

Article

Classification of Risks for Landslides in Slopes and Hillside of Volcanic Nature in Macaronesia and Their Application to the Canary Islands

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Abstract: Due to their genesis, volcanic rocks present some singularities that make their geotechnical characteristics significantly different from other more common types of massifs, such as sedimentary and metamorphic rocks. The formation mechanisms of volcanic rocks are varied, rapid, and, in general, of high energy. These processes give this type of rock a geotechnical behaviour and geomechanical properties that are totally different from those of other nonvolcanic materials, derived from their high heterogeneity and anisotropy. There are voids and cavities due to the alternation of strata of different competences and resistances, or susceptibility to erosion, and discontinuities and joints of very different genesis (of thermal origin, by mechanical forces, by erosive processes or by shrinkage—recrystallization). The phenomenology of the instability of blocks and stones is variable, which makes it very difficult to establish simple and concrete methodologies or procedures to study and analyse this problem. To date, the estimation of the risk of this type of phenomenon has been quantified using empirical methodologies; this approach is considered to be the most operative in responding to such a complex phenomenology in which a multitude of factors intervene. In the field of roads, the most widely used methods are RHRS and RHRON. Therefore, a new rockfall risk classification based on the RHRS (Rockfall Hazard Rating System) methodology is proposed in this article and specifically applied to the Canary Islands region.

Keywords: road maintenance; geological risks; volcanic rocks; hazard; rockfalls



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1. Introduction

Several factors contribute to the instability of a slope in most cases. Although an event is often attributed to the action of some factor that triggers the ground to break, instabilities would not have occurred if there were not a series of preconditioning or intrinsic factors that favour the phenomenon [1]. Knowledge of all these factors allows for the correct analysis of the slope, the assessment of the state of stability and, where appropriate, the design of measures to prevent movements (active solutions) or reduce their consequences on the element to be protected. To diagnose the state of a slope or hillside, one must begin by studying the factors that condition its state of equilibrium and the factors that, at any given moment, could trigger its instability.

The conditioning factors of slope instability are intrinsic to the materials the slope is comprised of, and their identification and evaluation are necessary to characterize the conditions of the geological environment in which a slope is located. In soils, lithology, stratigraphy and hydrogeological conditions determine the resistant properties and behaviour of the slope [2]. In the case of rocky masses, the main conditioning factor is the

geological structure, i.e., the arrangement of the strata and their resistances, as well as the degree of fracturing, orientation, and state of the diaclasses. The main factors that influence the stability of a slope are analysed below:

- **Geomorphological factors:** The spatial relationship between the slope and the planes of discontinuity of the soil masses or rock masses determines the stability conditions of these planes and defines the possibility of movements [3]. The erosion or undermining of the foot of slopes, escarpments and cliffs by river, coastal or other types of erosion leads to a loss of resistance in the area [4] and to modification of the state of tension. Together with the lack of support from the overlying material, this can cause instability and the generation of slides or landslides.
- **Geological factors:** Lithology and stratigraphy are related to the type of instability potentially expected, with different lithologies having different degrees of potential susceptibility to the occurrence of landslides or ruptures. The physical and resistance properties of each type of material, together with the presence of water, govern its mechanical behaviour [5]. Aspects such as the alternation of different materials, competition and degree of alternation, or the presence of layers of soft material control the types and dispositions of the breaking surfaces, which tend to be oriented by the upper areas of altered rock or by areas of more or less homogeneous soils. In rocky massifs, the existence of layers or strata of unequal competition can give rise to instabilities in terms of the movement of the slope related to differences in both the erosive characteristics and the speed of erosion, further complicating the characterization and behaviour of the slope.
- **Hydrogeological factors:** Groundwater control is an effective system for the stabilization of deep slides of great magnitude whose triggering is not related to seasonal meteorological phenomena but rather to long-term climatic conditions, because rainfall regimes and humidity conditions are capable of substantially modifying the phreatic levels and water content of the land [6].

