Scientific Research Publishing

International Journal of Geosciences, 2018, 9, 669-679
http://www.scirp.org/journal/ijg
ISSN Online: 2156-8367
ISSN Print: 2156-8359

Correlation between Rainfall and Mass Movements in North Coast Region of Sao Paulo State, Brazil for 2014-2018

Daniel Metodiev, Marcio Roberto Magalhaes de Andrade, Rodolfo Moreda Mendes, Marcio Augusto Ernesto de Moraes, Tehrrie Konig, Cassiano Antonio Bortolozo, Tiago Bernardes, Rafael Alexandre Ferreira Luiz, Juliano Oliveira Martins Coelho

National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN), Sao Jose dos Campos, Sao Paulo, Brazil
Email: daniel.metodiev@cemaden.gov.br, marcio.andrade@cemaden.gov.br, rodolfo.mendes@cemaden.gov.br, marcio.moraes@cemaden.gov.br, tehrrie.pacheco@cemaden.gov.br, cassiano.bortolozo@cemaden.gov.br, tiago.bernardes@cemaden.gov.br, rafael.luiz@cemaden.gov.br, juliano.coelho@cemaden.gov.br

How to cite this paper: Metodiev, D., de Andrade, M.R.M., Mendes, R.M., de Moraes, M.A.E., Konig, T., Bortolozo, C.A., Bernardes, T., Luiz, R.A.F. and Coelho, J.O.M. (2018) Correlation between Rainfall and Mass Movements in North Coast Region of Sao Paulo State, Brazil for 2014-2018. *International Journal of Geosciences*, **9**, 669-679.
https://doi.org/10.4236/ijg.2018.912040

Received: November 20, 2018
Accepted: December 24, 2018
Published: December 27, 2018

Abstract

The monitoring of related hourly and accumulated rainfall index requires that critical thresholds of accumulated 72 hours rainfall are updated frequently according with the factors and local conditions (natural and anthropic) of each specific risk area. The importance of empirical methods is fundamental to confirm the relationship between rainfall intensity and accumulated rainfall with the mass movement events, in order to establish the critical threshold values. The present work performs an evaluation of the record data of mass movement events occurred in Sao Paulo State North coast region for a 4-year period (2014 to 2018) considering different mass movement characteristics (slope type, magnitude and impact level). Some rainfall values were obtained to show that within these parameters an event related to natural and anthropic features was triggered. A database was created, sorting source of information and municipalities monitored, to implement the correlation between the mass movement events and the rainfall values. To elaborate the event's map, reliable record data of localization of the mass movement events was selected, as well as the nearest possible raingauges of CEMADEN (National Center for Monitoring and Early Warning of Natural Disasters); also the exact event triggering time, selection by the slope type, the magnitude and the impact level of the mass movement event. The rainfall values of these raingauges allowed the calculation of the accumulated rainfall index for 1, 3, 6, 24, 48, 72 and 96 hours, with the adoption of the 72 hours index for this work. The correlation graphics are divided by the slope type, the magnitude and the impact level of the mass movement event. Different critical thresholds appear, classifying such event by the influence level of triggering factors, natural and/or anthropic.

Keywords

Mass Movement Events, Rainfall Intensity, Accumulated Rainfall, Critical Thresholds, Sao Paulo State-Brazil

1. Introduction

Accordingly with the United Nations (1993) the mass movements are one of the natural phenomena that cause the most financial impact and deaths in the world. The mass movements assume catastrophic proportions in urban areas causing structural damages and human losses. In Brazil rainfall is the principal natural factor that causes floods, riverside collapses, intensification of erosional processes and evidently, they decisively contribute to mass movement triggering. As a result of specifically geological risk scenarios natural processes may occur in different scales becoming disasters and catastrophes with huge material and social impact [1]. Civil Defense Preventive Plan—PPDC (in Portuguese) was elaborated in 1988, specifically to attend the frequent mass movements in Serra do Mar Mountain slope in Sao Paulo State. PPDC constitutes an important technical tool for management, monitoring and control of mass movement risk areas. Evacuation of vulnerable population living insusceptible areas, before the mass movement events occur, is a main prevention al action of the PPDC.

The main operability of PPDC involves the monitoring of the related rainfall values (hourly and accumulated 72 hours rainfall index), as well as weather forecast, field inspection and emergency situations [2]. Currently, these activities are developed in ten regions of Sao Paulo State, considering that Baixada Santista and Litoral Norteare two of them. The PPDC deals with preventive actions of mass movement associated risk in slope and talus areas inappropriate for occupation.

