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Monitoring Landslides Conditions in Madeira Island Using NOAA Operational Satellites

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Abstract: Soil water excess, as well as deficit, leads to vegetation stress, i.e., photosynthesis decline, stomata closure, growth reduction, decrease in respiration and biomass production. Therefore, vegetation response can be used as indicator of changing in soil conditions, which corresponds to such phenomena as drought or soil waterlogging and associated natural disasters. During last 20 years, National Oceanic and Atmosphere Administration, National Environmental Satellite Data and Information Services (NOAA/NESDIS) satellite-based vegetation health indices (VHI) were successfully used for monitoring environmentally-based vegetation stress, including droughts, fire risk, soil saturation and other natural hazards around the world. In this study, the VHI were applied to verify the possibility their utilization for detection landslide risk areas in Madeira Island. Vegetation condition index (VCI) and registered precipitation were analyzed together with information on landslide occurrence in recent years.

Key words: Soil water excess, natural disasters, landslide, satellite products, vegetation health indices.

1. Introduction

The term "landslide" means the movement of a mass of soil, rock or debris down a slope under the effect of gravity force [1]. Landslides are part of the normal geomorphological process and the most common natural disaster in the mountain areas as well. Although the landslides are local phenomena, they can lead to huge direct and indirect human and economic losses. Various studies have reviewed the economic losses and casualties because of landslides [2-4]. Following Herath and Wang [4], during 1993-2002, total number of people, affected by landslides, made up 19,740 in Africa, 4,667,943 in America, 5,055,856 in Asia and 41,536 in Europe. Sidle and Ochiai [3] provide estimation of direct and total losses in various countries due to landslides (Table 1).

Landslides differ by material and type of movement and their occurrence and frequency are controlled by various factors, which can be grouped into preparatory, responsible for instability of the slope, and triggering, which cause landslide occurrence [1, 5]. The contribution of each factor into landslide occurrence and intensity depends on environmental conditions such as climate, internal relief, geological setting, geomorphological evolution and processes [6, 7]. Soil saturation by water is considered as a more usual natural cause of landslides because it leads to slope instability. Saturation may come because of heavy or persistent precipitation, melting and rapid changes in groundwater level along a slope. However, rainfalls are identified as the primary natural factor of slope movements worldwide [8, 9]. By this reason antecedent persistent rainfalls play important role in the landslide's initiation, even if the daily amount of precipitation was not large [6, 10-12]. Such rains over time might cause near-saturation state of soil and a loss of slope stability in mountain areas. This situation is very typical for Madeira Island, which is a well-known tourist place, visited by more than one million tourists each year [13]. Madeira suffers from

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Table 1 Average costs of annual landslides in various countries [4].

Country	Average annual direct costs	Average annual total costs
Canada		$70 million
Japan	$1.5 billion	$4 billion
Korea	$60 million	-
Italy	-	$2.6-5 billion
Sweden	$10-20 million	
Spain	$0.2 billion	
Former USSR	$0.5 billion	
China	$0.5 billion	
India	$1.3 billion	
Nepal	$19.6 million	

Table 2 Daily precipitation (mm), registered by the meteorological stations No. 967 and No. 970.

	No. 967	No. 970
07-01-2014	22.8	91.1
08-01-2014	36.8	25.5
09-01-2014	0.6	0.2
10-01-2014	0	0
11-01-2014	0	0
12-01-2014	33.2	12.9
13-01-2014	8.2	11.7
Total	101.6	141.4

landslides almost every year because of appropriate environmental conditions for landslide occurrence and well-developed urban areas and road net. Complex orography, altitudes up to 1,862 m, prolonged and accentuated rain season (September-May) and significant percentage of soils with large water retention capacity are the main natural reasons for frequent landslides, which sometimes lead to significant human and economic losses [14-16].

Thus, spatial and temporal distribution of soil moisture, which is controlled by rainfall, slope morphology, geological characteristics and peculiarities of 3-D soil profiles are the leading factors causing landslides. Unfortunately, these data are not available or difficult to get. Since antecedent rainfalls determine soil moisture, accumulated precipitation could be used as a criterion for evaluation of critical conditions for landslide initiation [12, 17, 18]. However, due to a large spatial and temporal precipitation variability and complex orography in mountain areas, even good density of meteorological stations (for example, in Madeira Island every station provides spatial coverage about 50 km^2) does not allow estimating intensity and spatial distribution of rainfalls and potential for landslides development. Meanwhile, vegetation response to soil water can be an effective measure of environmental changes and remote sensing of earth surface from operational satellites provides spatial information in near-real time, needed for early monitoring of landslides.

During the last 20 years, in National Environmental Satellite Data and Information Services of National Oceanic and Atmosphere Administration (NOAA/NESDIS), satellite-based method of vegetation health indices (VHI) was developed, tested, validated and applied globally and regionally for monitoring land surface changes. Vegetation health (VH) is represented by three indices: vegetation condition index (VCI), temperature condition index (TCI) and VHI. VCI, TCI and VHI are a proxy for vegetation moisture conditions, vegetation thermal conditions and moisture-thermal VH, respectively.

These indices were successfully used for monitoring environmentally-based vegetation stress, including droughts, fire risk, soil saturation and other natural hazards around the world (http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/index.php). This paper presents a new development in the application of VH method for monitoring landslide risk areas in Madeira Island.

2. Soil Water-Plant Relations and VHI

Excess of water in the soil, as well as a water scarcity, leads to plants stress. Therefore, vegetation is an excellent indicator of changing in soil conditions, which correspond to such meteorological phenomena as droughts, floods and associated natural disasters.

Physiological and biochemical vegetation response to soil water deficit is well investigated: plants under droughts stress exhibit growth reduction, photosynthesis decline, stomata closure, decrease in respiration and biomass production [19]. Therefore, even relatively short droughts, which coincide with crop growing period, can lead to big losses in crop yield later. Drought-related vegetation stress is well detected from satellite measurements and derived products. NOAA/NESDIS VHI method has demonstrated an excellent result in detection and monitoring droughts (drought start, end, area, intensity and duration, drought-related losses of crop and pasture production, wildfire risk) [20, 21]. VH indices are based on the Normalized Difference Vegetation Index (NDVI), brightness temperature (BT) and their climatology. NDVI reflects physiological and biochemical state of vegetation (chlorophyll, carotenoid, water content and cell structure) which are controlled by soil moisture. Since drought inhibits photosynthesis in plants by closing stomata, reducing chlorophyll contents and altering processes of metabolism, satellite-derived vegetation stress can be used as an indicator of soil moisture.

Vegetation stress due to waterlogging occurs when the soil was inundated or the water table rose, so that a part of root zone became near-saturated. Jackson [22] notes that in nature, almost all land surfaces (even deserts) were inundated because of rains. Moreover, intensive and large-scale irrigation of farmland can also increase the incidence of soil waterlogging and water table can rise as result. Most plants cannot grow and even can be destroyed in waterlogged soils. Plants need oxygen for normal metabolism. Waterlogging causes condition of hypoxia (low oxygen concentration) in soils because water fills all the pores and oxygen has the low water solubility. Waterlogging-based plant hypoxia leads to photosynthesis decline, stomata closure, growth reduction, decrease in respiration and biomass production, similar to drought stress [22, 23]. As a result, the plants can show wilting even when covered by water.

McFarlane and Cox [24] estimated crop losses due to waterlogging that occurred in Western Australia each year when rainfalls exceed 400 mm. Such waterlogging occurs in a minimum 8% of the total crop area (1.3 million hectares of pastures and near 500,000 ha of cultural land). On the area 250,000 ha the yield of barley was 20%-25% reduced. According to Hatfield [23], visible symptoms of wilting are notable after 7-8 d of flooding, while the reduction in photosynthetic activity is noticeable already 2 d after waterlogging. Therefore, NDVI-based indices are appropriate for soil water excess detection. For detection soil water excess in Madeira Island and investigation of potential of using, VHI method was applied, because it has shown an excellent result for operational monitoring of land surface conditions [20, 21, 25-28].

3. Environmental Conditions Favoring Landslides Occurrence in Madeira Island

The Madeira Island, with a total area of 742 km^2 (maximum length 58 km in East-West direction, maximum width 23 km in North-South), has a very rugged relief (Fig. 1). The high altitude mountains, separated by deep ravines, are predominated. The highest points, Pico Ruivo (1,862 m) and Pico do Arieiro (1,818 m), are in the central part of the island. The high cliffs predominate in the northern coast of Madeira; the plateau Paul da Serra (1,300-1,500 m) is situated in the central-western part of the island [29, 30]. In spite of small size the Madeira Island has 126 hydrological basins, 94% of which have less than 25 km^2 in size [31].

Madeira Island soils have volcanic origin, up to 64% of which belong to Andosols type [30, 32-34]. They are rich in organic matter, have fine texture, high percentage of silty clay and most of them are deeper than 50 cm. Having high proportion of medium and large pores, they are characterized by fast water transport (compared to other soils), low bulk density and large water retention capacity. As to Atterberg limits [35], andosols have very high liquid limit, but a low range where the soil is plastic. Thixotropy, a special property of andosols, means that the soil can reach the liquid limit, changing from plastic state to liquid upon disturbance and becoming water saturated. Therefore, since soil water content is the principal reason determining thixotropic soil behavior [36], landslides are easy to occur in case of prolonged and extreme precipitation. Thus, landslides usually occur on slopes with andosols [37].

