Computational System for Monitoring and Risk Analysis Based on TerraMA2

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Abstract. *The intensity to which natural phenomena have been occurring and surprising the population imposes on Engineering the search for preventive measures that minimize the contingent of people affected by these tragedies. It happens due to the imminent risks of disasters, posed by rain combined with the soil properties, slope and the type of use and land occupation existing in the region. From this perspective, an experimental program aimed at issuing warnings is justified from the technological point of view. Therefore, the present work presents an elaboration of a monitoring system to analysis and alert generation of risks for the city of Ouro Preto, state of Minas Gerais, based on TerraMA2. The project used as a case studies 33 occurrences of slope disruption in the city of Ouro Preto, made available by the city's Civil Defense. The obtained results showed that the generated model, based on the intensity of the accumulated rainfall, as well as the lithological maps, use and occupation and slope, would be effective to identify, in advance, risk situations.*

1. Introduction

Natural disasters have affected human survival since the beginning of times, due to the intense, and numerous types of destruction they cause. The problem of significant numbers of casualties and damage to property and to the economy has contributed to a greater focus on this issue. From this perspective, it is evidenced landslides. Dias et al. [2] suggest that these events have generated significant numbers of casualties and causing significant losses related to the destruction of buildings. Dias et al. [2] also state that, according to the United Nations, mass movement is a damaging catastrophe only inferior to earthquakes, and floods among natural phenomena that most impact humanity.

Lopes et al. [6] define the process of sliding of gravitational mass, which generally occurs when a strand already saturated with water is achieved by an intense precipitation. They also point out that the process is induced by climatic, hydrological, geological, geomorphological factors, the vegetation, and also by humans.

Regarding these mass movement processes, weather is highlighted as the precursor of these incidents. According to Wolle [15], the climate is characterized as a potentiating agent because of instability of slopes, and also the immediate cause of breaking slopes, usually due to heavy rains. Lopes et al. [6] point out that rain interferes with the safety of slopes, favoring an increase in the specific weight of the soil, minimizing the cohesion and internal friction angle of the material, and promoting the formation of a water level that creates parallel streams to the hillside, with the same direction of shear stress.

Brazil is one of most affected countries by climate disasters [8]. According to the United Nations Office for Disaster Reduction (UNISDR) and the Centre for Research and Epidemiology of Disasters (CRED), Brazil is the only country in the Americas on the list of 10 countries with the highest number of people affected by disasters between the years 1995 and 2015. In these two decades, about 51 million Brazilians have been affected by disasters [8]. Thus, a system of monitoring, analysis, and risk alerts through mathematical-computational models is justified. In order to do so, it was necessary to construct a computational framework that would be able to bring together the different sources of data already existent, combining with other local information that could be processed, in such a way as to provide gradual alerts, that increase their level as the situation becomes increasingly serious.

From this perspective, this work had as general objective the development of a system of monitoring, analysis, and alert of real risks of landslides. The system implements an analysis model for different districts of the city, calibrated according to the specific characteristics of such to which the model refers. Based on this premise, we have specific objectives like the elaboration and calibration of a risk analysis model for slopes and barriers, the development of monitoring mechanisms for excess rainfall, as well as the design of different levels of alerts, according to the geographic region's setting. This mechanism is intended to generate warnings in a timely manner so that responsible authorities as well as community leaders can take appropriate action to mitigate potential damages to the communities concerned.

2. Related Work

Intrieriet al. [5] propose a set of techniques to be used as a warning system for a given region that suffers from the hazard of soil slip. This study covers several components. Among the most relevant ones are: the geological characterization, risk scenarios and defining the most appropriate level of alarm. Through this type of monitoring, it is sought to predict, as realistic as possible, the risk of collapse of an area, informing the users. However, this research is guided by techniques that have a relatively high implementation cost, due to the need of specific devices for the system.