Therefore, the aim of this study is to present the interaction between the accumulated 6 h × 72 h rainfall correlated with the triggering time of the mass movement events in connection of the critical pluviometric thresholds [3]. The last is of extreme importance for the functional efficiency of the PPDC preventive actions. It is suggested an evaluation model of the mass movement events' register and the rainfall database for a 4-year period (2014 to 2018) in Baixada Santista and Litoral Norte regions (**Figure 1**). The intention is to perform an actualization and classification of the critical thresholds. This may be considered a very important empirical tool for the landslide risk management efficiency due to the preventive action improvement and the social/material impact mitigation.

2. Methodology and Development of the Proposed Model

Figure 2 presents the proposed model applied in area which is situated on Sao

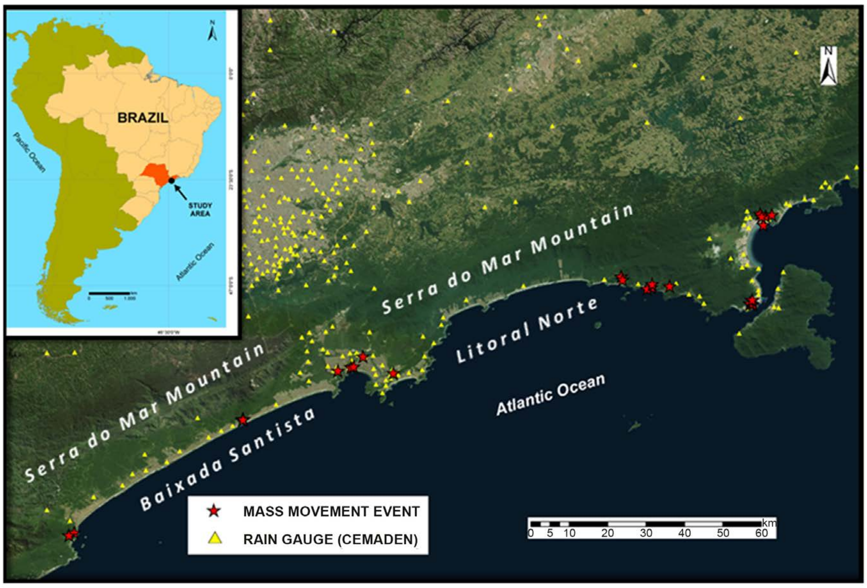

Figure 1. Map of the study area with geographic position of the CEMADEN rain gauge network and the evaluated mass movement events.

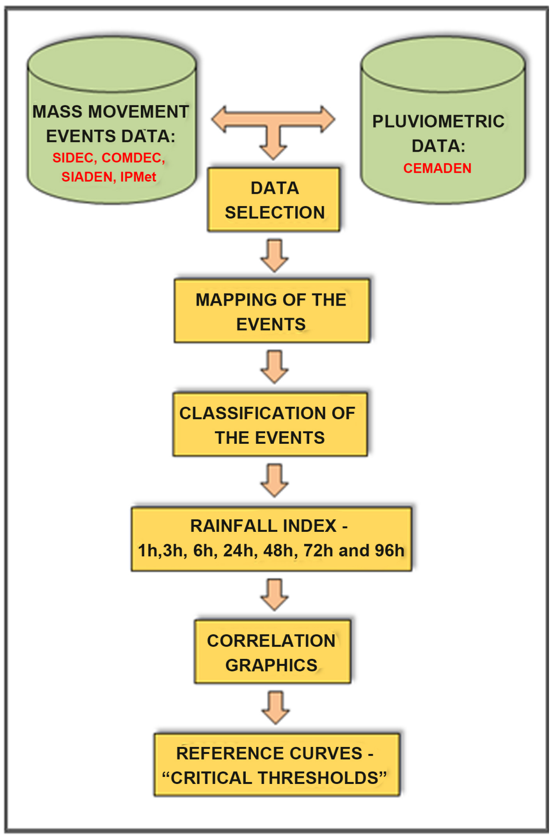

Figure 2. Flowchart of sequential stages to correlation between rainfall values and mass movement events.