Trigger factors must also be considered; these are external factors that modify the initial properties or conditions of the materials of the slopes and embankments [7,8] in such a way that they generate an increase in the thrust or a reduction in the shear strength in certain areas or in the potential breakage planes. The most important are:

- **Meteorological phenomena:** the risk of landslides or rock falls on slopes is greatly increased when adverse meteorological phenomena occur, such as storms, squalls and sea storms that bring high levels of precipitation, waves to the coast and gusts of wind that can unbalance the forces acting on the slopes, causing their destabilization. However, we consider rain to be the factor that most influences the loss of balance in slopes because most of these events occur after intense rain or during rainy periods [9].
- **Seismicity:** earthquakes can cause all kinds of movements on slopes and embankments [10], depending on both the characteristics and properties of the materials and the magnitude of the earthquake as well as the distance to the epicentre and hypocentre 1).

Anthropic actions: Human actions modify the conditions and forces acting on slopes or generate new states of stress. Excavations, the construction of buildings, structures, embankments, fillings or rubble on slopes and blasting in nearby areas, among others, cause variations in the stress states, the hydrogeological conditions, and the geotechnical properties of the land, triggering consequent instabilities.

Due to the fact that 90% of landslide losses can be avoided if the event is recognized before it occurs [11], and due to the tendency of this type of natural phenomenon to occur in the Canary Islands, a classification of risks for landslides is proposed for slopes on volcanic rocks, VRHRS. Although there are methodologies for this purpose, such as the Rock Mass Rating [12] or the Q-system [13], none are specific to volcanic rocks applied to areas in transit. Therefore, it is necessary to create a method to identify the degree of slope stability for the areas surrounding the roads of the Canaries. Previous studies of rockfall

exposure applied to static situations do exist, but the degree of exposure of the element to be protected when it leaves the study area threshold is not considered. [14]. Volcanic rocks are characterized by their marked heterogeneity, which makes their treatment even more difficult [15].

This article presents work that has culminated in the proposal of a new rockfall risk classification based on the RHRS (Rockfall Hazard Rating System) but is adapted to the geological, geomorphological and climatic particularities and singularities of the slopes and hillsides that make up Macaronesia and, in particular, the Canary Islands archipelago. The procedures described in this article are not applicable to the design of slopes; they are only applicable to the diagnosis and evaluation of the risk of rockfalls on existing slopes and hillsides on roads in this specific area. The aim is threefold: to document and understand the risks related to rockslides and their probability of occurrence, to be able to make related decisions in a justified way, and to facilitate the prioritization of the local investments available at any given moment.

2. Materials and Methods

2.1. Study Area

The Macaronesian region extends over a very large maritime area, although the emerged territories cover only 15,000 square kilometres. The Macaronesian archipelagos have their volcanic origin in common (Figure 1). All the islands can be considered oceanic since they have emerged from the sea after successive submarine eruptions of mainly basic magmas (basalt) through fractures and areas of weakness in the oceanic crust. However, there are some islands, such as Lanzarote and Fuerteventura, which, being closer to the mainland, lie on transitional continental-oceanic crust. Therefore, the magma, in its ascent, can drag fragments of sedimentary rock from the African continental rim to the surface [16].