Dai et al. [1] present a study relating rainfall to landslides in Hong Kong, that is a region characterized with high steepness. Through a historical research, a study was made which shows the volume of earthworks with rainfall intensity, establishing a frequency of occurrence of such event. However, it was not discussed in this work any mitigation technique of these events, or even any risk warning system.

Salciariniet al. [13] develop a research directed to establish where and when the risk of landslides in Seattle, USA can occur. For this, they took into account different recurrence times, rainfall durations, properties of embankments, among other factors. The product of this study can be summarized in a map that shows the probability of recurrence of events that cause such disasters.

Lopes et al. [6] present a survey guided in monitoring and risk alert through SISMADEN software [6](Monitoring System and Natural Disaster Alert) in which the slope is considered the main factor of landslides. By monitoring these areas and through the data of rainfall estimates in real time, it is possible to alert the probability of events, such as those that occurred in Angra dos Reis, Brazil and neighboring municipalities, in December 2009.

Reis et al. [10] propose monitoring and alert in advance to extreme events that may occur in the metropolitan region of São Paulo, Brazil. For this, they used the SISMADEN software. They also used hydrometeorological basis and nowcasting which allow short-term forecasts. Other tools used were FORTRACC and HYDROTRACK that identify distribution, the development and the transportation of rainfall. However, the results found by HYDROTRACK were not satisfactory, thus requiring further analysis.

Reis et al. [11] propose a monitoring and risk warning system through SISMADEN software. For this research, it was used the hydrometeorological satellite data, registries from data collection platform (DCP) and numerical weather prediction - ETA model. As a result, it was possible to identify the risks of extreme events with approximately 18 hours in advance, which would help in the decision-making process of the Civil Defense.

In figure [7], it is presented a study related to the risk of landslides in the São Paulo region, Brazil. The relevant factors of the analysis relate to the understanding of the use and occupation of the soil, the high potential of precipitation, with its time of recurrence, and relief features. This diagnosis was supported by IPT experts (Technological Research Institute) that predicted the potential for ground handling risk in the region. By overlaying these elements, there was provided a slip threat model, which resulted in a map of levels of collapsing risk.

Among the several research and data studied, there are some documents that present the development of risk analysis of certain regions and later present some kind of alert to the population of interest. However, these works do not include regions that are in need, suffering intensely from catastrophic events due to natural phenomena and victimizing thousands of people. Furthermore, the purpose of this research is to carry out a large-scale system of monitoring, analysis, and alert of risks, in regions that are affected by geological accidents; in a way that the alert system is of easy control, easy access to the people, and also is as close as possible to reality.

3. Methodology Proposal

The study area chosen for the development of the research was the municipality of Ouro Preto, as shown in Figure 1.

This was the case of study due to the geological risks related to mass movement and also because the Civil Defense and the Municipal Government of Ouro Preto made available the data collection of the municipality. In this perspective, the considerable risk-increase in these areas, over the years, is highlighted, mainly with a disorganized occupation. Faced with this prerogative, surveys were made of events occurred in this municipality between 2005 and 2012, and the results were from heavy rains. During this period, the cumulative rainfall in the defined region reached above 128mm of rain on five consecutive days, which according to Ouro Preto Meteorological Alert System (SAMOP) the probability of occurrence of more severe accidents increases [9].

