Landslides in Central Italy identified from Sentinel 2 multispectral imaging time series analysis with Google Earth Engine

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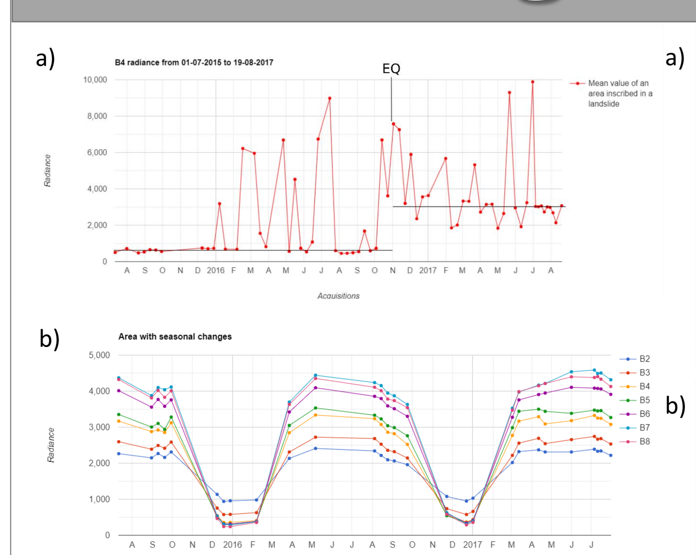
1. Introduction

- Aim of the study: individuate the areas affected by landslides triggered by the October 30 2016 earthquake
- Study area: Visso(MC), Central Italy
- Multispectral satellite images (Sentinel 2) analysis carried out in Google Earth Engine environment
- Distinguish anthropogenic changes in land-use (e.g. construction of buildings, crop rotation) in the time period from landslide areas

2. Methods

- Multispectral images analysis:
  - Selection of the images avoiding clouds and the seasonal shadowing effect of the hills due to steep terrain, guaranteeing the same solar elevation (July 11 2015, July 10 2017)
  - Correction of the images displacement
  - Analysis of 7 bands on always illuminated by the Sun, always in shadow and reference areas
  - Calculation of the ratio between the two images selected
- ArcGIS software
  - Creating a slope map from DEM
- Combine radiance coefficient to slope angle to distinguish anthropogenic changes in the land-use