The archipelago of Madeira (except for high areas with lower temperatures) is located in the subtropical region, with a mild climate in winter and summer. There are 14 meteorological stations, distributed mostly on the cost of Madeira (Fig. 1). During the winter months, low air pressure systems, crossing the Atlantic down to the latitudes of Madeira, are the main reason for abundant rainfalls. The high altitude topography favors the occurrence of excessive precipitations, making some areas of Madeira Island very wet. However, summer rainfalls are much lower than the rest of the year. Another important climate feature is a considerable decrease in precipitation from north to south, especially in summer (Fig. 2). In spite of good density of meteorological station, their number is not sufficient to characterize precipitation distribution, because of Madeira's complex geographic features.

Summarizing, due to complex orography, prolonged, excessive winter rains and a large percentage of andosols soils, Madeira Island has frequent landslides. Taking into account peculiarities of orography, soils, climate, weather and large number of hydrological basins, detection of potential landslide areas requires monitoring land surface and environmental conditions of Madeira with the appropriate high spatial resolution. Therefore, in this study it was applied the method, which is able to detect temporarily waterlogged areas, which, along with complex orography and clay soils, become an indicator of landslide risk areas.

4. Data

Two data types (satellite and ground) were used in this research. Satellite data were represented by radiance measured using advance very high resolution radiometer (AVHRR) on National Oceanic and Atmospheric Administration (NOAA) polar-orbiting operational environmental satellites. The AVHRR provides observations in five spectral bands or channels: (i) 0.58-0.68 μm (Ch1 or visible (VIS)), (ii) 0.725-1.10 μm (Ch2 or near infrared (NIR)), (iii) 3.55-3.93 μm (Ch3 or mid-IR), (iv) 10.3-11.3 μm (Ch4, IR), and (v) 11.5-12.5 μm (Ch5, IR). These measurements are collected for each pixel (area 4 km × 4 km) for the entire world. The VH method is using calibrated channels 1, 2 and 4 to calculate the NDVI (NDVI = (Ch2 – Ch1)/(Ch2 + Ch1)) and BT (BT from Ch4) [38, 39]. NDVI quantifies vegetation greenness and BT quantifies radiating temperature in each pixel. Weekly composited NDVI and BT, from NOAA polar-orbiting operational satellites, are available from 1981.

Landslides data were collected by University of

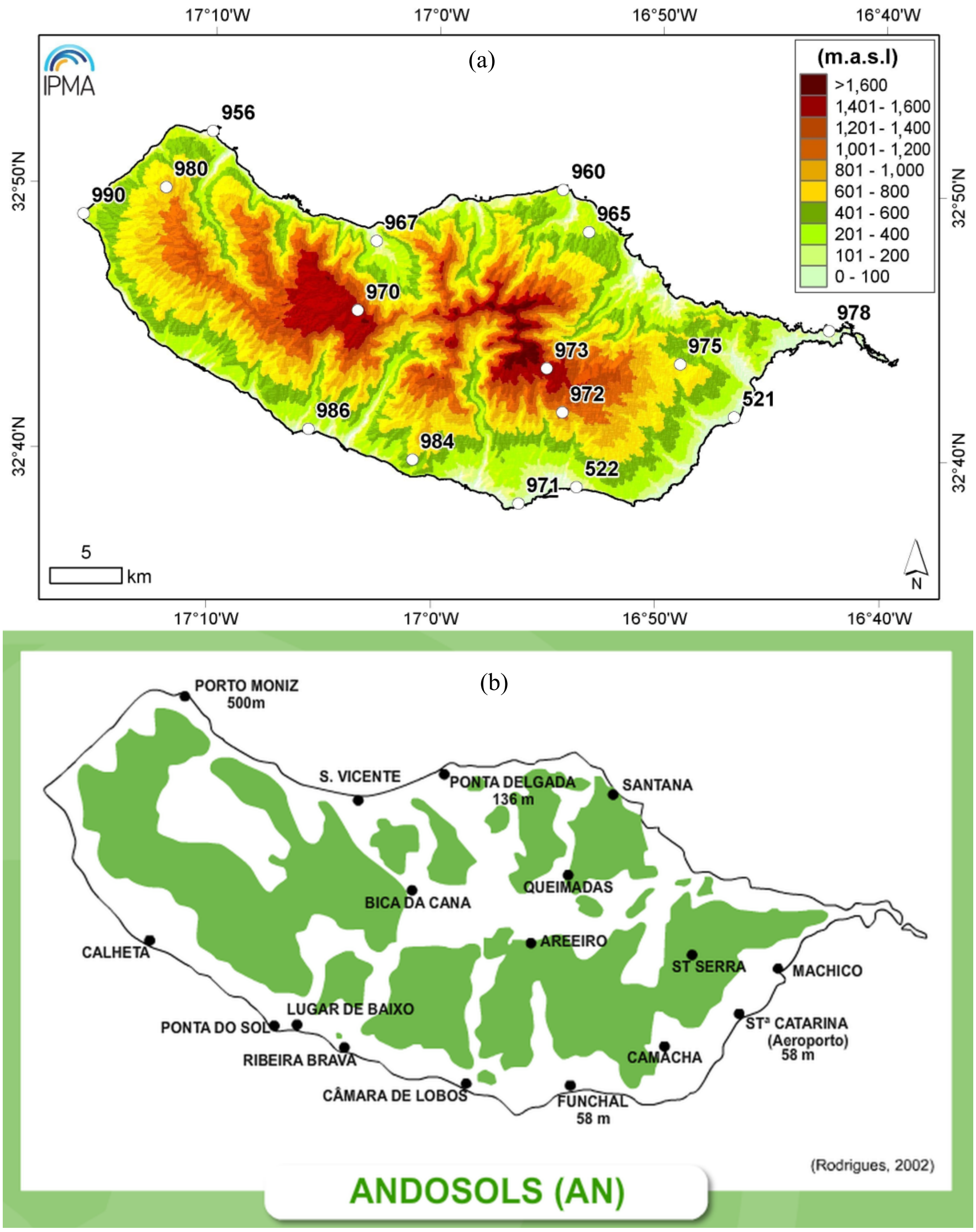
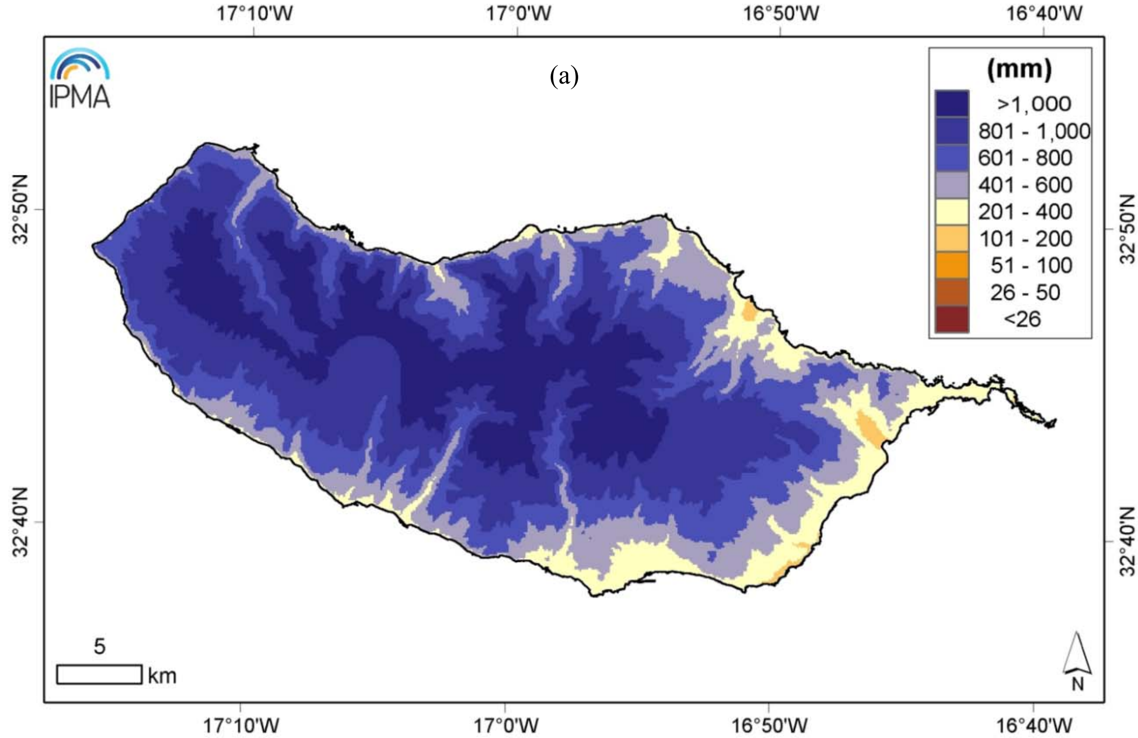


Fig. 1 Relief of Madeira Island and location of weather stations (a); andosols distribution on Madeira Island (b) [31].

Madeira for the period 2010-2012 and published in Technical Report [40] of Portuguese Meteorological Service. These data were collected for the 2010-2012 period. Additionally, national newspapers were used as the sources for identification of more recent landslide occurrence in Madeira Island between 2013 and 2014.