Paulo State north coast between Serra do Mar Mountains and the South Atlantic Ocean. This area covers 13 municipalities—Peruibe, Itanhaem, Mongagua, Praia

Grande, Sao Vicente, Cubatao, Santos, Guaruja and Bertioga (Baixada Santista-region) and SaoSebastiao, Ilhabela, Caraguatatuba and Ubatuba (Litoral Norte-region). The mass movement susceptibility varies of each COMDEC (Regional Civil Defense Municipality Units) attendance area of all these 13 municipalities, being a reflex of the physical factors and conditions (lithological and pedological substrate, relief, slope position and declivity, vegetal covering, pluviometric precipitation patterns, etc), as well as the anthropic conditions of the risk area (environmental degradation, slope cut, dumped landfills and embankments on top of the talus, pipe leakages and other).

2.1. Mass Movement Events Data

For development of this study mass movement events data has been acquired from official registers [4], such as the Civil Defense Integrated System of Sao Paulo State (SIDEC), which includes field inspection reports of the Sao Paulo State Geological Institute (IG) and of the Institute of Technological Research (IPT).

Other data sources that could be used—COMDEC (Regional Civil Defense Municipality Units), Meteorological Research Institute (IPMet) of the State University of Sao Paulo (UNESP) and of the newly created database of the Natural Disaster Alerting System (SIADEN) of CEMADEN, but these data sources will be included and analyzed at the next stage of the study. The correlations in this work were elaborated with SIDEC mass movement events data, essentially (**Table 1**).

2.1.1. Data Selection

There were evaluated 32 mass movement event registers, but some of them (8) cannot be used due to absence of important data, such as correct date and time of the event. For example, the lack of event time or confusion on the report tab page between triggering time and Civil Defense actioning/attending time, and the lack of correct event location (wrong coordinates or/and incomplete addresses). These generate a lot of uncertainties on the organization of the mass movement database [5]. A generalization of all type of events during their registration process mixing and confusing different events and disasters is a common mistake in the field reports. For example, mixing of landslides with riverside and roadside collapses, floods and rainfall torrents, gravitational soil subsidences, falling/slumping of rock blocks and other. Another important factor to be considered in an empirical correlation study is the distance between the rain gauges and the mass movement events. Inexistence of rain gauges within a distance of 3 km from the event to be analyzed makes the correlation results more abstract, especially the critical thresholds.

2.1.2. Mapping of the Events

Is necessary to geo-reference the coordinates (latitude and longitude) to provide the correct location of each mass movement event data, as well as to identify the

Table 1. An example for elaboration of mass movement events database for Baixada Santista and Litoral Norte regions for a 2014 to 2018 period (source: SIDEC).

N	MUNICIPALITY	LOCATION[1]		TYPE	MAGNITUDE[2]	IMPACTS[3]	DATE/TIME[4]
				BAIXADA SANTISTA region			
92	Guaruja	7,347,705	372,006	Natural slope/dumped landfill	500 m^3	44 remov. residents/ 11 interd. housing	26/03/14 - 16.00 h
118	Mongagua	7,335,069	336,162	Slope cut	4 m^3	8 remov. residents/ 3 interd. housing	28/02/16 - 22.40 h
119	Mongagua	7,335,343	336,331	Natural/slope cut/ compacted landfill	5 m^3	13 remov. residents/ 3 interd. housing	29/02/16 - 00.30 h
120	Mongagua	7,335,318	336,319	Natural/slope cut	10 m^3	4 remov. residents/ 4 interd. housing	29/02/16 - 06.00 h
146	Santos	7,351,980	364,754	Slope cut/dumped landfill	90 m^3	12 remov. residents/ 3 interd. housing	23/01/15 - 01.40 h
147	Santos	7,349,107	361,915	Slope cut/dumped landfill	600 m^3	64 remov. residents/ 16 interd. housing	23/01/15 - 00.50 h
148	Santos	7,349,230	361,593	Natural slope	960 m^3	0 remov. residents/ 0 interd. housing	23/01/15 - 02.30 h
163	Sao Vicente	7,348,211	358,756	Compacted landfill	no data	0 remov. residents/ 0 interd. housing	21/01/17 - 17.40 h
				LITORAL NORTE region			
48	Caraguatatuba	7,389,376	462,078	Slope cut	100 m^3	28 remov. residents/ 7 interd. housing	31/01/15 - 20.00 h
49	Caraguatatuba	7,386,697	460,046	Slope cut	41 m^3	8 remov. residents/ 2 interd. housing	23/03/16 - 22.00 h
50	Caraguatatuba	7,389,634	459,494	slope cut	15 m^3	28 remov. residents/ 7 interd. housing	15/03/17 - 05.00 h
51	Caraguatatuba	7,389,181	460,017	Natural slope/debris flow	no data	60 remov. residents/ 15 interd. housing	15/03/17 - 05.30 h
151	Sao Sebastiao	7,366,229	457,076	Natural/slope cut	100 m^3	12 remov. residents/ 3 interd. housing	23/12/14 - 16.40 h
153	Sao Sebastiao	7,366,081	457,654	Natural/slope cut	90 m^3	20 remov. residents/ 5 interd. housing	15/01/16 - 03.20 h
155	Sao Sebastiao	7,372,365	426,521	Natural slope	3000 m^3	148 remov. residents/ 37 interd. housing	29/02/16 - 04.50 h
157	Sao Sebastiao	7,370,362	433,404	Natural slope	320 m^3	24 remov. residents/ 6 interd. housing	29/02/16 - 05.10 h
158	Sao Sebastiao	7,370,014	432,415	Natural/slope cut	160 m^3	0 remov. residents/ 1 interd. housing	29/02/16 - 05.10 h
159	Sao Sebastiao	7,371,245	433,533	Natural slope/debris flow	800 m^3	20 remov. residents/ 5 interd. housing	29/02/16 - 05.10 h
160	Sao Sebastiao	7,370,747	437,769	Natural/slope cut	900 m^3	26 remov. residents/ 7 interd. housing	29/02/16 - 05.30 h
176	Ubatuba	7,404,719	491,165	Slope cut	250 m^3	6 remov. residents/ 3 interd. housing	23/02/18 - 01.00 h
178	Ubatuba	7,404,657	491,033	Slope cut	80 m^3	8 remov. residents/ 4 interd. housing	23/02/18 - 01.00 h