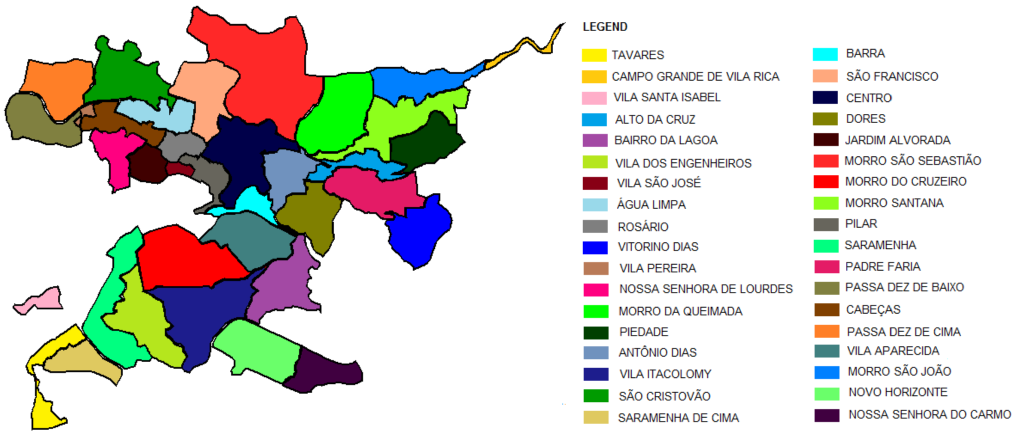


Figure 1: Map of counties of the municipality of Ouro Preto.

3.1. Materials

In the execution of this research, TerraMA2[1] software was used for the development of the monitoring system, analysis, and alerts of risks. The proposal of this tool is to create a system that exposes environmental information related to climatic and hydro-meteorological extremes to the mapping of areas with great potential for risk. In this context, it is expected that the intersection of all data will allow high-risk situations to be identified. Based on this premise, there is a need to insert hydro-meteorological data on the platform. Such data is provided by institutes such as CPTEC / INPE [4] . For this research, the Ouro Preto city provided rainfall data regarding data collection points (PCD's) in the regions studied, between November 2005 and January 2012, and CPTEC/INPE [4] provided satellite precipitation data (hydro-estimator). Also in this period. Tied to these environmental data, static data was introduced from the region of interest, which consists of the lithological map, slope, land use and occupation, as well as the map of neighborhoods, all provided by the city of Ouro Preto. Regarding the calibration of the system, 33 occurrences of landslide slopes of the municipality of Ouro Preto, made available by the Civil Defense of the municipality, were analyzed as shown in Table 1.

3.2. Methods

According to Reis [12], the TerraMA2 platform basically has the function to look for data from different servers and associate them in a database with the purpose to perform the analysis' models, and for each new data collected and entered in the database is performed further analysis to assess whether it is or not a risk. From this premise, if a threat is identified, a warning signal is generated.

[1] http://www.dpi.inpe.br/terrama2/

Table 1: Slippage occurrence data in the municipality of Ouro Preto.

Nº	Date	Neighborhood	Street	Number	X Coordinate	Y Coordinate
1	29/11/2005	Padre Faria	8 de setembro	86	657408	7744983
2	10/12/2005	Alto da Cruz	Francisco Isaac	328	657432	7744626
3	11/12/2005	Alto da Cruz	Maestro Joaquim	251	657645	7745361
4	11/12/2005	Morro Santana	XV de Agosto	771	657107	7745280
5	13/12/2005	Alto da Cruz	Francisco Isaac	60	657326	7744781
6	15/12/2005	Piedade	José Anastácio	217	658115	7745318
7	01/12/2006	Barra	OthonGuimarães	33	656626	7744290
8	06/12/2006	Piedade	Ladeira da Piedade	7	657780	7745027
9	13/12/2006	Alto da Cruz	Francisco Isaac	336	657432	7744626
10	30/12/2006	Piedade	18 de Maio	891	657684	7745166
11	31/12/2006	Piedade	13 de Maio	871	657661	7745520
12	31/12/2006	Rosário	Domingos Vidal	69	655432	7745470
13	02/01/2007	São Cristovão	Padre Rolim	2003	654384	7745836
14	05/01/2007	Rosário	Domingos Vidal	83	655434	7745482
15	08/01/2007	Padre Faria	08 de Setembor	36	657396	7744980
16	11/01/2007	Morro Santana	XV de Agosto	s/n	658582	7746137
17	15/01/2007	Piedade	da Abolição	309	657415	7745109
18	17/01/2007	São Cristovão	Valdomiro Félix de Mattos	142	654910	7746450
19	28/01/2007	São Cristovão	Platina	6	654909	7746100
20	01/01/2009	São Cristovão	Manganês	191	657263	7744657
21	09/01/2009	São Cristovão	Padre Rolim	2008	654281	7745752
22	27/01/2009	São Francisco	Vereador Miguel Alves Pereira	s/n	655681	7745894
23	28/01/2009	São Cristovão	Padre Carmélio Augusto	100	654781	7746139
24	29/01/2009	Morro Santana	XV de Agosto	785	657480	7745491
25	04/01/2011	Alto da Cruz	Francisco Isaac	196	657389	7744696
26	04/01/2011	Piedade	Treze de Maio	341	657287	7745242
27	04/01/2011	São Francisco	José Pedro de Meira	54	655644	7745940
28	05/01/2011	ÁguaLimpa	Tomé de Vasconcelos	303	655223	7745907
29	02/12/2011	Morro Santana	Campinas	41	657631	7745369
30	21/12/2011	ÁguaLimpa	Francisco Nunes	75	655254	7745550
31	04/01/2012	ÁguaLimpa	Professor AntônioRibas	249	655547	7745760
32	07/01/2012	Padre Faria	Desidério de Matos	600	657531	7744709
33	09/01/2012	NossaSenhora de Lourdes	Presidente Castelo Branco	129	655029	7745388