5. VH Method

The changes in land surface from satellites were traditionally described by means of NDVI and BT. VHI were developed from calibrated weekly NDVI and BT. The algorithm includes (a) complete elimination of low and high frequency noise from NDVI and BT time series, (b) approximation of their



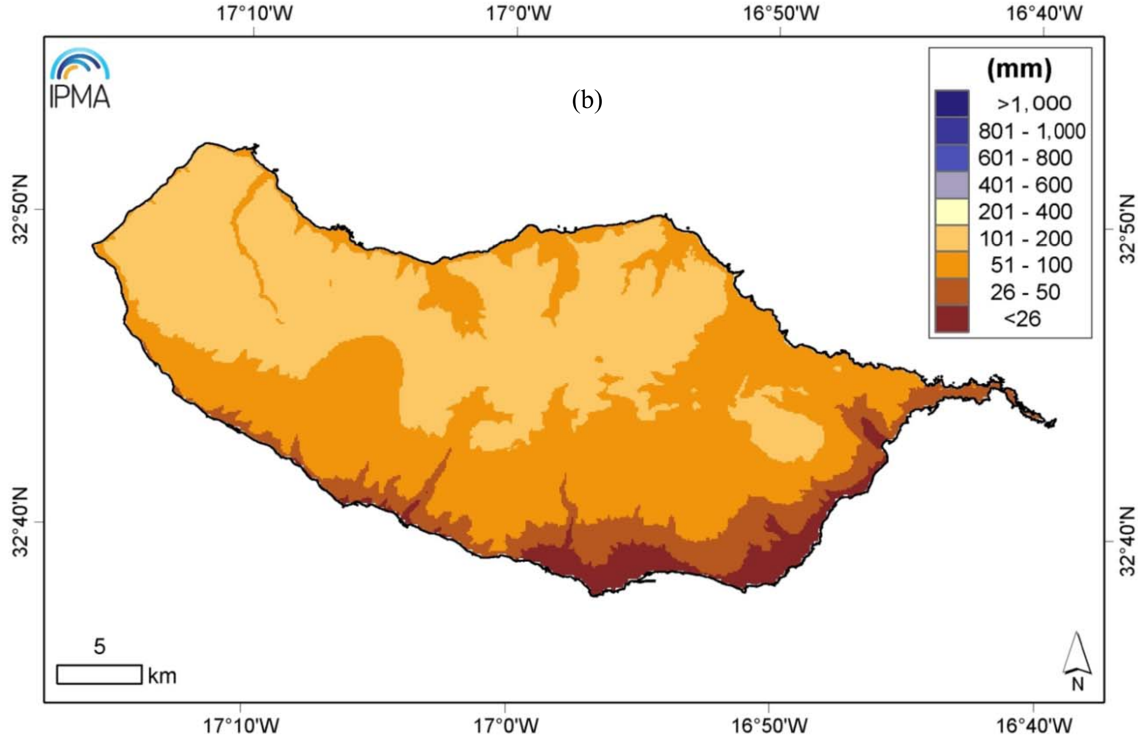


Fig. 2 Madeira winter (a) and summer (b) total precipitation (1971-2000) (climatological data of Portuguese Meteorological Service).

annual cycle, (c) calculation of multi-year aggregated values (called climatology) of NDVI and BT and (d) calculation of a departure of no noise weekly NDVI and BT from their climatology for each 4-km² land pixel. The VH indices were called as NDVI-based VCI, BT-based TCI and VHI, which combined VCI and TCI (Eqs. (1-3)). VCI, TCI and VHI serve as proxy for moisture, thermal and total health conditions, respectively [38, 41].

$$VCI_{ijkl} = 100 \times (sNDVI_{ijkl} - sNDVImin_{ikl}) \times (sNDVImax_{ikl} - sNDVImin_{ikl})^{-1} \quad (1)$$

$$TCI_{ijkl} = 100 \times (sBTmax_{ikl} - sBT_{ijkl}) \times (sBTmax_{ikl} - sBTmin_{ikl})^{-1} \quad (2)$$

$$VHI_{ijkl} = \alpha \times VCI_{ijkl} + (1- \alpha) \times TCI_{ijkl} \quad (3)$$

where sNDVI, sBT are smoothed (without high frequency noise) weekly NDVI and BT; sNDVImax, sNDVImin, sBTmax and sBTmin are smoothed multi-year (1981-1993, 1995-2015) weekly absolute maximum (max) and absolute minimum (min) NDVI and BT (called climatology); *i*—week number in the annual cycle (*i* changes from 1 to 52), *j*—year, *k*—raw number in a global file starting from the North (75.024°), *l*—column number in a global file starting from the West (-180°).

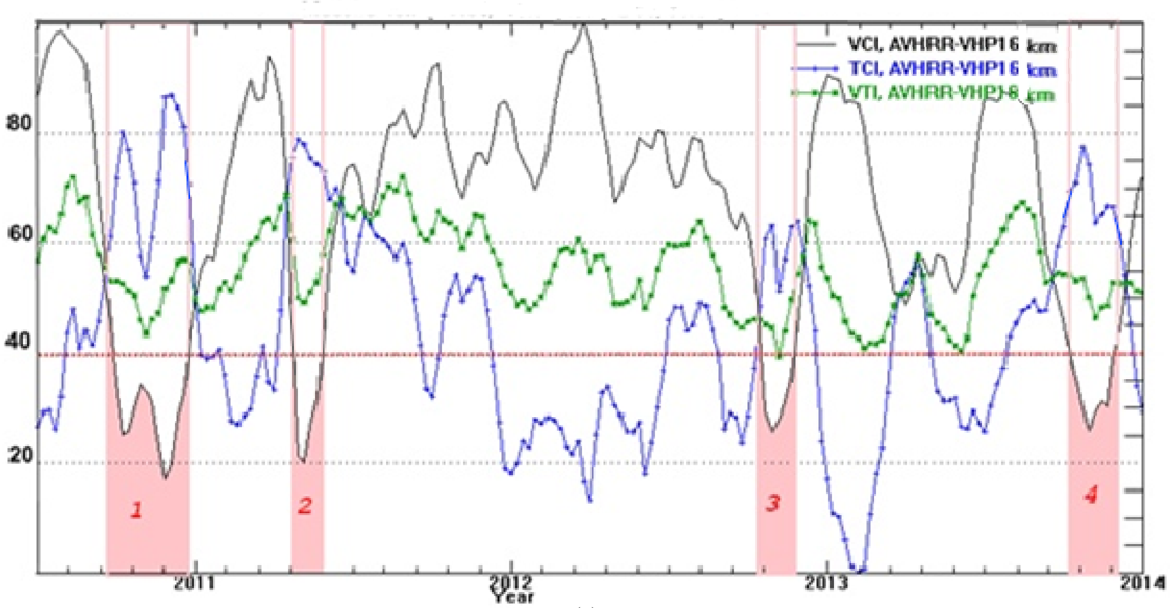
Since the absolute maximum and minimum reflect the lowest and the highest values of NDVI and BT during the 35-year observation period, they characterize the extreme thresholds of weekly NDVI and BT fluctuations due to weather variation for each week during 35 years period (and from year to year). The weekly max-min envelops, outlining these thresholds in the annual cycle, permitting one to estimate if a particular week and year NDVI and BT are closer to minimum (the lowest greenness (Eq. (1)) and the highest BT (Eq. (2)), indicating vegetation stress, or NDVI and BT are closer to maximum (the highest greenness and lowest BT), indicating healthy vegetation conditions. The VCI, TCI and VHI change from zero quantifying extreme vegetation stress to 100, indicating optimal condition [42]. Comparison of these indices with crop yield showed that from the level of 40 down to zero, the yield starts to decrease below long-term mean [21]. These indices have been used globally since the 2000s because they portray accurately VH conditions. They are user-friendly and also were validated in 29 countries for various environmental-related applications [26, 28, 43-45]. For users outside of NOAA, VH indices (global, continental, country and first order administrative regions) are available weekly in real-time and historically (1981-2017) on the NOAA web portal: http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/index.php.

6. VH as Characteristics of the Landslides Conditions

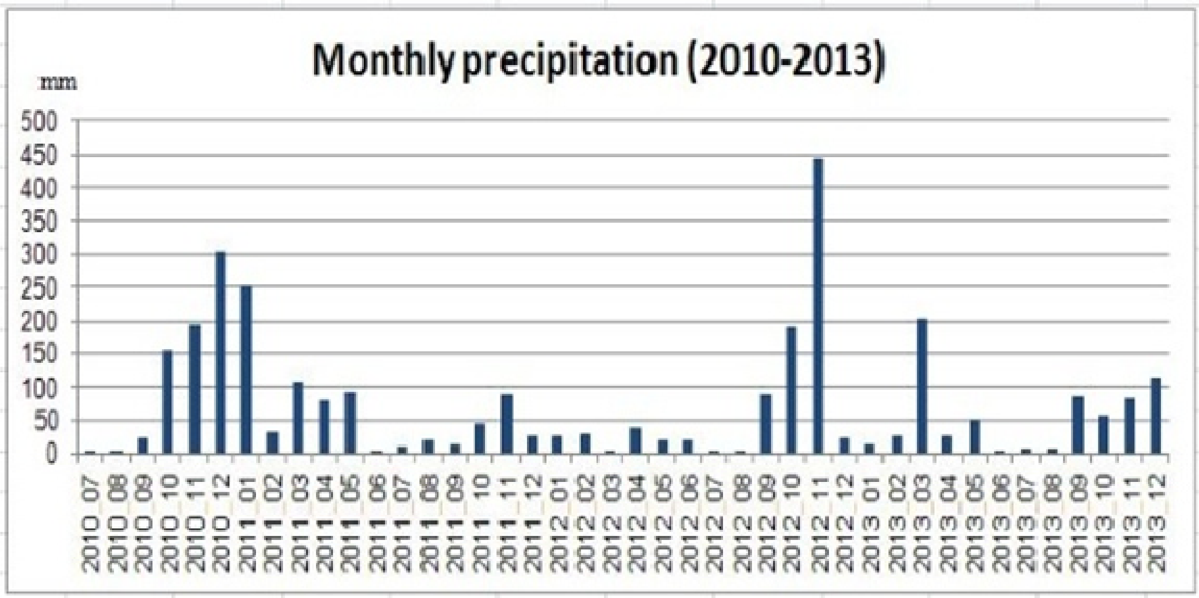
Since Madeira Island has relatively small area, for a coarse estimation we have analyzed the dynamic of the island-averaged VCI, TCI and VHI values along with collected landslide occurrences and cumulative precipitation. During June 2010-December 2013, there were four episodes of landslides activity in Madeira. These periods of landslide activity are shown in Fig. 3a (red bars with numbers). The damages were described by Lopes *et al.* [40] as: (1) inundations, alluviums, turbulent fluvial dynamics in October-November 2010; (2) rock falls in May 2011; (3) landslides, inundations, falling trees, wounded people in October-November 2012; (4) rock falls, inundations, landslides, debris flows, falling trees in November 2013. It is easy to see that these episodes (Fig. 3a) coincide with periods of heavy precipitation (Fig. 3b).