Continued

179	Ubatuba	7,401,486	491,541	Natural/slope cut	400 m^3	15 remov. residents/ 5 interd. housing	23/02/18 - 05.00 h
180	Ubatuba	7,402,055	491,413	Natural slope	50 m^3	8 remov. residents/ 2 interd. housing	23/02/18 - 05.00 h
187	Sao Sebastiao	7,366,179	457,060	Natural/slope cut	no data	28 remov. residents/ 7 interd. housing	15/02/18 - 03.40 h
TOTAL				24 MASS MOVEMENT EVENTS	**584 removed residents/156 interdited housing**		

[1]UTM Location of Fuse 23 South. [2]Estimated Volume of Mobilized Mass Material. [3]Interim and/or Permanent Measures and Actions. [4]GMT Revised Date/Time.

rain gauges within the radius of the pluviometric influence. It is very important detail before to start the acquisition and processing of the rainfall triggering values [6]. From the data spatial positioning is possible to connect the important key-points (mass movement events/rain gauges) with existing thematic data of the area–geological, geotechnical, geomorphological and pedologicalmaps of the region, but also with urban development municipal layouts from the last 20 - 30 years [7].

2.1.3. Classification of the Events

The classification of landslide and mud/debris flow events allows making a more detailed evaluation with regard to the proportions and the triggering causes in order to define the critical thresholds of each mass movement event locality:

- **Typology of the events**—were prioritized only translational/rotational landslides, natural/induced, mud/debris flows. The correlation graphic (**Figure 3**) considers a classification of the events divided by sloping rupture and sloping movement type: natural slope (1), dumped/compacted landfill (2) andslope cut (3).
- **Magnitude**—it was estimated considering the total volume of the mobilized material (m^3) in mass movement volumescale (**Figure 4**): low < 15 m^3 (1), medium low 16 - 100 m^3 (2), medium high 101 - 500 m^3 (3), high 501 - 1000 m^3 (4), very high > 1001 m^3 (5) and not available data (6).
- **Impact and damages**—a classification was adopted by 4 (four) groups of affected houses (**Figure 5**): low < 2 (1); medium low 3 - 6 (2); medium high 7 - 10 (3) and high > 11 (4).