In the execution of this work two types of data were used, the dynamic environmental data and the static data, the later related to the geographic object monitored, i.e. municipality of interest. In relation to the dynamic environmental data, precipitation values collected by PCDs located in this municipality were used where the readings occur through a rain gauge. Satellite precipitation (hydro-estimator) could not be used in the research, because its resolution was not compatible with the studied region, showing its inefficiency. In Figure 2, this problem can be observed.

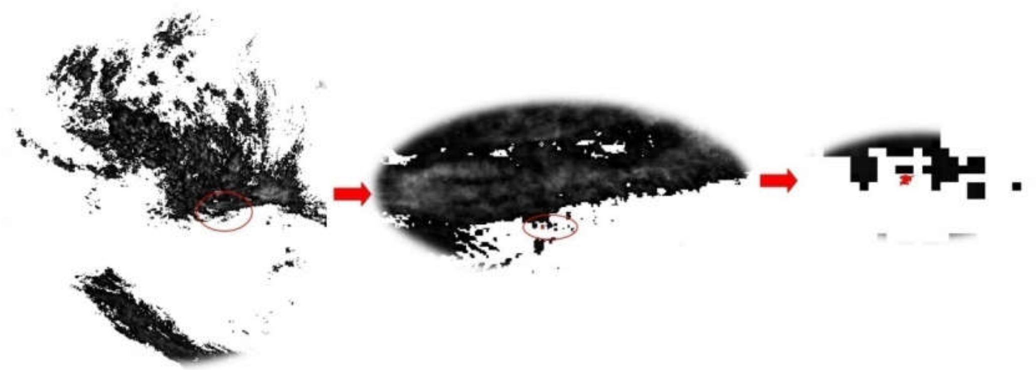


Figure 2: Resolution of the Hydro-estimator in relation to the study region.

The data from the monitored object refer to the existing lithology, the map of use and occupation and the slope of the city of Ouro Preto. Soil is one of the determining factors of the land vulnerability regarding the movements and consequently possible accidents [2], which combined with the slope of the region, the type of use and occupation contribute markedly to the collapse of soil masses. Through TerraView these maps are combined to generate a database, which will be used as subject of study.

Subsequently, the risk analysis model is developed in TerraMA2 platform. The model was calibrated from the study and analysis of ten periods between the years 2005 to 2012, being 5 of these periods without occurrence of events and 5 with occurrences of mass movement. These respective periods analyzed are shown in Table 2.