Joint analysis shows, that VCI values were below 40 for all four cases of landslide activities, indicating vegetation stress due to soil saturation from persistent rainfalls, and TCI values were above 50, indicating absence of thermal stress. Thus, even coarse analysis of joint dynamic of VHI, accumulated precipitation and landslide occurrence have demonstrated clear connection between landslides activity and low values of VCI, which together with moderate or high values of TCI and large quantity of total precipitation correspond to conditions of soil water excess.

To verify possibility to use VCI-indices for detection of landslide risk areas in Madeira Island, VCI maps were analyzed together with information



(a)



(b)

Fig. 3 Dynamic of mean of Madeira vegetation health indices (VHI) and four periods of landslides activity (a); mean of Madeira monthly precipitation during July 2010-December 2013 (b).

about the recent landslides.

Fig. 4 presents the map of VCI in the 45th week of 2012 (period 4.11.2012-10.11.2012) as well as the locations of the landslides which happened in Madeira on November 5-6, 2012. Landslides events: Seixal—several landslides, house, dragged by water; São Vicente—several landslides, flooded houses, cars, dragged by water; Faial—floods, landslides [46, 47].

Fig. 5 presents the map of VCI for period 26.11.2013-02.12.2013 together with landslide location, which occurred on November 29, 2013 in Porto da Cruz (Machico). In this case intense rainfalls caused various landslides and the overflow of several rivers, which blocked traffic on regional and local roads and destroyed some parts of them. Also, there were flooded buildings; one house was totally and six houses were partially destroyed; the population was insulated, some people and cars were dragged by water flows. The local authorities estimated the situation not far from catastrophe [48].

Fig. 6 presents the map of VCI for second week 2014 (period 8.01.2014-14.01.2014), as well as the locations of two first landslides of 2014, which happened during this week. Landslides were not strong in both cases and resulted in some material damages, road cuttings and cleaning works [49, 50].

It is very interesting that for all landslide cases in Figs. 4-6 the areas with low VCI values, indicating vegetation stress due to water surplus, were persistently observed in the locations of landslides activity, at least, during few weeks before landslide occurrence (Fig. 7). In plain areas the soil saturation depends on amount of precipitation, capacity of soil infiltration and evapotraspiration. Capacity of soil infiltration depends on the soil moisture content. Increasing in soil moisture content leads to reducing soil capacity of infiltration. In the mountain areas the saturation occurs by different way because of drain and runoff down the slope. So, in mountain areas soil saturation needs more time.

Two meteorological stations of Portuguese meteorological service (967 and 965) are situated near the landslide occurrence (white squares in Fig. 6), so it was possible to join registered precipitation for analysis (Fig. 8). As seen in both diagrams of Fig. 8, the 2013-2014 rain season started at the end of August (it was rainy almost every week since that time). During end of August 2013-January 2014 amount of accumulated precipitation made up: 662.8 mm—for station 965 and 521.6 mm—for station 967. VCI had showed low values in the northern part of Madeira Island already in October 2013. Therefore,

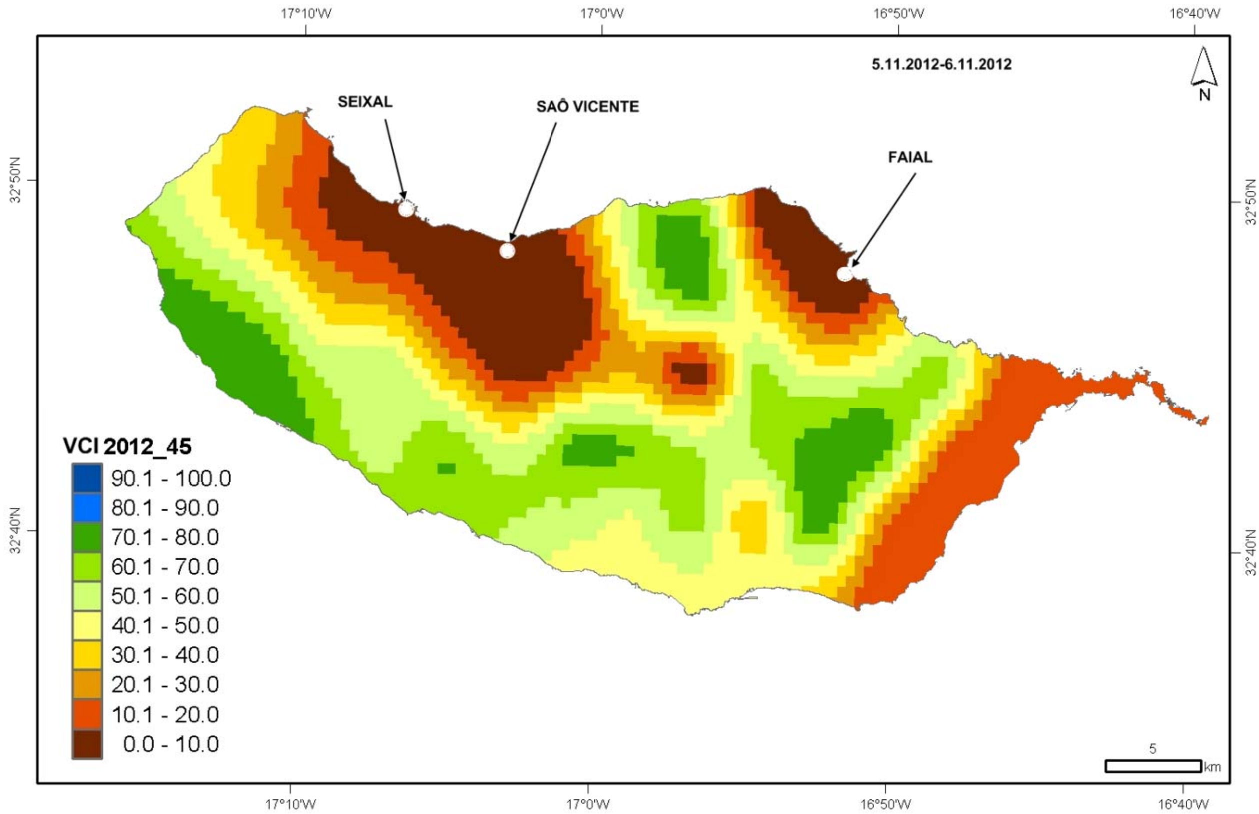


Fig. 4 Map of 4 km^2 vegetation condition index (VCI) and landslide locations, occurring 5.11.2012-6.11.2012.

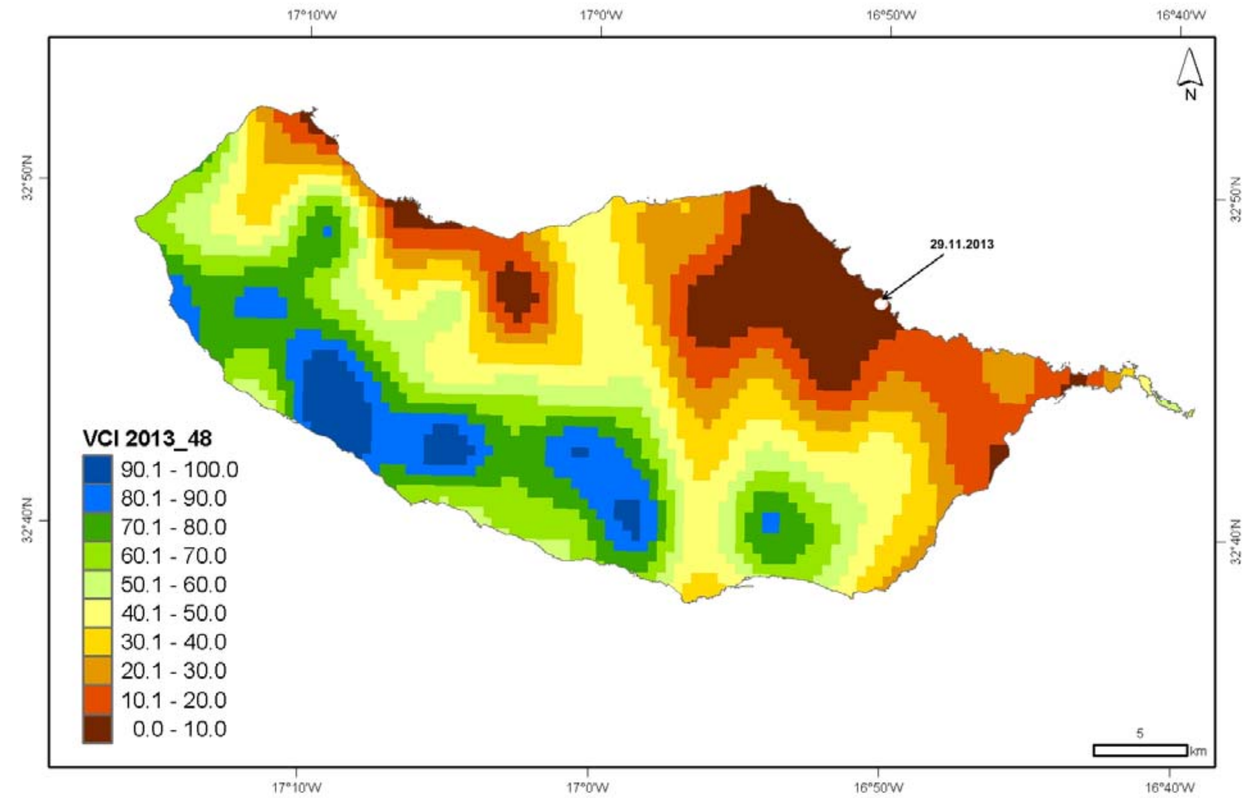


Fig. 5 Map of VCI and landslide location (29.11.2013).