2.2. Pluviometric Data

Rainfall data was obtained directly from the information platform of the CEMADEN monitoring automatic pluviometric network. To select all specific rainfall data, a 3 kilometers effective distance was adopted between the mass movement event location and the closest rain gauge in operation (**Table 2**). Due to the absence of any rain gauges in the proximity of some mass movement events the distance less than 3 kilometers is not recommended. Depending on the type and the scale of the triggering rainfall (Isolated Tropical Convection or

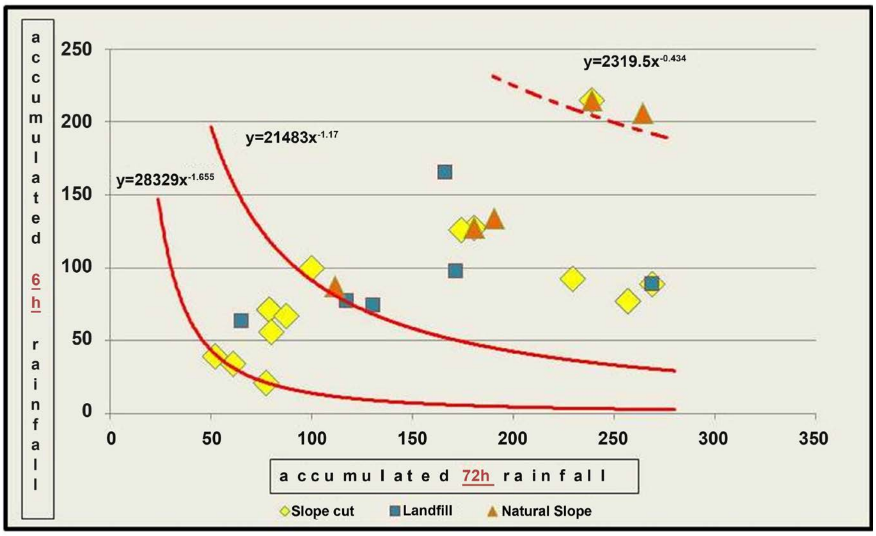

Figure 3. Graphic showing the relation between accumulated 6 h × 72 hrainfall from the local time of the mass movement events divided by the type of the slope and the talus rupture.

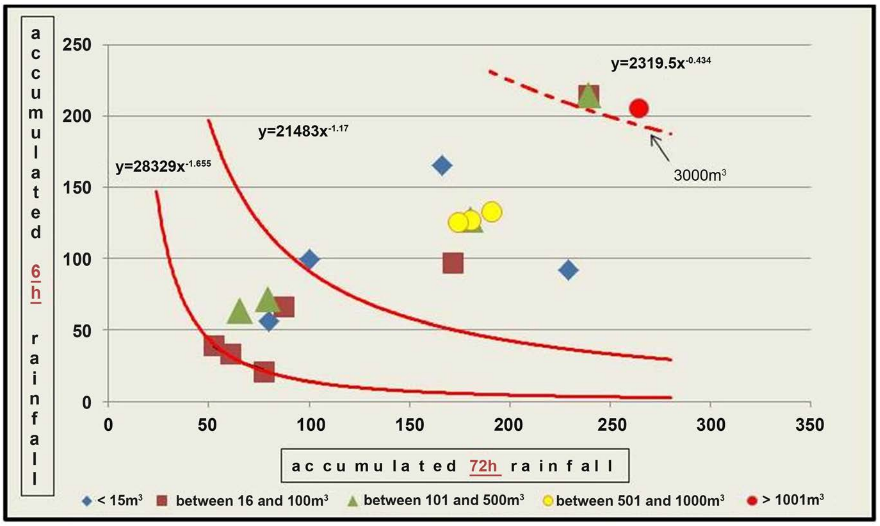

Figure 4. Graphic showing the relation between accumulated 6 h × 72 h rainfall from the local time of the mass movement events divided by magnitude (m^3).

Table 2. Correlation between mass movement event time and accumulated rainfall index for Baixada Santista/Litoral Norte regions (pluviometric data source: CEMADEN).

N	MUNICIPALITY	STATION[1]	DISTANCE[2]	ACCUMULATED RAINFALL INDEX[3]						
				1 h	3 h	6 h	24 h	48 h	72 h	96 h
				BAIXADA SANTISTA region						
92	Guaruja	351870119A	1.014	49.3	63.5	63.5	64.9	64.9	65.3	111.4
118	Mongagua	353110003A	2.755	74.6	99.4	99.4	99.4	99.4	100.2	100.2
119	Mongagua	353110003A	3.050	36.0	144.0	165.3	165.3	165.3	166.1	166.1
120	Mongagua	353110003A	3.022	1.2	2.6	92.5	228.5	228.5	229.3	229.3