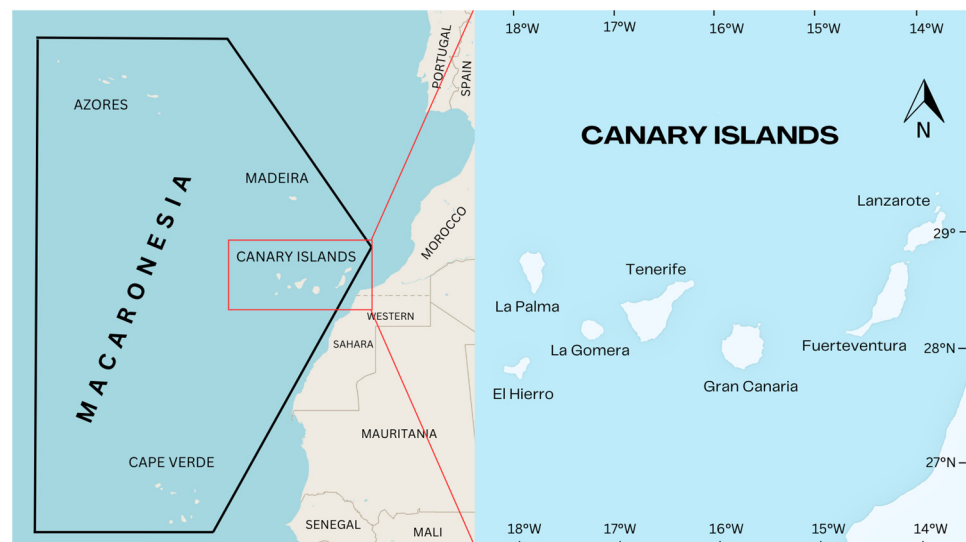


Figure 1. The Canary Islands, an archipelago belonging to the Macaronesia region (Cape Verde, Azores, Madeira and Canary Islands).

The Canary Islands are an archipelago of volcanic nature belonging to Spain and located approximately 100 km off the coast of Morocco. The oldest island of the Canaries is Fuerteventura, which is 20.5 million years old, and the youngest is El Hierro, which is 0.8 million years old, where underwater eruptions have recently occurred [17].

Due to their volcanic origin, the Canary Islands present a geology in which massive rocks coexist with levels of lava slags and pyroclastic materials (Figure 2). This heterogeneity means that landslides and rockfalls recur frequently on the islands, which can affect roads, buildings, and recreational and pedestrian areas [18].



Figure 2. Formation of cornices in “aa” basaltic casts by erosion of the lower levels of lava slugs and pyroclastic materials (Area *Siete Lomas*, C.I. TF-523, Island of Tenerife, Canary Islands).

Based on the geotechnical units and their characteristics, as well as the types of problems and the most likely mechanism of breakage they may present, a classification of the slopes in volcanic terrain has been divided into three typologies: A, B or C. Each type of massif has its own characteristics and parameters to be observed, which are specific to the material or materials that form it and the way in which instabilities are triggered in each case. Each type and the factors associated with them are described below:

- Type A slopes are those in which hard rocks predominate, such as basalt and salt casts (trachytes, phonolites and rhyolites) or compact pyroclasts, such as welded tuff or ignimbrites. Therefore, the lithotypes corresponding to Geotechnical Units II, III, IVa and Va would be included in this typology, according to GETCAN-011 [19]. The behaviour of this type of slope is strongly conditioned by the presence of discontinuities in the rock and its orientation or spatial arrangement. The characteristics of the joints (persistence, roughness and opening) and the presence of holes and altered areas also condition their stability. The most frequent mechanism of breakage or instability is associated with this degree of fracture and its orientation with respect to the face of the slope, giving rise to local or partial fractures of the planar, wedge-shaped, overturning or chinning type and/or small detachments limited to the most superficial level of the slope.
- Type B slopes: These are solid or made up of deposits of pyroclastic materials, both basaltic and salic, loose or weakly welded or cemented (known as *picón* or pumice). Therefore, the lithotypes corresponding to the Va (tuff) and Vb geotechnical units would be included in this typology. The most common instabilities in this type of slope are due to chinning or falls of small-sized edges, although the presence of larger pumps wrapped in their matrix can mean a greater risk when these are left uncovered and without support due to processes of differential erosion. Eventually, on slopes with a strong inclination and with little or no degree of welding or cementing, mass movement processes (rotational slides) may be triggered.
- Type C slopes: These are massifs formed by sequences of materials of different competences and/or resistances, for example, alternations between compact levels of lava and levels of slag or pyroclast that erode at different rates. This would fundamentally affect Geotechnical Units IV and V and could also occur in Units II and III when they

alternate on the slope with other units from other eruptive episodes. The behaviour of this type of slope is strongly conditioned by the differences in the erosive characteristics and the speed of erosion of the different strata it contains. The most frequent mechanism of breakage or instability is associated with the fall of blocks due to the removal of the base or loss of support of the most resistant levels (basaltic and saline casts), caused by the formation of visors or cornices due to greater erosion at the less competent levels.

