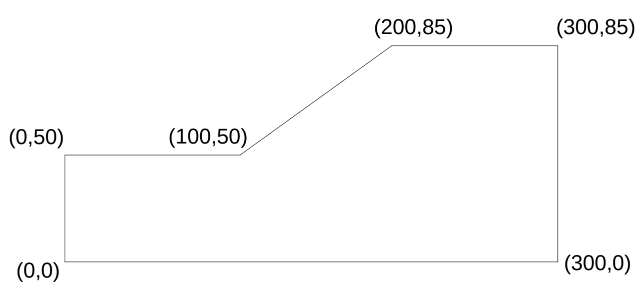

Figure 4: The modeling of the slope in the code of calculation FLAC 2D.
code FLAC calculation FLAC 2D.

The result is obtained in the form of safety factor which translates the chance following three degrees:

- ➢ $Fs \geq 1,5$ Low hazard ;

- 1 ≥Fs ≥ 1,5 Average hazard;
- 1 ≤ Fs High hazard.

The calculation gave a safety factor equal to 1,45. The map of the natural chance is represented by Figure 5.

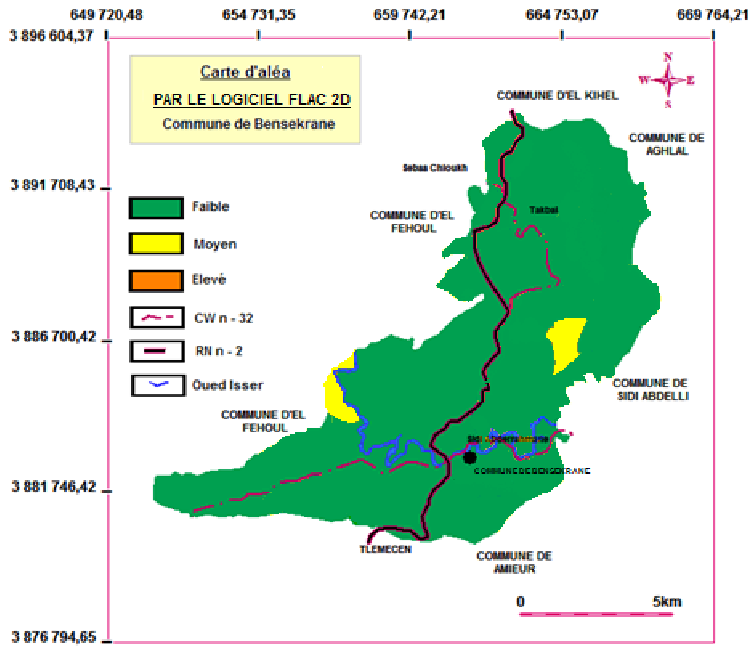

Figure 5: Map of natural hazard of the movements of slope by the software FLAC 2D.

By using the method of Farès

The methodology consists in mapping separately factors bound to the slope, to the lithologie and to the indications of instability. We attribute afterward for every factor an index (I) concerning the importance of the genesis of these instabilities. This allows us to translate the cards of factors into maps of simulation of the hazard. The combination of these cards by using the arithmetical and probability evaluation allows to realize two maps of hazard.

The map of factors bound to the present slope 6 classes, knowing the limit slope which equal to 70 %, the index of slope took the following values:

[0-10%]	Ip =1.
[10-15%]	Ip =1.
[15-20%]	Ip =1.
[20-25%]	Ip =1.
[25-30%]	Ip =1.
[30-35%]	Ip =1.

The lithology is an essential factor in the stability of hillsides. The distribution was made in the following way:

Clay marly	IL = 3.
Stoneware	IL = 2.
Travertine	IL = 1.

The Signs of instability were observed on the ground and classified :

Gully (soil erosion) II = 5

Strike slip II = 4
Soil creep II = 3
Leaning trees II = 2
Surface Erosion II = 1

The natural hazard is determined according to the arithmetical and probability evaluation. The first one consists in making the sum of the indications IP + IL + II, which gives a minimum of 3 and a maximum of 12.

These zones are reduced to four classes defined as follows:

Class 1 (3,4,5) : Low hazard, represented by the green color
Class 2 (6,7,8) : Average hazard, represented by the yellow color;
Class 3 (9,10) : High hazard, represented by the orange color;
Class 4 (11,12) : Very high hazard, represented by the red color.