Table 2: Analysis periods for system calibration.

Analysis	Occurrences	Period
1	There have been	01/11/2005 to 31/12/2005
2	There have been	01/12/2006 to 31/01/2007
3	There have been	01/01/2009 to 30/02/2009
4	There have been	01/01/2011 to 30/02/2011
5	There have been	01/12/2011 to 31/01/2012
6	There were no occurrences	01/07/2005 to 30/08/2005
7	There were no occurrences	01/04/2006 to 05/30/2006
8	There were no occurrences	01/01/2008 to 30/02/2008
9	There were no occurrences	07/01/2010 to 08/30/2010
10	There were no occurrences	06/01/2011 to 30/07/2011

The purpose of this whole apparatus is to perform several tests in order to calibrate the system. Depending on the type of present risk, TerraMA2 will offer different alert levels. In Table 3 are presented the alert levels provided by TerraMA2 that were used in the study [9], plus a new sign, the 'No alert', in order not to be issued irrelevant alerts. There are 5 alert levels which are characterized as follows:

- Level 0: No Alert - At this level there is no probability of occurrence of events;
- Level 1: Observation - At this level constant meteorological monitoring is done;
- Level 2: Attention - At this stage the Municipal Contingency Plan is started, with monitoring of rainfall indexes and meteorological bulletins issued by state and federal agencies;
- Level 3: Alert - This level is characterized by prolonged rains and requires greater monitoring of rainfall indices and meteorological data that are issued by state and federal agencies;
- Level 4: Maximum Alert - This level is characterized by prolonged rains and forecast of continuity for the next days. This situation requires careful monitoring of the rainfall indexes and meteorological bulletins issued by state and federal agencies.

Table 3 - Alert levels used and available by TerraMA2.

Alert levels		
1		No alert
2		Note
3		Attention
4		Alert
5		Maximum alert

4. Experiments and Results

At first, only a soil map was used but the results were not satisfactory, since the alerts did not reach the affected region. Thus, another static information data were introduced, like lithological map of slope and of use and occupation, as well as the counties' map. Through the TerraView software, an intersection between the region of interest and the maps was performed, resulting in maps of the studied region. In order to obtain the best calibration for the system, several tests were performed on the TerraMA2 platform.

In relation to lithology, an analysis was made to determine how much these is favorable to erosive processes. Thus, after a careful study of each lithology present, a weight was assigned to each type. It should be noted that this weighting underwent several adjustments so that it was calibrated and consistent with the events that occurred.

In relation to the declivity map, a striped division was made according to the existing slope level. Weight was also inserted at these levels. Table 5 shows the slope intervals and the weights assigned to them.

Regarding the map of use and occupation, an analysis of the region was carried out and, depending on the type of occupation, weight was also attributed to them. Table 6 shows how the process of weighting was done.

Table 4: Weighting of Lithology.

Lithology	Classification	Weighting
Carbonate-quartz-feldspar-biotite-chlorite shale, sericite-biotite-chlorite-quartz shale, quartz-chlorite shale, cacissylic rock, metaconglomerate and iron formation	1	0,125
Diabásio	1	0,125
Quartzite with conglomerate lenses and filito	1	0,125
Quartzite, phyllite, some conglomerate	1	0,125
Quartzite, phyllite, quartz-sericite shale and conglomerate	1	0,125
Quartz-mica-chlorite shale, chlorite shale, biotite-mica feldspathic shale, local iron formation	1	0,125
Metavulcanic rocks, green shale, chlorite shale, phyllite and quartzite, with conglomerate lenses	1	0,125
Canga: limonitic capping	2	0,375
Dolomite, magnesium limestone and dolomitic itabirite, with phyllite and quartzite	2	0,375
Filito, dolomitic phyllite, dolomite; Quartzite and subordinate iron formation	2	0,375
Graphite shale, shale mica and phyllite	2	0,375
Graphite shale, mica schist, phyllite and some quartzite	2	0,375
Laterite, bauxite and uncemented ferruginous detritus	2	0,375
Quartzite	2	0,375
Talus: slip lands; Rock fragments with soil	3	0,625
Alluvium: sand, clay, and gravel	4	0,875
Itabirito	4	0,875
Itabirito, phyllite and dolomitic itabirite	4	0,875
Itabirito, phytic and dolomitic itabirite	4	0,875
Ferruginous quartzite, silver phyllite, sericite shale	4	0,875

Table 5: Weight of slope.