3. Images selection



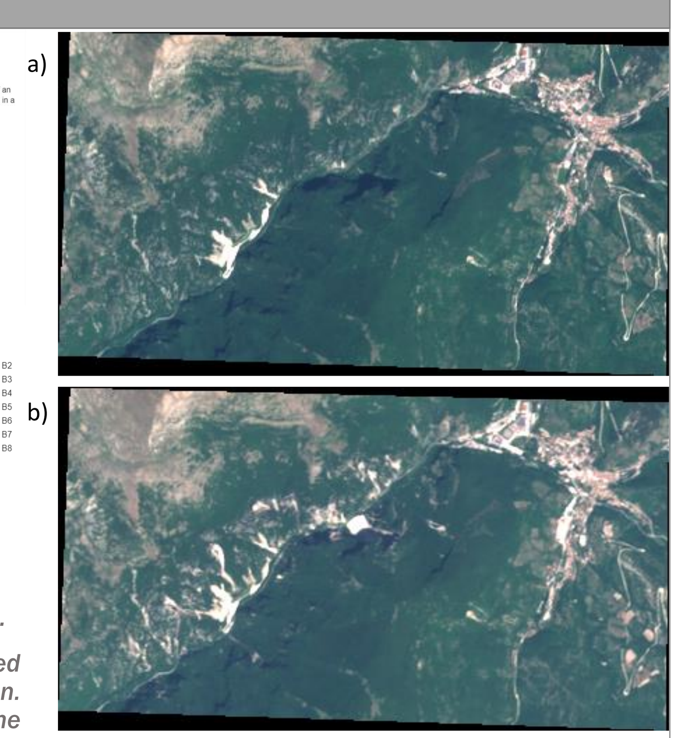


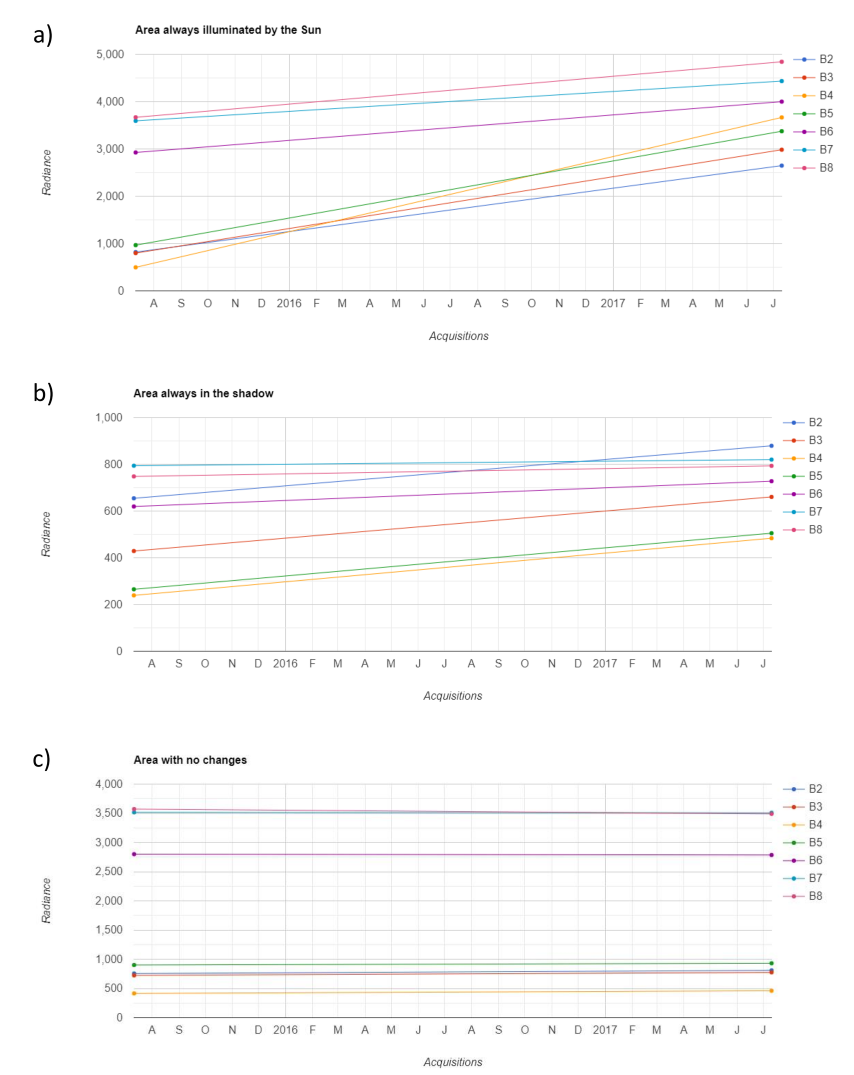
Figure 1: Radiance values from Google Earth Engine.

a) Example of radiance variation of an area affected by landslide and always illuminated by the Sun. Sentinel 2, band 4. Peaks are due to cloudy days. The upward shift of the low radiance level is due to exposure of limestone rocks which have higher reflectivity than the plant cover.

b) Radiance variation of a landslide scar that is in the mountain shadow zone only in winter. The scar was pre-existent before the 2016 seismic crisis. Cloudy days excluded.

Figure 2: True colour images straddling the 2016 earthquake taken by Sentinel 2 and downloaded from Google Earth Engine. a) July 11 2015. b) July 10 2017.

4. Bands analysis



	B2	B3	B4	B5	B6	B7	B8
Exposed							
11/07/2015	819	798	498	967	2.926	3.594	3.668
10/07/2017	2.647	2.984	3.666	3.375	4.000	4.434	4.842
Ratio	3,2	3,7	7,4	3,5	1,4	1,2	1,3
Not Exposed							
11/07/2015	655	429	239	265	619	794	748
10/07/2017	879	660	484	505	728	820	793
Ratio	1,3	1,5	2,0	1,9	1,2	1,0	1,1
Reference							
11/07/2015	755	723	414	901	2.800	3.516	3.572
10/07/2017	809	775	460	930	2.785	3.508	3.490
Ratio	1,1	1,1	1,1	1,0	1,0	1,0	1,0

Figure 3: Radiance variation between the two images straddling the earthquake of October 30 2016. a) landslide area always sun-lit. b) landslide area always in shadow. c) area not affected by landslide as reference.