The probability method consists in converting the indications in partial probability. The products of these PP × PL × PI × 100 estimate the hazard. The percentages are classified in four levels:

Level 1 [1-10%] : Low hazard, represented by the green color
Level 2 [10-30%] : Average hazard, represented by the yellow color;
Level 3 [30-50%] : High hazard, represented by the orange color;
Level 4 [50-100%] : Very high hazard, represented by the red color.

These classes and these intervals are afterward translated into map of natural hazard (figure 6 and 7).

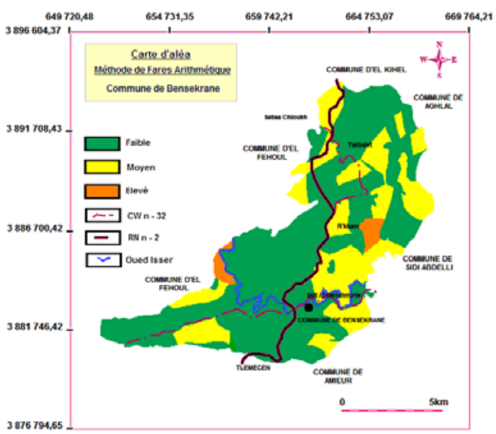

Figure 6: Natural hazard by the arithmetic method of FARES

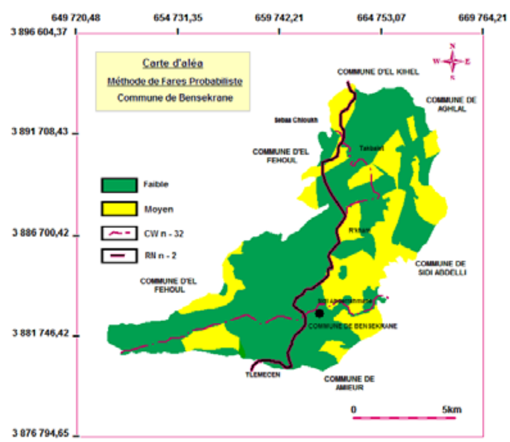

Figure 7: Natural hazard by the probabilistic method of FARES

By using the proposed method

This method takes into account other factors which we considered not insignificant It is about the effect of the groundwater, about the seismicity of the region and the vegetation cover. The cards of hazard were established by basing itself on the same logic as the method of Farès to be able to compare between them. The taken into account factors are the permanent factors: the slope, the lithology and the indications of instability and the dynamic or time-varying factors: the groundwater, the seismicity and the vegetation cover. We shall thus add three maps of simulation of the risk bound to the groundwater, to the seismicity and to the plant place setting. Those bound to the slope, to the lithology and to the indications of instability do not change.

Concerning the effect of the groundwater, if his depth is between:

0-25m In = 4
25-50m In = 3
50-75m In = 2
75-100m In = 1

In our case In is taken equal to 1 because the piezometric level of the groundwater is situated between 80m and 200m of depth.

By taking into account the new zoning of the Algerian earthquake-resistant regulation RPA 99 version 2003, Is was classed as follows:

Zone 0 Is = 1
Zone I Is = 2
Zone 2a Is = 3
Zone 2b Is = 4
Zone III Is = 5

Knowing that the municipality of Bensekrane is classified in the zone I, Is = 2.

The vegetation cover can contribute in the stability of slopes, it is a factor that should not be overlooked. Iv is determined by the vegetation of the area:

Very dense vegetation cover, forest vegetation Iv =1.
Medium dense vegetation cover, surface of moderate vegetation Iv = 2.
Low vegetation cover some plantations Iv = 3
Arid soil Iv = 4.

The natural hazard is determined according to the arithmetical and probability evaluation (figure 8). The first one consists in making the sum of the indications IP + IL + II + IN + Is + Iv which gives a minimum of 6 and a maximum of 25.

These zones are reduced to four classes defined as follows:

Class 1 (6,7,8,9,10) : Low hazard, represented by the green color
Class 2 (11,12,13,14,15) : Average hazard, represented by the yellow color;
Class 3 (16,17,18,19,20) : High hazard, represented by the orange color;
Class 4 (21,22,23,24,25) : Very high hazard, represented by the red color.

The conversion of the indications in partial probability by making the product:

PP × PL × PI × PN × Ps × Pv ×100 estimate the hazard. The percentages are classified in four levels:

Level 1 [0-0,5%] : Low hazard, represented by the green color
Level 2 [0,5-1,25%] :Average hazard, represented by the yellow color;
Level 3 [1,25-4%] : High hazard, represented by the orange color;
Level 4 [> 4%] : Very high hazard, represented by the red color.