Declivity	Classification	Weighting
0 - 10 %	1	0,025
10 - 20 %	2	0,125
20 - 40 %	3	0,625
40 - 60 %	4	0,875
60 - 100 %	5	1,000
>100 %	6	1,200

Within this perspective two models of analysis written in LUA[2] were created. The models are based on data accumulated in 24 hours of precipitation, i.e. the precipitation data provides the daily data. Figure 3 shows the two models being the left side representative of the model of analysis in grids, from static matrix planes and the one on the right side, the analysis model from the monitored object. Since the grid model is incorporated into the model of the monitored object.

[2] https://www.lua.org/

After completing all the system configuration and establishing all the input parameters, the program was executed in order to check its warning signals. This study was implemented for the ten periods mentioned in Table 2. Figure 4 show images generated by the system, and in the first one, Figure 4(a), there is an eminent risk of slope deflagration, in which two mass movement events occurred (marked as black point in the image). In the second image, Figure 4(b), is presented an alert map, in which there was no registered catastrophic event of any kind.

Table 6: Weighting of types of land use and occupation.

Use and occupation of soil	Classification	Weighting
Commercial area	1	0.875
Dense forest area	2	1,000
Area of undergrowth	3	0.625
High standard residential area	1	0.875
Standard low residential area	1	0.875
Average residential area	1	0.875

When analyzing the alert map of Figure 4, the agreement between the maximum alert generated and the incidents occurred in the municipality of Ouro Preto, as presented in Table 1, was verified. This occurred for all 33 events in which there were deflagration of slopes. This shows that the calibration of the system presented a satisfactory result, in view of the catastrophic incidents that occurred. The other counties also received maximum alerts due to high rainfall incidents. Even though Civil Defense has not recorded any occurrences, they may have happened in the region. If the population had access to this signal they could have the chance to evacuate the area and thus avoid the any chance of fatalities. It is possible to observe that all regions with red staining, Figure 4(a), present eminent risks of deflagration of slopes, which is evidenced when analyzing the type of lithology, slope and use and occupation present in the region. These regions present greater susceptibility to occurrence of erosive processes, when allied to increasing values of precipitation, passing the critical threshold 128mm rain accumulated on 5 consecutive days, as shown by SAMOP [9].

5. Conclusion

It is unacceptable that geological accidents still make too much victims in modern societies, specially because today's societies are highly characterized by the use of technological advances. Certainly, there are other variables involved in this problem, as the acceptance and trust of the population in the authorities issuing these warning signs. Thus, the developed tools must be precise and accurate, in order to minimize the effects of disasters due to extreme behavior of nature.