2.2. VRHRS Classification

Landslides or falling blocks represent a significant risk to proper conservation and operation of roads, especially when this problem, affects a significant length of the road network that runs through uneven relief or steep terrain. This is the case on most of the islands that make up Macaronesia because of their orography and geological nature.

Although it is true that the economic costs associated with block slides are generally much lower than those derived from the overall or general instability of the slope, the number of accidents caused by both types of phenomena is usually of the same order of magnitude. Their lower economic cost has undoubtedly been one of the reasons for fewer studies and slower progress in relation to the understanding of general stability of slopes.

Landslides are sudden falls of blocks or masses of rocky blocks, separated by pre-existing planes of discontinuity, that descend down the slope mainly by free fall, bouncing or rolling. The origin of these events is caused both by preconditioned or intrinsic factors of the slope itself (geometric, geological, geotechnical and hydrogeological) and by external or triggering factors (rain, wind, earthquakes and human actions). The phenomena of the instability of blocks and stones is variable, which makes it very difficult to establish simple and concrete methodologies or procedures to study and analyse this problem. To date, estimation of the risk of this type of phenomenon has been quantified using empirical methodologies since this approach is considered the most operational for responding to these complex phenomena in which a multitude of factors intervene. These methods are based on a series of quantitative and qualitative parameters that allow the evaluation of risks relating to rock falls and their probability of occurrence, in order to facilitate decision making and prioritization of the investments available at any given time. With direct application to roads and high-capacity roads, at present, the two most commonly used methodologies are those developed by the Roads Division of the State of Oregon in the USA “RHRS Rating, Rockfall Hazard Rating System” [20] and in the Canadian State of Ontario “RHRO Rating, Rockfall Hazard Rating Ontario” [21].

However, the volcanic nature of the slopes and hillsides present in the Macaronesian Islands, whose characteristics and behaviour clearly differ from the rocky materials that make up the mountains in these two regions, together with the action of a different rainfall and temperature regime, make it advisable to review and adapt this methodology to the conditions present in these archipelagos.

3. Results and Discussion

Based on the study of 94 slopes of different lithotypes distributed throughout the Canary Islands archipelago, a new landslide risk classification has been developed. The new classification system is based on the Oregon RHRS method but is adapted to the geological, geomorphological and climatic particularities and singularities of the slopes and hillsides that make up Macaronesia and, in particular, the Canary Islands archipelago. Of the slopes inspected, 48 are located on the island of Tenerife, 20 on the island of Gran Canaria and 26 on the island of La Palma.

The following VRHRS Classification (Volcanic Rockfall Hazard Rating System) is proposed, which is based on the Geomechanical Classification for slopes in volcanic rocks (VSR Index) developed ad hoc by the CEDEX Geotechnical Laboratory [22].

The VRHRS index is obtained as the sum of $VRHRS_{basic}$ and two adjustment factors F_1 (slope hazard adjustment) and F_2 (exposure adjustment):

$$VRHRS = VRHRS_{basic} + F_1 + F_2 \quad (1)$$

where $VRHRS_{basic}$ is the index relative to the general quality and degree of stability of the rock mass from the score obtained in the VSR Index (Table 1) according to the following expression:

$$VRHRS_{basic} = 200 - e^{-0.034 \cdot VSR} \quad (2)$$

Table 1. VRHRS values as a function of VSR values (CEDEX).