These classes and these intervals are afterward translated into card of natural chance (figure 9 and 10)

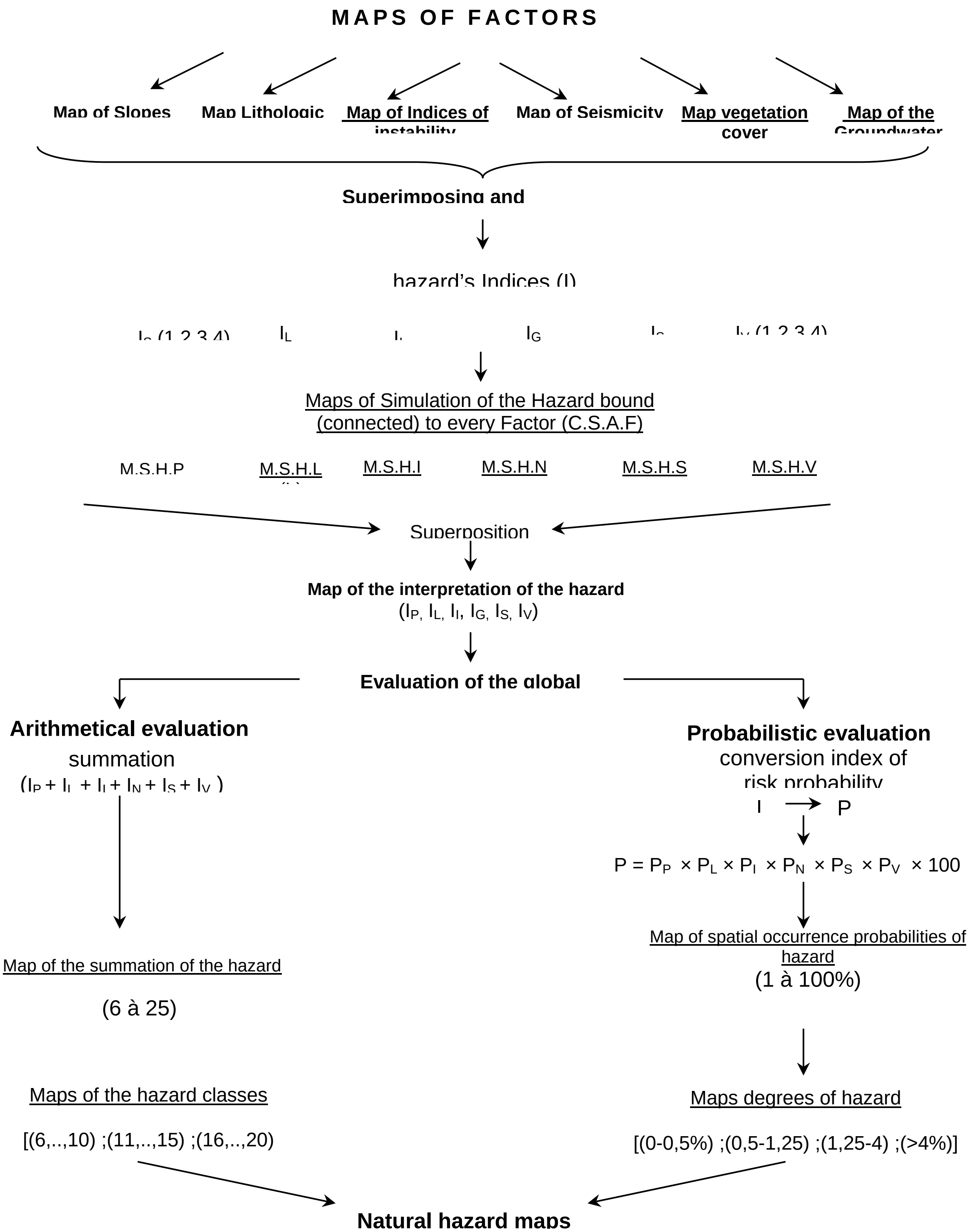

Figure 8: Schematic of the proposed method for mapping natural hazard of slope movement