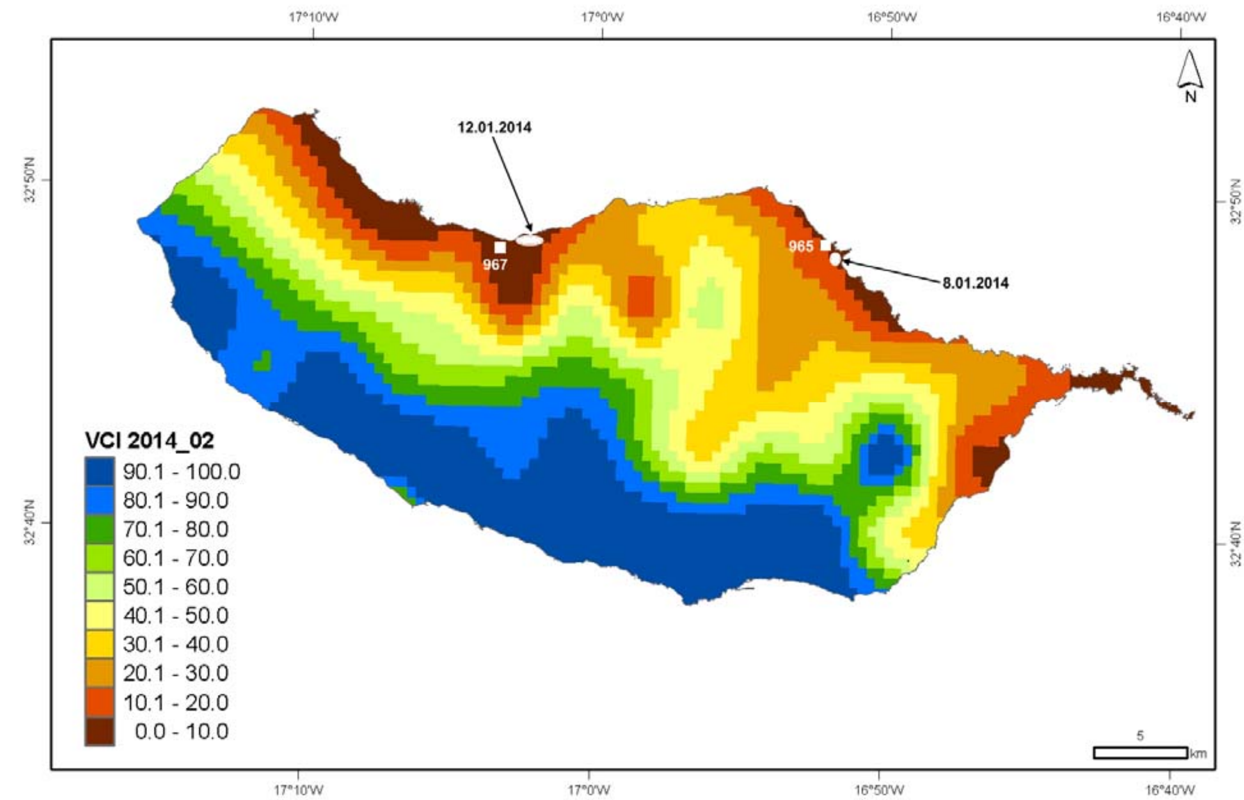


Fig. 6 Map of VCI and landslide locations (8.01.2014 and 12.01.2014).

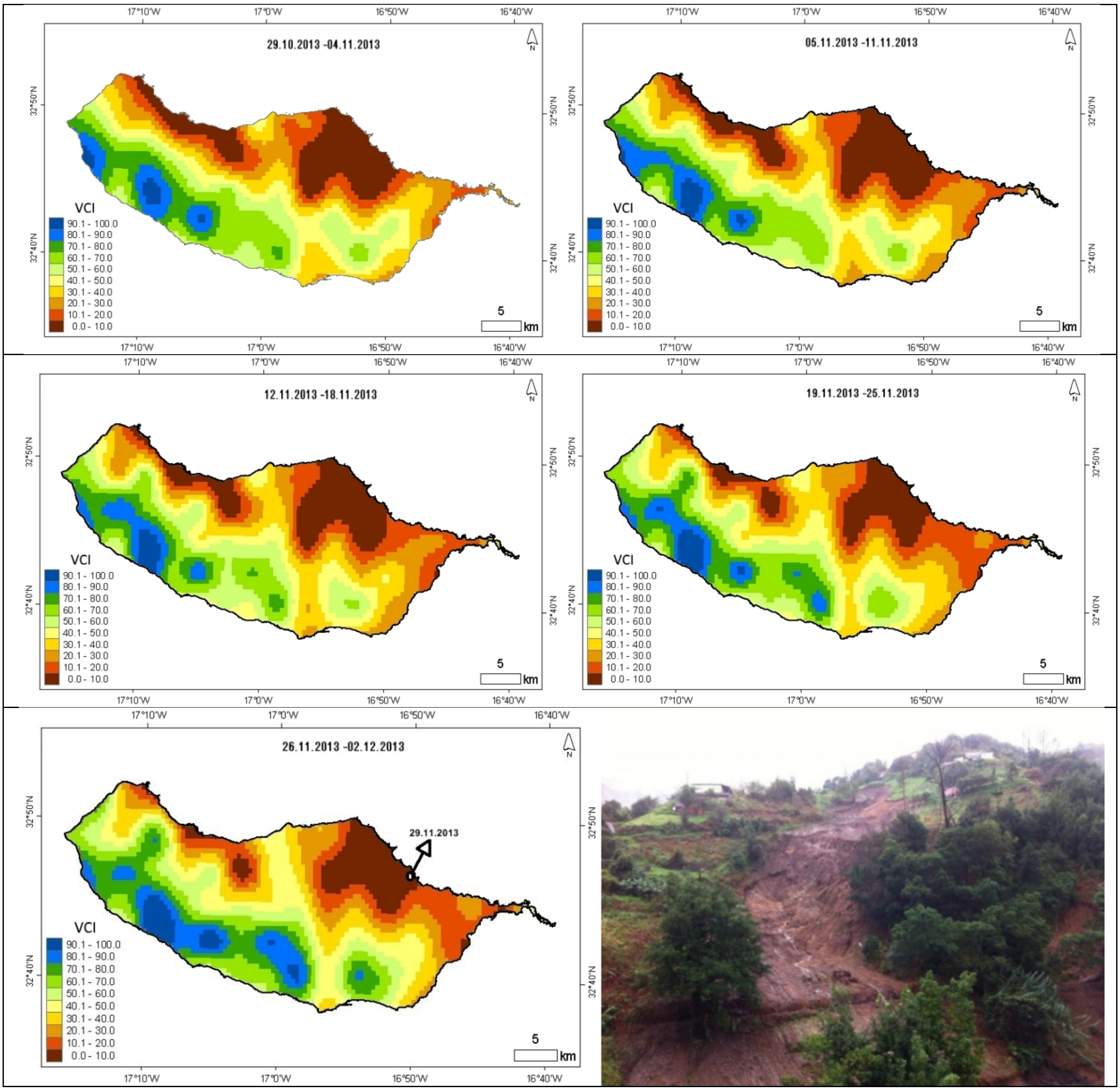


Fig. 7 VCI dynamic (29.10.2013-2.12.2013) and landslide location (29.11.2013).