VSR Index	VRHRS Basic
Class V (VSR 0–20)	162
Class IV–III (VSR 21–60)	54
Class II (VSR 61–80)	18
Class I (VSR 81–100)	6

F_1 is the adjustment factor for the level of danger of the slope. It is the sum of the partial scores obtained for each of the following evaluation parameters, varying between a minimum value of 18 points and a maximum of 600 points: height of the slope; effectiveness of the receiving ditch; width of the roadway including the shoulder; size of the individual block/volume of rocks per event; climate and presence of water in the slope; and history of events or falling blocks.

F_2 is the adjustment factor for exposure of the element or set of vulnerable elements to be protected. It is the sum of the partial scores obtained for each of the following evaluation parameters, varying between a minimum value of 6 points and a maximum of 200 points: average vehicle risk (AVR) and percentage of visibility (SD) versus reaction distance (DSD).

As established in the Oregon RHRS method [19], each of the parameters included in the adjustment factors are valued exponentially according to the following mathematical expression:

$$y = 3x; (x = 1, 2, 3 \text{ or } 4) \quad (3)$$

Table 2 shows the eight parameters (six for F_1 and two for F_2) to be evaluated. For each of them, the description of the different conditions is presented with scores between 3 and 81 points. For simplicity, the values proposed in Table 1 are used (and properly interpolated if necessary).

If the parameters of the detailed classification are to be calculated analytically, the formulas contained in Table 3 should be used.

Depending on the final score obtained for each of the slopes or rock masses studied, the following guidelines or actions are recommended and detailed in Table 4.

The different evaluable parameters are described as follows:

- **Slope height:** The blocks of rock that fall from a greater height have greater potential energy than those that fall from a lower height [23]; thus, the former represents a greater risk and will receive a higher score. The height will be measured from the highest point of the slope from which the rocks can fall. If the possibility of falling rocks from any area of the natural slope located above the clearing slope of the road is detected, this will be considered for the purposes of the vertical height.

Table 2. Estimation of the detailed classification of VRHRS. Adapted from RHRS [19].

Quality and Grade of General Stability of Rocose Mass (VRHRS Basic)				
VRHRS basic	$200 - e^{-0.034 \cdot VSR}$		$100 > VSR > 0$	VSR =
Score:				1
Adjusting for Slope Hazardz (F ₁)				
Parameter	Evaluation Criteria and Scoring			
	(x = 1)	(x = 2)	(x = 3)	(x = 4)
	3 Points	9 Points	27 Points	81 Points
Height of the slope	7.5 m	15.0 m	22.5 m	30 m
Effectiveness of the receiving gutter	Good	Moderate	Limited	Null
Roadway width including the verge	13.5 m	11.0 m	8.5 m	6.0 m
Individual block size (e)	0.3 m	0.6 m	0.9 m	1.2 m
Volume of rocks per event	2.5 m ³	5.0 m ³	7.5 m ³	10 m ³
Climate and presence of water on slope	Climatic zone 1 (ZC ₁)	Climatic zone 2 (ZC ₂)	Climatic zone 3 (ZC ₃)	Climatic zone 4 (ZC ₄)
Event history or block fall	Few landslides	Occasional landslides	Many landslides	Constant landslides
Score:				2
Exposure Adjustment (F ₂)				
Parameter	Evaluation Criteria and Scoring			
	(x = 1)	(x = 2)	(x = 3)	(x = 4)
	3 Points	9 Points	27 Points	81 Points
Average vehicle risk (AVR)	25% of the time	50% of the time	75% of the time	100% of the time
Percentage of visibility (SD)	Sufficient visibility	Moderate visibility	Limited visibility	Very limited visibility
Decision sight distance (DSD)	(100% DSD)	(80% DSD)	(60% DSD)	(40% DSD)
Score:				3
Final score VRHRS Index:				1 + 2 + 3
Class				
A (maximum risk)		B		C (minimum risk)
VRHRS > 500		500 ≥ VRHRS ≥ 300		VRHRS < 300

Table 3. Formulas for calculating the exponent in the classification parameters.