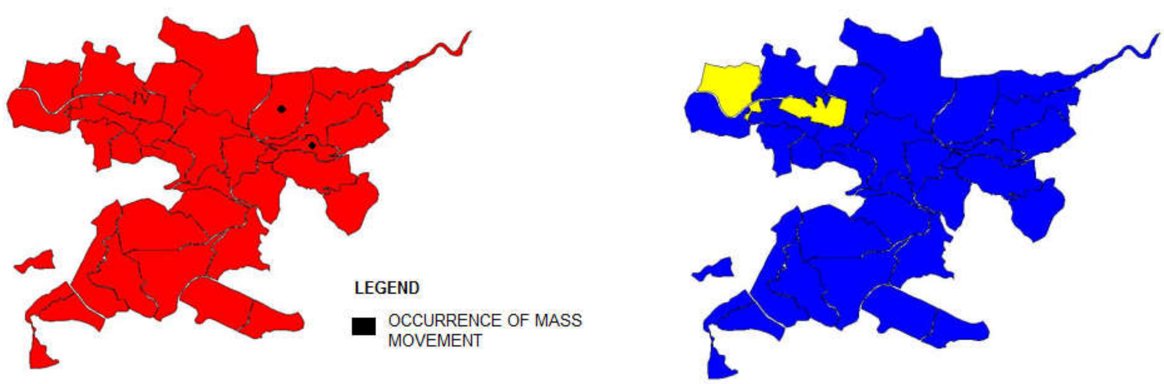
When performing an analysis of the results obtained, it can be observed that the analysis of the precipitation data with the static maps of the studied region presented satisfactory results when compared with the events occurred in the municipality. In fact, an empirical method was used to calibrate the system, but it presented results well in line with reality.

For a broader approach to the potential of the presented system, other variables can be considered, such as permeability map and hydrogeological parameters, as well as the continuity in the evaluation of the series of temporal precipitation data, in order to avoid false warnings. The issuance of these alerts can generate expensive costs to the population, so the reality must be the most reliable.

```
local vuso = amostra('usoocupacao_final_1') or 0
local lito = amostra('litologico_final_1') or 0
local decliv = amostra('declividade_final_1') or 0


local plito = 0
if lito == 1 then
 plito = 0.125
elseif lito == 2 then
 plito = 0.375
elseif lito == 3 then
 plito = 0.625
else
 plito = 0.875
end

local pdecliv = 0
if decliv == 1 then
 pdecliv = 0.025
elseif decliv == 2 then
 pdecliv = 0.125
elseif decliv == 3 then
 pdecliv = 0.625
elseif decliv == 4 then
 pdecliv = 0.875
elseif decliv == 5 then
 pdecliv = 1
else
 pdecliv = 1.2
end

local pvuso = 0
if vuso == 1 then
 pvuso = 0.875
elseif vuso == 2 then
 pvuso = 1
else
 pvuso = 0.625
end

return 1.93  * pvuso +
      2.32 * plito +
      2.78 * pdecliv
```

```
local pcd_novelis=0
local pcd_novelis_1=influencia_pcd('pcd_novelis_1')


for i,v in ipairs(pcd_novelis_1) do
         pcd_novelis =
media_historico_pcd('pcd_novelis_1', 'pluvio', v, 1)
end

print('Media pcd_novelis')
print(pcd_novelis)


local var1 = minimo('Risco') or 0
var1 = var1 + 0.58*pcd_novelis

if var1 < 5.125 then
   return 0
  elseif var1 < 8.385 then
   return 1
  elseif var1 < 13.855 then
   return 2
  elseif var1 < 16.125 then
   return 3
  else
   return 4
end
```

Figure 3: Analysis Model.



(a) **Alert Map for 11/12/2005** (b) **Alert Map for 18/01/2012**

Figure 4: Alert Maps Generated

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References

[1]DAI, F.C.;LEE, C.F. “Frequency–volume relation and prediction of rainfall-induced landslides”, Engineering Geology, Volume 59, Issues 3–4, April 2001, Pages 253-266, ISSN 0013-7952, http://dx.doi.org/10.1016/S0013-7952(00)00077-6.

[2]DIAS, L. R. P. T.; FONSECA, A. V.; COUTINHO, R. Q. “Identificação de áreas suscetíveis a deslizamento de terra utilizando sistema de informações geográficas”. Dissertação de Mestrado em Engenharia Ambiental Urbana - Salvador - Bahia, 2006.

[3]FERNANDES, L. S. O.; CAMPOS, L. E. P. “A influência da infiltração das chuvas na estabilidade de um talude natural”. Dissertação de Mestrado em Engenharia Civil – Especialização em Geotecnia - Porto – Portugal, 2014.