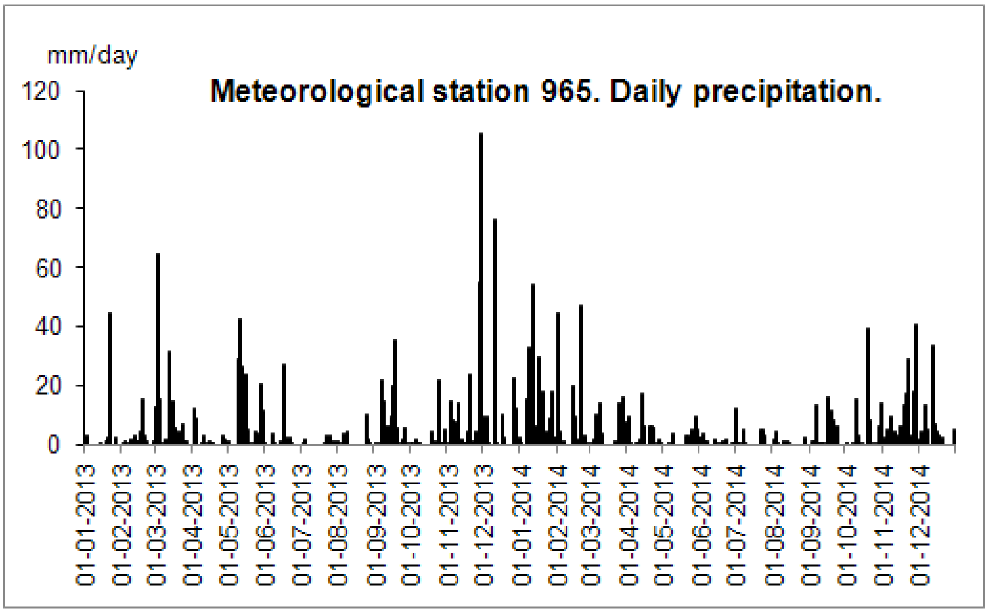
October, November and December 2013 were marked with some landslides and rock falls [51-53].

The heaviest landslide took place on November 29, 2013. Meteorological station 965 had registered 54.6 mm on November 28 and 105.3 mm on November 29. Heavy rains disturbed near saturated soils and triggered landslide activity.

Landslide event on January 8, 2014: closest to landslide occurrence meteorological station 965 had registered total precipitation 15.6 mm on January 7 and 32.7 mm on January 8, respectively. Strong winds, moderate and intense rains triggered a landslide, which, fortunately, was not strong.

Landslide event on January 12, 2014: intense rains in the mountains, up from the landslide location (meteorological station 970, Fig. 1a), few days before that day and moderate rains near landslide location led to the land and rock fall (Table 2).

In winter 2015-2016, there were not landslide cases in Madeira Island, which is a rare case. This fact is



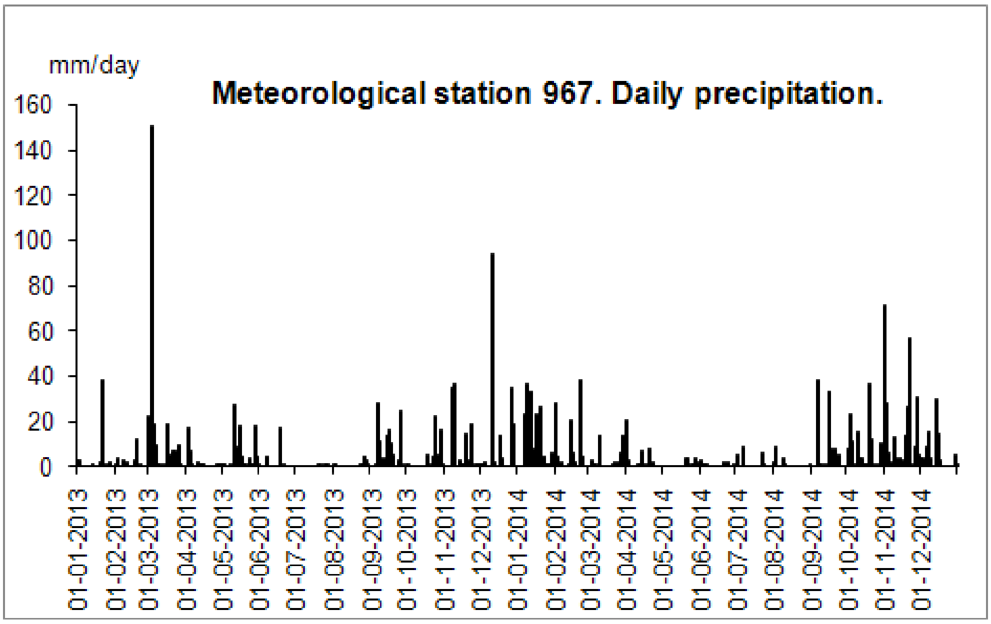


Fig. 8 Daily precipitation (2013-2014).

confirmed by VCI dynamic: during the 2015-2016 rain season the VCI did not show persistent areas of low values, which indicates excessive soil water vegetation stress (Appendix).

This situation was analyzed. Fig. 9 represents weekly total precipitation, which was registered by meteorological stations, across Madeira Island from north to south and from east to west (Fig. 1a). As can be seen, the rainy season began in September with the total precipitation close to climatological norm. But October was surprising: observed monthly precipitation exceeded climatological norm considerably for the most meteorological stations (Fig. 10). Moreover, during one week of October (15.10.2015-21.10.2015, week 42) some meteorological stations have registered the amount of precipitation, which exceeded monthly climatological norm of December (which is the rainiest month). Thus, during this week meteorological station 973 (Peak Arieiro) registered 478.6 mm; station 975 registered 312.6 mm. Both stations are situated in the mountains. Complex topography and heavy precipitation during week 42, 2015 should result in floods and landslides, however, this did not happen. It could be explained with the fact that huge amount precipitation fell in October, when the soil was dry after summer months. And accumulated precipitation of September and first half of October was not enough to saturate soil, which is the main "preparatory condition" for landslide occurrence in Madeira. As seen in Fig. 10, November, December and January rainfall was much below climatological norms and was not sufficient to create conditions for landslides activity.

During 2016-2017 rain season there were not landslide cases also. Analysis of satellite data has shown that there were no persistent areas with low VCI values, corresponding to vegetation stress due to soil water excess.

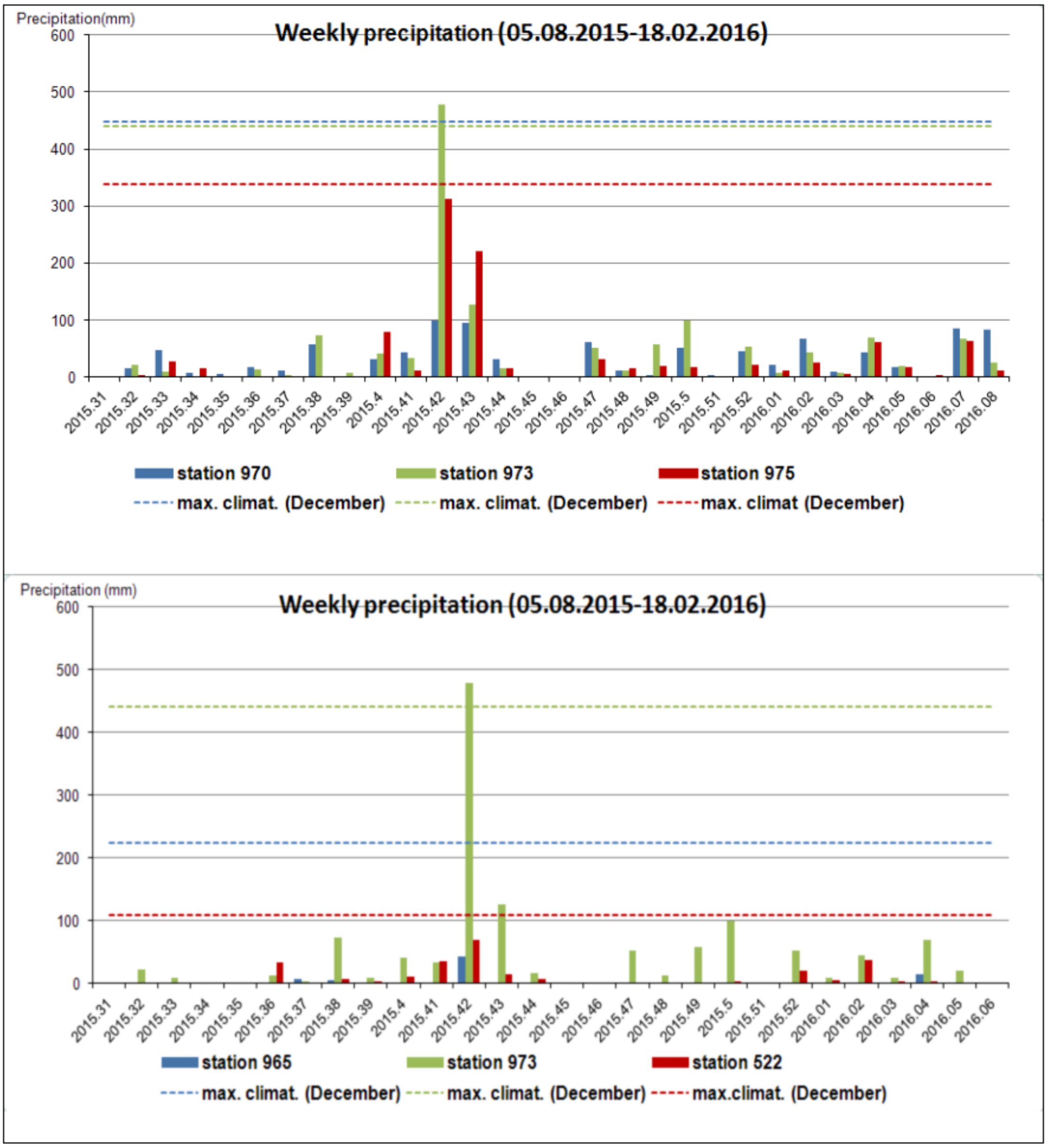
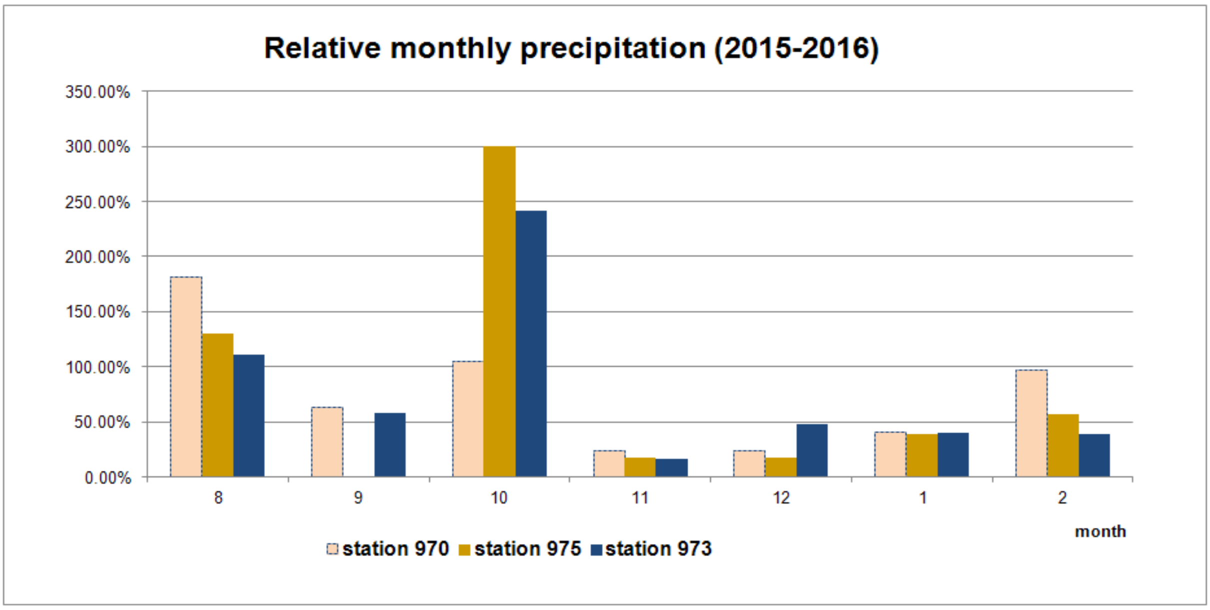