Parameter of Category	Proposed Formulas for Estimating the Value of the Exponent, x *
Height of the slope	$x = \frac{\text{Height (m)}}{7.5}$
Roadway width	$x = \frac{65 - 4.1 \times \text{Roadway width (m)}}{10}$
Block size	$x = \frac{10 \times \text{Block size (m)}}{3}$
Volume of rocks per event	$x = \frac{4 \times \text{Volume (m}^3\text{)}}{10}$
Average vehicle risk	$x = \frac{\% \text{ period considered}}{25}$
Visibility	$x = \frac{120 \% \text{ visibility}}{20}$

* In any case, a value of x ≥ 1.

Table 4. Recommendations based on the total VRHRS score.

Class	Final Score VRHRS	Recommendations
A (highest risk)	>500	Road embankments requiring immediate action
B	300–500	Road slopes requiring priority action in the short to medium term
C (lowest risk)	<300	Road slopes with low priority action

- Ditch effectiveness: The effectiveness of a ditch is measured by its ability to limit the amount of stone that is removed from the road. Depending on the slope of the embankment, there can be four types of trajectories of the rocks during their fall: free falling, bouncing, rolling, and sliding. To estimate the effectiveness of a ditch, the assessor should consider the height and angle of the slope; the width, depth, and shape of the ditch; the size of the block that can be detached; and the irregularities present (berms, projections, visors, cavities, etc.) that may have a possible effect on the trajectory.
- Roadway width: This dimension, measured transversely to the axis of the track, represents the margin of manoeuvre available to the user to avoid impact with a possible rock fall. This measure should be the minimum width when the roadway width is not constant. The width of the hard shoulder shall be considered only if it is paved.
- Block size: This parameter represents the phenomenon of the most likely detachment [24]. If individual blocks are involved, the score will depend on the size of the blocks. However, if the fall of a fractured rock mass is expected, the volume of the fracture is what is valued. The decision regarding which to use should be determined, where possible, from the fall or landslide history available to the Road Maintenance Service or Department.
- Climate and presence of water on the slope: Water and ice/thaw cycles contribute to wear or weathering and sliding of rocky materials. If water is known to flow continuously or intermittently down the slope, this factor can be weighted accordingly. The impact of the ice/thaw cycle can be interpreted from the freezing conditions and their effects on the area. To facilitate the work of the evaluator, four climate zones were established for the Canary Islands, as a result of the CLIMCAN-010 study [25].
- CZ1: Slopes or hillsides located in areas of low precipitation, <300 mm/year. These are characterized by low to moderate precipitation, without periods of frost or water on the slope.
- CZ2: Slopes or hillsides located in areas of moderate precipitation at an elevation below 2000 m a.s.l., 300–500 mm/year. The area is characterized by moderate precipitation or with short periods of frost, or where the presence of water is intermittently detected on the slope is.
- CZ3: Slopes or hillsides located in areas of moderate precipitation at or above 2000 m a.s.l. or slopes or hillsides located in areas of high precipitation, 501–1000 mm/year. The area is characterized by high precipitation or long periods of frost, or where there is a continuous presence or upwelling of water on the slope.
- CZ4: Slopes or hillsides located in areas of very high precipitation, 1001–2000 mm/year. These are characterized by high precipitation and long periods of frost or by the continuous presence of water on the slope and long periods of frost.
- Rockfall history: This is a parameter that considers past landslides as an indicator of potential future events. It is essential to have this historical information, as far as possible, which should be based on the reports of the road conservation or maintenance teams attached to the slope or rock massif under study. In areas of recent construction or where no information or documented records of previous events are

available, the assessment will be made on the basis of similarity with other slopes, indicating the convenience of revising this assessment in the future as more information becomes available.