Continued

146	Santos	354850013A	1.272	26.7	72.2	97.5	119.1	171.7	171.7	171.7
147	Santos	355100903A	0.599	18.1	55.6	74.0	106.1	130.5	130.5	130.5
148	Santos	355100903A	1.237	33.2	93.9	133.6	145.0	190.5	190.5	190.5
163	Sao Vicente	355100904A	0.931	36.3	76.8	76.8	85.7	101.5	117.6	138.3
				LITORAL NORTE region						
48	Caraguatatuba	351050017A	0.447	3.5	10.0	20.8	77.2	77.2	77.2	77.2
49	Caraguatatuba	351050007A	2.800	21.4	66.8	66.8	66.8	66.8	87.3	87.3
50	Caraguatatuba	351050010A	1.802	55.1	55.9	56.1	68.8	80.0	80.0	80.0
51	Caraguatatuba	351050010A	1.082	66.3	87.3	87.5	99.8	111.4	111.4	111.4
151	Sao Sebastiao	355070409A	0.778	32.1	33.7	33.7	48.0	60.9	60.9	60.9
153	Sao Sebastiao	355070409A	0.378	11.4	23.6	39.2	43.5	43.7	52.2	63.7
155	Sao Sebastiao	355070411A	0.135	82.3	86.3	205.9	258.5	258.5	264.2	264.2
157	Sao Sebastiao	355070406A	0.86	84.6	88.2	127.3	177.5	177.5	180.5	180.5
158	Sao Sebastiao	355070406A	1.128	84.6	88.2	127.3	177.5	177.5	180.5	180.5
159	Sao Sebastiao	355070406A	0.828	84.6	88.2	127.3	177.5	177.5	180.5	180.5
160	Sao Sebastiao	355070419A	1.655	88.7	89.7	126.1	173.6	173.8	174.2	174.2
176	Ubatuba	355540606A	1.877	27.0	31.5	71.3	73.3	79.0	79.2	79.8
178	Ubatuba	355540606A	2.019	27.0	31.5	71.3	73.3	79.0	79.2	79.8
179	Ubatuba	355540623A	2.602	7.5	109.0	215.1	230.7	238.7	238.9	241.1
180	Ubatuba	355540623A	2.259	7.5	109.0	215.1	230.7	238.7	238.9	241.1
187	Sao Sebastiao	355070409A	0.797	26.2	58.1	77.4	214.9	224.3	257.0	257.0

[1]Nearest Pluviometric Station (CEMADEN); [2]Distance in km; [3]Percipitation in mm.

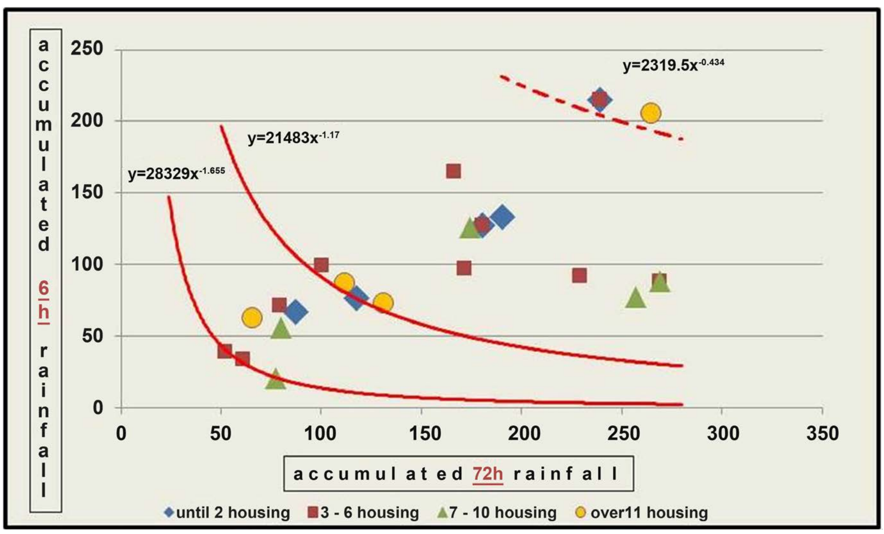

Figure 5. Graphic showing the relation between accumulated rainfall 6 h × 72 h from the local time of the mass movement events divided by the impact level: affected houses.

Cold Front), the distance higher than 3 kilometers puts at risk the quality and relevance of the correlation results obtained.