[4]INPE. Centro de Previsão de Tempo e Estudos Climáticos (CPTEC). Disponível em: <http://www.cptec.inpe.br/>. Acesso em: 09 de setembro de 2015.

[5]INTRIERI, E.; GIGLI, G.; MUGNAI, F.; FANTI, R.; CASAGLI, N. “Design and implementation of a landslide early warning system”, Engineering Geology, Volumes 147–148, 12 October 2012, Pages 124-136, ISSN 0013-7952, http://dx.doi.org/10.1016/j.enggeo.2012.07.017.

[6]LOPES, E. S. S.; NAMIKAWA, L. M.; REIS, J. B. C. “Risco de escorregamento: monitoramento e alerta de áreas urbanas nos municípios no entorno de Angra dos Reis - Rio de Janeiro”. In: 13° Congresso Brasileiro de Geologia de Engenharia e Ambiental, 2011, São Paulo. Anais. 2011.

[7]Mega Cidades. Cenários de risco e vulnerabilidades associadas a deslizamentos. Disponível em: <http://megacidades.ccst.inpe.br/sao_paulo/VRMSP/capitulo7.php>. Acesso em 18 de outubro de 2015.

[8]ONUBR. Nações Unidas no Brasil. ONU: Brasil está entre os 10 países com maior número de afetados por desastres nos últimos 20 anos. Publicado em: 24 de novembro de 2015.Disponível em: <https://nacoesunidas.org/onu-brasil-esta-entre-os-10-paises-com-maior-numero-de-afetados-por-desastres-nos-ultimos-20-anos/>. Acesso em: 01 de junho de 2016.

[9]Prefeitura de Ouro Preto. “Alerta Metereológico: Ouro Preto em estado de alerta”. Disponível em: <http://www.ouropreto.mg.gov.br/alerta-meteorologico/92/ouro-preto-em-estado-de-alerta>. Acesso em: 10 de abril de 2016.

[10]REIS, J. B. C.; SANTOS, T. B.; LOPES, E. S. S. “Monitoramento em tempo real de eventos extremos na Região Metropolitana de São Paulo – uma aplicação com o SISMADEN”. In: 14° Simpósio Brasileiro de Geografia Física Aplicada, 2011, Dourados, MS. Anais. 2011.

[11]REIS, J. B. C.; CORDEIRO, T. L.; LOPES, E. S. S. “Utilização do Sistema de Monitoramento e Alerta de Desastres Naturais aplicado a situações de escorregamento - caso de Angra dos Reis”. In: 14° Simpósio Brasileiro de Geografia Física Aplicada, 2011, Dourados, MS. Anais. 2011.

[12]REIS, J.B.C. “Monitoramento e alerta de inundação no município de Itajubá (MG) através de modelos matemáticos”. Dissertação de Mestrado em Ciências em Meio Ambiente e Recursos Hídricos – Itajubá - MG, 2014.

[13]SALCIARINI, D.; GODT, J. W.; SAVAGE, W. Z.; BAUM, R. L.; CONVERSINI, P. “Modeling landslide recurrence in Seattle, Washington, USA”, Engineering Geology, Volume 102, Issues 3–4, 1 December 2008, Pages 227-237, ISSN 0013-7952, http://dx.doi.org/10.1016/j.enggeo.2008.03.013.

[14]SILVA, N. L. Correlação entre pluviosidade e movimentos gravitacionais de massa no Alto Ribeirão do Carmo/MG. Mestrado em Geotecnia. Universidade Federal de Ouro Preto, UFOP, Brasil, 2014.

[15]WOLLE, C.M. “Análise dos escorregamentos translacionais numa região da Serra do Mar no contexto de uma classificação de mecanismos de instabilização de encostas”. 1988. 394f. Tese (Doutorado em Engenharia) – Escola Politécnica da USP, São Paulo.