- Average vehicle risk (AVR): This parameter measures the risk associated with time in percentage of vehicles on the road section with the possibility of landslides. Its value can be obtained by means of the following equation, based on the length of the section (in front of the study slope), the average daily vehicle intensity (AVD) and the speed limitations established therein:

$$AVR = \frac{IMD \text{ (veh/day)} \cdot \text{Slope length (km)}}{\text{Speed limitation (km/h)} \cdot 24 \text{ h/day}} \cdot 100\% \quad (4)$$

- Decision sight distance (DSD): length or distance required to have a driver stop their vehicle when making a complex or unpredictable decision, such as when there is an unexpected obstacle (e.g., a rock in the road) in their path [26]. The recommended values for this parameter as a function of speed can be found in Table 5.

Table 5. DSD values in meters, depending on speed in km/h.

V (km/h)	Values (m)	DSD (m)
40	35–40	40
50	48–58	60
60	63–79	80
70	82–106	110
80	103–138	140
90	127–176	180
100	154–220	220
110	185–272	275
120	219–335	335

Sight distance (SD): the distance between an obstacle on the roadway and the position of a vehicle travelling towards that obstacle, in the absence of intermediate vehicles, at the time when it can be seen, without later disappearing from the field of vision, until it is reached. With these data and the DSD, the percentage of visibility can be calculated:

$$\% \text{ decision visibility} = \frac{\text{Visibility (SD)}}{\text{Reaction distance (DSD)}} \cdot 100\% \quad (5)$$

In brief, the parameters that must be evaluated in order to obtain the VRHRS index, which will allow users to determine the relative risk of rockslides from the slopes or hillsides near the road, can be seen in summary form in Figure 3.

The empirical methodology proposed allows for the quantification of the risk of landslides on slopes and slopes of a volcanic nature in the area of roads, classifying it into three levels or classes (A—maximum risk, B—medium risk, and C—minimum risk), for which a series of guidelines or actions to be followed are established. This method also makes it possible to order the slopes according to their severity, thus facilitating prioritization of the investments available at any given moment.

Assessed risk refers to the measure (qualitative or quantitative) of the magnitude of damage to the element or set of elements to be protected in a dangerous situation. It should not be confused with susceptibility of slope instability, since the latter does not indicate a probability of occurrence but refers to the possibility of instability occurring under the influence of certain conditions, which are not considered in the analysis. In other words, although one slope may be less susceptible to instability than another, it may be more likely to generate instability if its boundary conditions are more conducive to its development. Therefore, a result of very high susceptibility does not necessarily imply that the slope will be imminently unstable, but that a more detailed study should be carried out

urgently. Likewise, risk should not be confused with hazard level, since the latter refers to the probability of occurrence of a process (rockfall), with a given level of intensity or severity, within a given period of time in a specific area.