COMPARISON BETWEEN THE METHODS

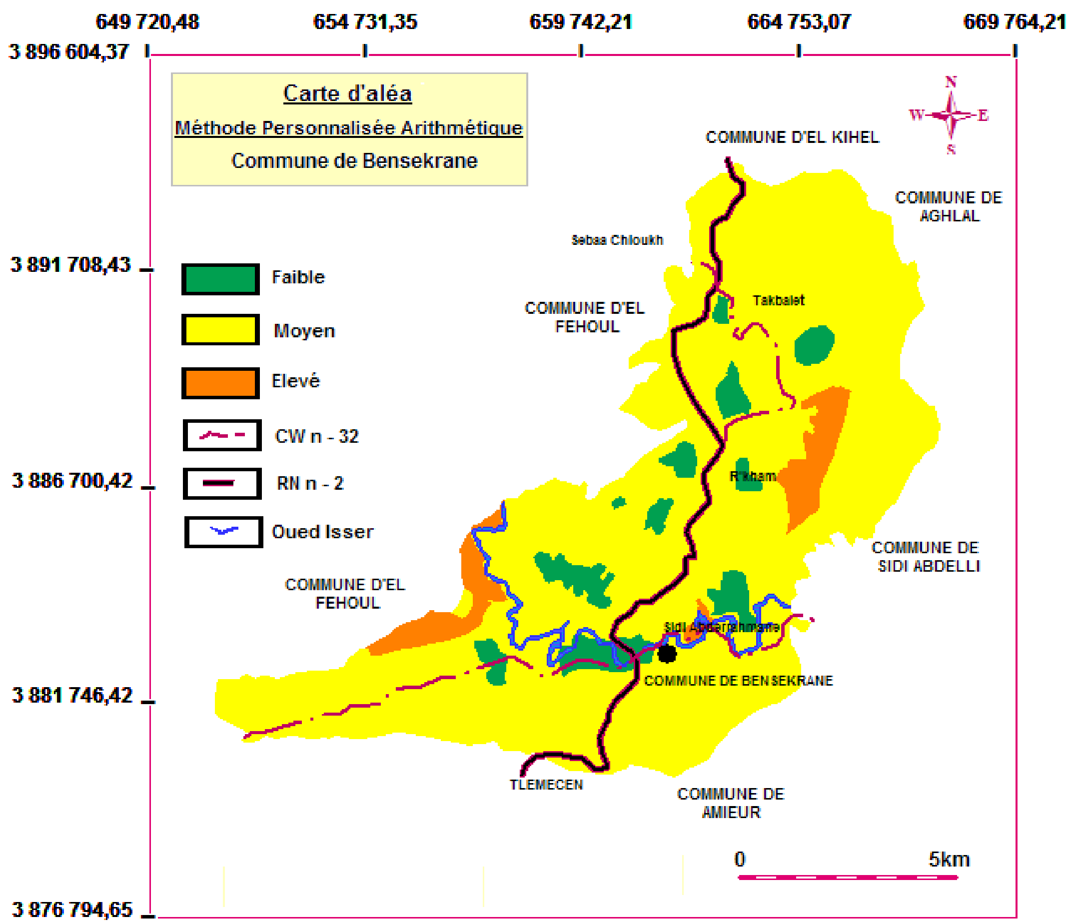

Figure 9: Natural hazard by the proposed *arithmetic* method

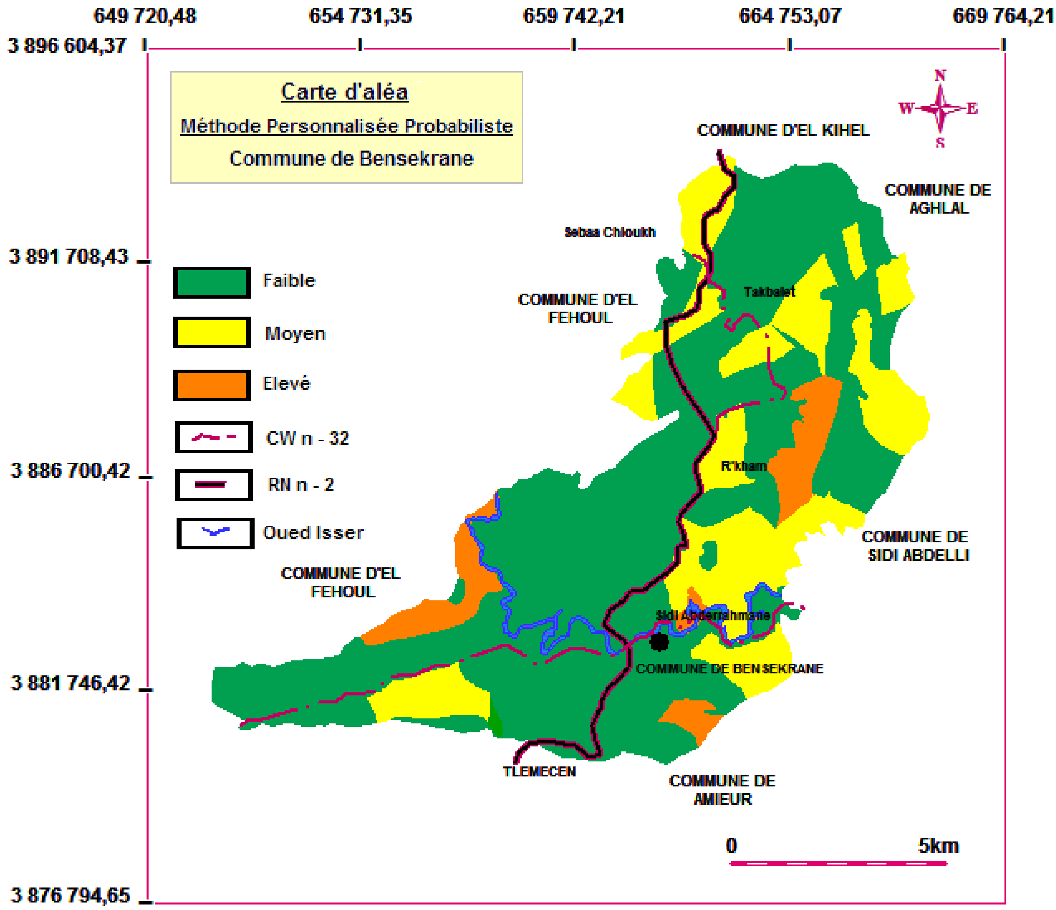

Figure 10: Natural hazard by the proposed *probablity* method

If we compare both maps of natural hazard by using the arithmetical method, we notice that the map realized with the proposed method is more pessimistic than that realized with the method of FARES. The addition of the dynamic factors had influenced the determination of the hazard; the effect of the groundwater has no big influence, because of its depth; on the other hand the vegetation cover and the seismicity of the zone influenced on the result. This sees itself very well on the map; zones in green are the ones which have a vegetation cover.

Arithmetic evaluation leads an accumulation of intensities of factors, thus leading to a pessimistic assessment. However, the interaction between the factors is possible in the probabilistic assessment. The probabilistic assessment of the hazard by the two methods yielded results almost similar, the difference is still due to added factors that will surely bring more to the level of reliability of the results.

The code of calculation FLAC gave a safety factor equal to 1,45; only the zones of slope varying between 30 and 35 % present an average hazard. The rest of the municipality presents a low hazard, the obtained result is more optimistic than two others. This is due to the absence of the determining factors; the software takes into account only characteristics of the ground and the slope. The card obtained by FLAC does not seem to us realistic. This is due to the fact that the analysis of the movements of slope cannot be arrested that under a purely mechanical angle with equations and laws of behavior. The movements of slope are complex phenomena with very diverse causes and would require in fact a systematic approach which would complete the analytical approach. HENRI CAMBEFORT is it not, who said advisedly, "the generalization of the circle of sliding, expensive to the mathematicians, is one of the most beautiful deceits of the mechanics of soil ".