Rainfall Index

In Baixada Santista and Litoral Norte regions, rainfall values related to each individual mass movement event (32) were the basis for definition of the critical thresholds and their associated triggering rainfalls. The CEMADEN automatic pluviometric network sends the rainfall values acquired with 10 minutes frequency. Pluviometric indices were calculated according to the studies of Tatizana *et al.* [8] and Santoro *et al.* [9]. These studies present de relation between accumulated rainfall in 1, 3, 6, 24, 48, 72 and 96 hours. In correlation graphics can be observed that accumulated 6 h × 72 h rainfall index relation could divide some mass movement events groups [10], indicating specific critical thresholds between each type of event (**Figures 3-5**).

3. Correlation Graphics between Mass Movement Events and Rainfall: Critical Threshold Elaboration

In **Figures 3-5** stands out that many mass movement events are triggered due to rainfall intensity or/and accumulated precipitation regime below the PPDC official critical threshold pattern [8] and [11]. For induced landslides in the regions Baixada Santista and Litoral Norte a new critical thresholds values of the triggering rainfall can be suggested. They could be considerably less of the PPDC proposed triggering reference lines. Then mass movement events present low critical thresholds could stay far below of the Tatizana *et al.* [8] triggering reference line. They could be associated with a high contribution of several triggering anthropic actions [12].

Critical thresholds by the type of the slope and the talus rupture—the graphic suggests that the slope cut landslides could have lower triggering thresholds than the PPDC proposed (**Figure 3**). Dumped landfill landslides are triggered in 50 mm/72 h accumulated precipitation index, natural slope landslides occurring above of 100 mm/72 h accumulated precipitation index and debris/mud flows usually occurring above of 220 mm/72 h accumulated precipitation index.

Critical thresholds by magnitude—the graphic suggests that an accumulated rainfall above of 50 mm/72 h precipitation index could cause high magnitude landslides (**Figure 4**).

Critical thresholds by the impact—the graphic suggests that accumulated rainfall above of 50 mm/72 h of precipitation index could cause medium to high impact landslides (**Figure 5**).

Main critical threshold line—the graphic suggests that the principal critical threshold line is fixed in 100 mm (accumulated 72 h rainfall index) separating rainfall triggered mass movement events from induced events by anthropic factors (**Figure 6**). In the zone above the critical line, the events data presents higher level of accuracy than in the zone below this line that presents lower accuracy level.

Is important to highlight that between the first (50 mm) and the second (100

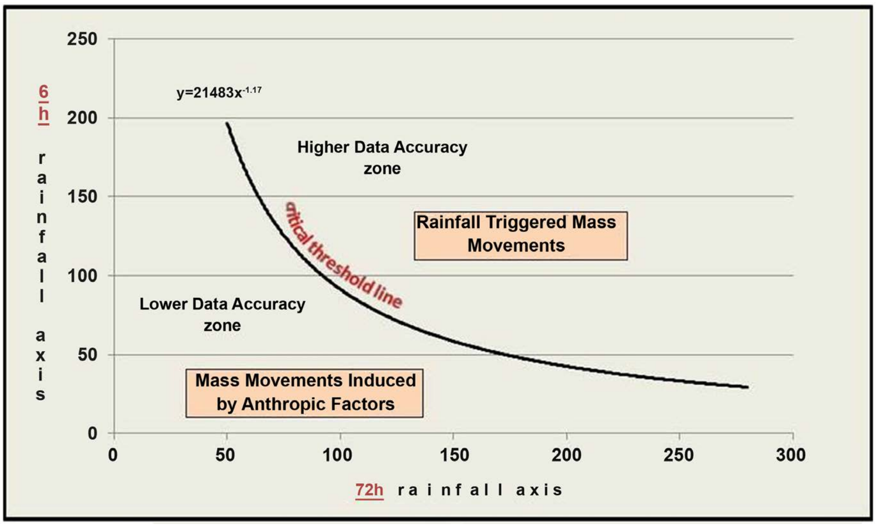

Figure 6. Graphic showing the most relevant critical threshold line separating natural from induced mass movement event zones.

mm) critical threshold line there is clear evidence of interaction between the inducing and the natural triggering factor. However, when the critical threshold line increase, the level of data uncertainties reduce. The same happen when the critical threshold line decrease and inducing factor begins to prevail, the level of data uncertainties reduce.