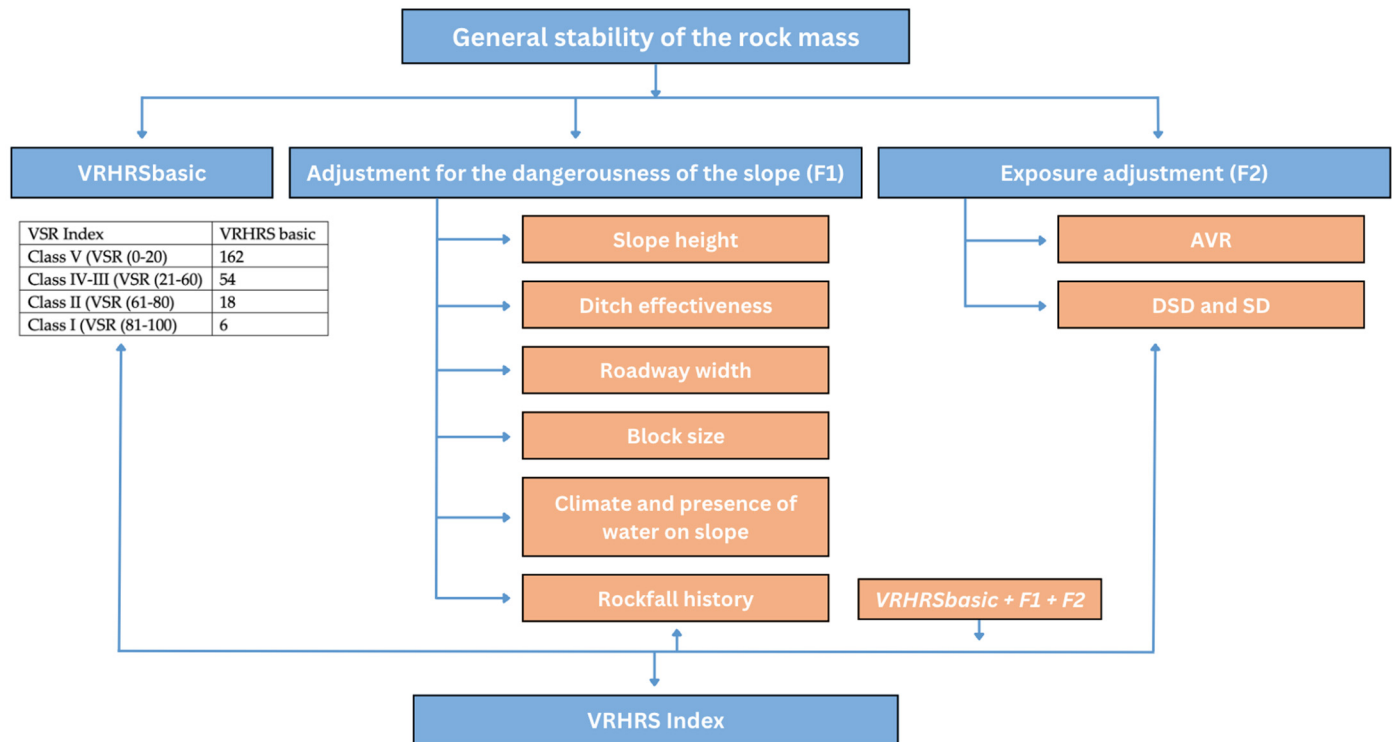


Figure 3. Scheme for the calculation of VRHRS through F1 and F2. Source: Own elaboration.

Finally, it should be noted that the results obtained after application of this tool should not be considered invariable since slopes and hillsides are dynamic elements that are constantly changing, making it necessary to update the quantification of the risk assessed from time to time.

4. Conclusions

The empirical VRHRS method presented here is a rockfall risk classification system that was created in response to the need for a methodology to assess this risk in transit areas (roads) but in a way that is more adjusted and focused on the geological, geomorphological and climatic particularities and singularities of the slopes and hillsides that make up Macaronesia. It will undoubtedly facilitate the work of technicians when faced with the complex and difficult task of analysing, diagnosing and evaluating the risks of landslides on roads, with the triple aim of knowing the relative risks of rockslides and their probability of occurrence, being able to make related decisions in a justified way and facilitating the prioritization of the investments available at any given moment.

The new classification is based on the RHRS method (Rockfall Hazard Rating System), developed by the Oregon Department of Transportation, a method that has been revised, modified and adapted to the conditions of the Canary Islands archipelago. It takes into account not only the volcanic nature of its slopes and hillsides but also the climatic conditions and rainfall regime and the national technical regulations applicable to roads.

The novelty of the proposed methodology lies in the fact that the assessment of risks related to the intrinsic conditions of instability of the slope itself (i.e., the quality of the rock massif in relation to its structural condition and erosive characteristics) is evaluated on the basis of the Geomechanical Classification for slopes in volcanic rocks (VSR Index—Volcanic Slope Rating). This was developed ad hoc within the MACASTAB project with the

collaboration of CEDEX, with the aim of developing a tool that would allow the evaluation of the degree of slope stability in volcanic materials in the Canary Islands.

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