CONCLUSION

(1) The reliability of these maps can be known only after 50 - 100 years. It is the appearance of the instabilities or not at the level of the site which allows us to say that the map is reliable or not. When we speak about the reliability we also speak about the used method.

(2) Three methods allowed us to realize five maps of hazard. His evaluation is very delicate; the master's degree and the choice of factors require a big experience. We cannot say that such or such map is reliable. Only the time can answer us, because the appearance or not instabilities at the level of the site allows to confirm the reliability of the map which depends on the used method. Having said that, the most delicate point is the appreciation, even summary, of deadline before failure, in other words of the level of probability of occurrence, which in fact modulates the degree of attributed hazard. This requires a quantitative surveillance of embankment at risk and the use, when it is possible, other methods.

(3) As regards our work, our method introduced new factors, this makes her more interesting; it is necessary to note that the addition of the seismic effect was made according to the zoning in Algeria. So, there are always things to be refined, to be added who will be the object of areas of later research.

(4) A large surface of the zone of study presents a low hazard to way that the urbanization and the extension can be envisaged without taking big protective measures. So the zone exposed to the high hazard can be urbanized but it is necessary to realize works of protection.

(5) The map of natural hazard has a projected character. It presents an essential utility, its purpose is to help the planners and the builders in their choices for security and town planning.

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