Fig. 9 Weekly precipitation (2015-2016).



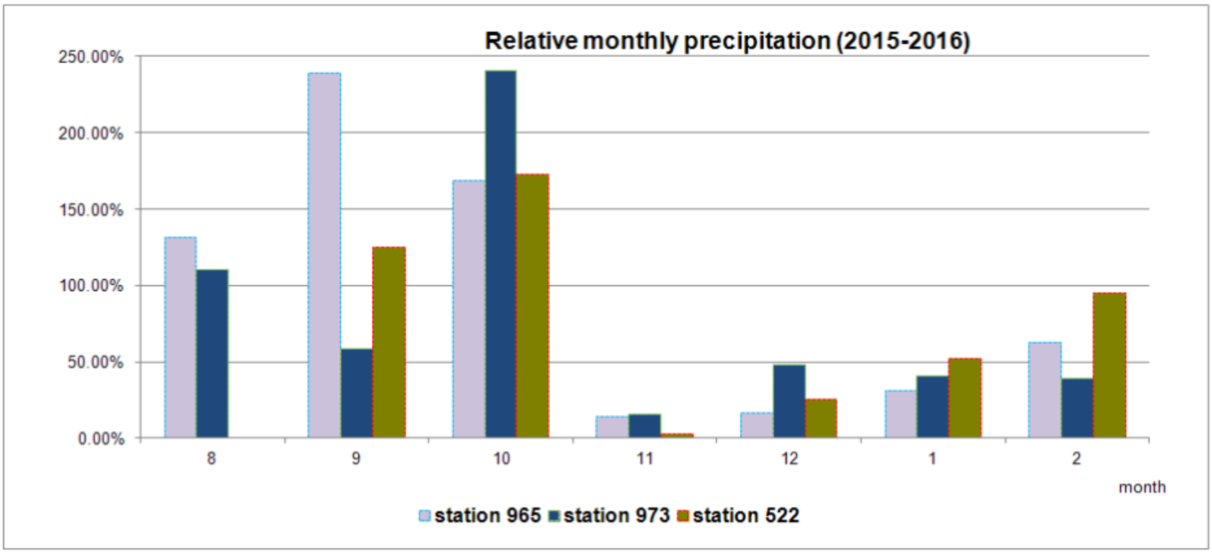


Fig. 10 Relative monthly precipitation (2015-2016).

7. Conclusions

Rain-induced landslides are one of the most common types of natural disasters. Antecedent persistent rainfalls are the preparatory factor for such kind of landslides, because they may lead to near-saturation soil state and instability of the slope in mountain areas. By this reason, evaluation of critical conditions for landslide initiation with accumulated precipitation is one of the common approaches to landslides risk detection. However, the density of meteorological stations is never enough and meteorological observations are limited compared to satellite. Near-saturation state of the soil leads to plant hypoxia, alters plants physiological processes and metabolism and leads to vegetation stress similar to drought stress. So as VHI-method shows good results for detection drought stress, this approach was applied for detection of near-saturated areas in Madeira Island and VCI was tested an indicator of landslide risk areas.

Rain-induced landslides occur in Madeira Island because of peculiarities of the climate (accentuated rain period), soils (large percentage of andosols), mountainous and rugged relief. The study showed that for the period June 2010-December 2013 conditions of vegetation stress due to the water surplus coincided with the periods of landslides activities. Positions of landslides during 2012-2014 rain seasons coincided with areas of persistent low VCI values, which reflect vegetation stress due to soil water excess. Persistence of low VCI values is necessary conditions, because in mountain area soil water surplus can drain and flow down the slope. Thus, the soil needs more time to be saturated with water. It was shown that during 2015-2016 rain season there were not areas with persistent low VCI values as well as landslide occurrence in Madeira Island. At the same time the predominant soils of Madeira are andosols, which possess special property tixotrophy, which can lead to the slope soil instability in certain conditions. Therefore, future researches should extend this approach to other regions of landslides, with different soils and natural conditions. The biggest problem is the rain-induced landslide data for long period, which could allow realizing statistical analysis.

Proposed method for detection of rain-induced landslide risk areas does not need special equipment. Nowadays satellite observations, as well as satellite-derived products, are available and free for any kind of users. Considering the fact that landslides are the reason of big human and economical losses and the rain-induced landslides are the most widespread, the new approach, represented in this paper, could be useful in the development of potential landslides maps and for elaboration of early warning system.