4. Conclusions

The results, although preliminary, indicate some relevant trends on analysis, which point to reach a better understanding of the mass movement dynamics in the regions concerned. The COMDEC (Regional Civil Defense Municipality Units) data sources and nonevent rainfall data to be incorporated in the future will allow more consistency of the mass movement event analysis and could confirm these correlations.

This kind of data in Brazil, such as rainfall values as well as mass movement event data, is very sparse and hampers the robust analysis, making more difficult the critical threshold actualization with the necessary precision. That takes the critical threshold definition at even lower levels, which can create a disproportionately large amount of alerts, many of them without any associated mass movement event.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Tominaga, L.K. (2012) Escorregamentos. In: Tominaga, L.K., Santoro, J. and Amaral, R., Eds., *Desastres Naturais*: *Conhecer para prevenir* 2, GeologicalInstitute, Sao Paulo/SP, 2.

[2] Mendes, R.M., Valério Filho, M., Bertoldo, M.A. and Silva, M.F. (2015) Estudos de

limiares críticos de chuva deflagradores de deslizamentos no município de São José dos Campos (Brasil). In: *Territorium*, Coimbra/PT, 22, 119-129.

[3] Jamaludin, S. and Ali, F. (2011) An Overview of Some Empirical Correlations between Rainfall and Shallow Landslides and Their Applications in Malaysia. *Electronic Journal of Geotechnical Engineering*, **16**, 1429-1440.

[4] Ide, F.S. (2005) Escorregamento, meteorologia e precipitação: Uma proposta de método de investigação para prevenção e monitoramento de riscos, aplicado em Campinas/SP. Master's Thesis, Technological Research Institute—IPT, Sao Paulo.

[5] Fernandez, G.N. (2018) Determinação de limiares críticos de chuva deflagradores de movimentos gravitacionais de massa, Município de São Bernardo do Campo, SP. Master's Thesis, Geosciences Institute, University of Sao Paulo, USP, Sao Paulo/SP, 126 p.

[6] D'Orsi, R., D'Ávila, C., Ortigão, J.A.R., Dias, A., Moraes, L. and Santos, M.D. (1997) Rio-Watch: The Rio de Janeiro landslidewatch system. *In Conference*: *Conferência Brasileira Sobre Estabilidade de Encostas* 2, Rio de Janeiro/RJ, 1997, Vol. 1, 21-30.

[7] Alheiros, M.M., Souza, M.A.A., Bitoun, J., Medeiros, S.M.G.M. and Amorim Jr., W.M. (2003) Manual de ocupação de morros da Região Metropolitana de Recife. Recife: Fundação de Desenvolvimento Municipal, Recife/PE, 384 p.

[8] Tatizana, C., Ogura, A.T., Cerri, L.E.S. and Rocha, M.C.M. (1987) Modelamento numérico da análise de correlação entre chuvas e escorregamentos aplicado às encostas da Serra do Mar no município de Cubatão. In: *Anais do Congresso Brasileiro de Geologia de Engenharia* 5, São Paulo/SP, 1987b, 2, 237-248.

[9] Santoro, J., Mendes, R.M., Pressinotti, M.M.N. and Manoel, G.R. (2010) Correlação entre chuvas e deslizamentos ocorridos durante a operação do plano preventivo de defesa civil em São Paulo, SP. In: *Anais do Simpósio Brasileiro de Cartografia Geotécnica e Geoambiental* 7, Maringá/PR, 2010, 1-15.

[10] Guidicini, G. and Iwasa, O.Y. (1976) Ensaio de correlação entre pluviosidade e escorregamentos em meio tropical úmido. In: Technological Research Institute—IPT, 1080, Sao Paulo, 1-48.

[11] Elbachá, A.T., Campos, L.E.P. and Bahia, R.F.C. (1992) Tentativa de correlação entre precipitação e deslizamentos na cidade de Salvador. In *Conference*: *Conferência Brasileira Sobre Estabilidade de Encostas* 1, Rio de Janeiro/RJ, 1992.

[12] Parizzi, M.G., Sebastião, C.S., Viana, C.S., Pflueger, M.C., Campos, L.C., Cajazeiro, J.M.D., Tomich, R.S., Guimarães, R.N., Abreu, M.L., Sobreira, F.G. and Reis, R. (2010) Correlação entre chuvas e movimentos de massa no município de Belo Horizonte, MG. In *Geografias*, Belo Horizonte/MG, Vol. 6, 2, 49-68.