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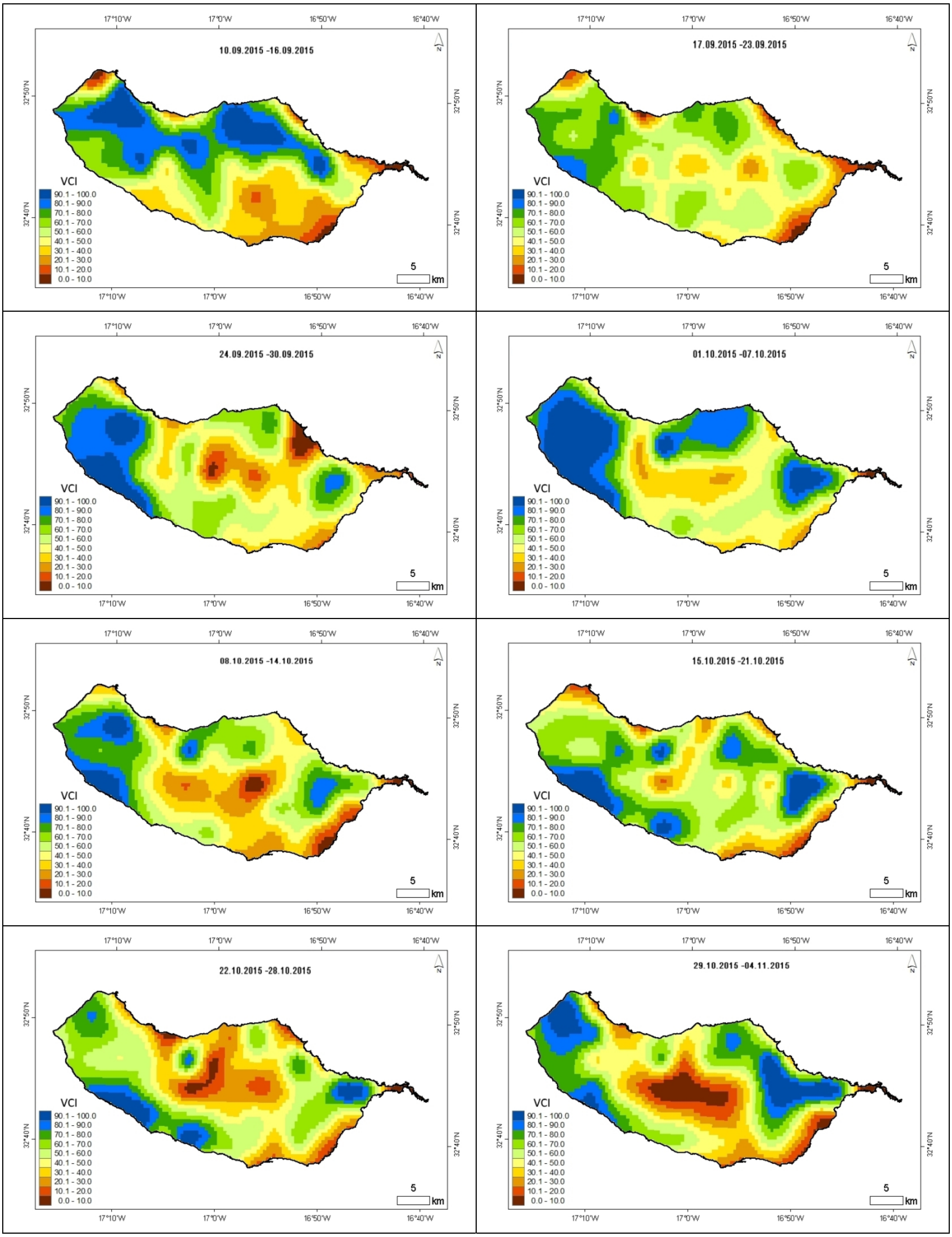
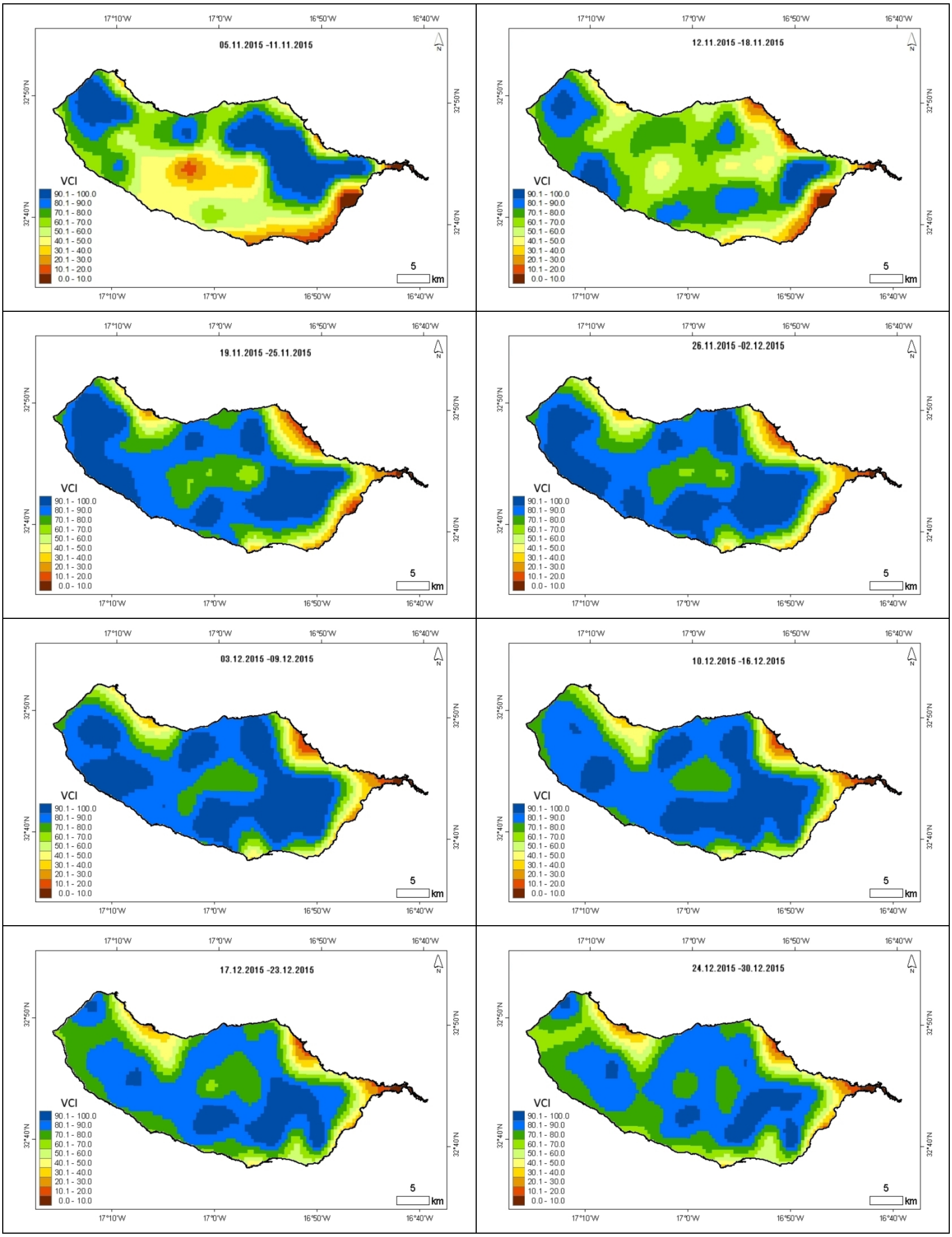
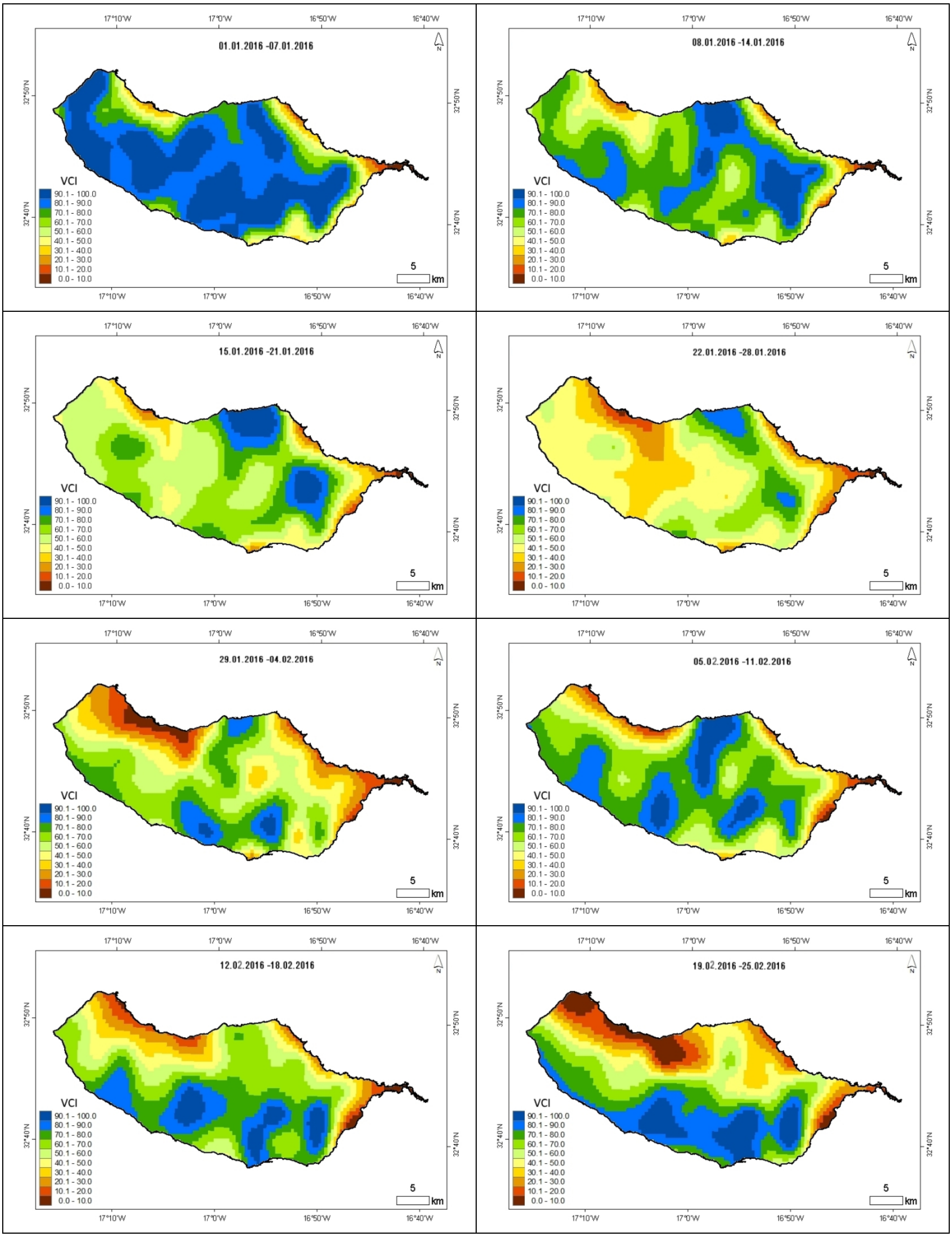
Appendix: VCI dynamic in 2015-2016 rain season.




05.11.2015 -11.11.2015
12.11.2015 -18.11.2015
19.11.2015 -25.11.2015
26.11.2015 -02.12.2015
03.12.2015 -09.12.2015
10.12.2015 -16.12.2015
17.12.2015 -23.12.2015
24.12.2015 -30.12.2015
VCI
90.1 - 100.0
80.1 - 90.0
70.1 - 80.0
60.1 - 70.0
50.1 - 60.0
40.1 - 50.0
30.1 - 40.0
20.1 - 30.0
10.1 - 20.0
0.0 - 10.0
17°10'W
17°0'W
16°50'W
16°40'W
32°50'N
32°40'N
5
km


01.01.2016 -07.01.2016
08.01.2016 -14.01.2016
15.01.2016 -21.01.2016
22.01.2016 -28.01.2016
29.01.2016 -04.02.2016
05.02.2016 -11.02.2016
12.02.2016 -18.02.2016
19.02.2016 -25.02.2016
VCI
90.1 - 100.0
80.1 - 90.0
70.1 - 80.0
60.1 - 70.0
50.1 - 60.0
40.1 - 50.0
30.1 - 40.0
20.1 - 30.0
10.1 - 20.0
0.0 - 10.0
5
km
17°10'W
17°0'W
16°50'W
16°40'W
32°50'N
32°40'N