Table: Radiance values of the three areas and the ratio between the two images (2017 on 2015). Band 4 is the most subjected to change due to the plant cover that has been removed by landslide bringing to light the limestone substrate.

5. Ratio

Figure 4: Band 4 image ratio (highest value in red) calculated in Google Earth Engine. In the squares the zoom of the circled areas of 2015, on the left, and 2017, on the right. a,b,c,d: areas subjected to landslides. e): area probably subjected to fire prevention interventions. f): area with anthropogenic changes.

6. Combining band ratio and slope angle

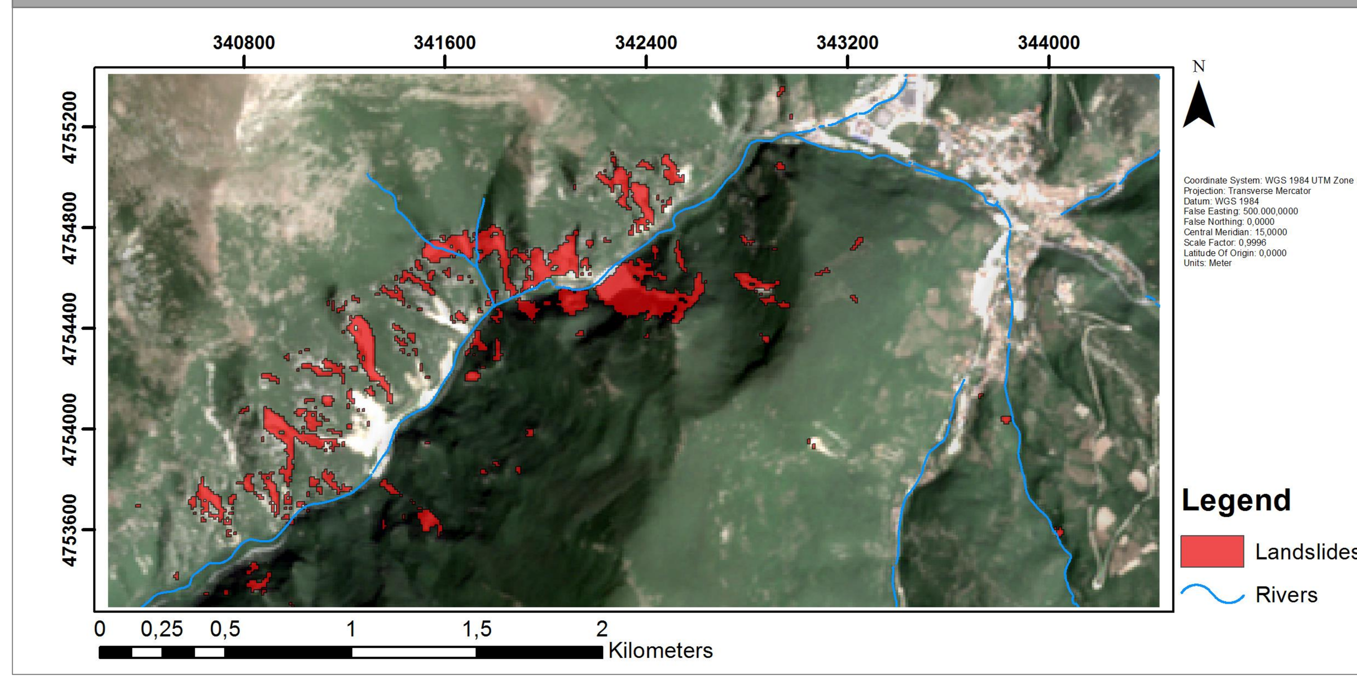


Figure 5: Result combining band 4 ratio (≥1.5) and slope angle (≥25°) in ArcGIS environment. The minimum ratio value also takes into account areas always in shadow, while the slope minimum angle value is needed to distinguish anthropogenic changes in land-use which are hardly done in steep areas. Isolated pixels, with more than 15 meters from other pixels, have been removed while neighbouring pixels with common boundary have been joined using ArcGIS functions. The background image is that of 2017, the same in figure 2b.

7. Results

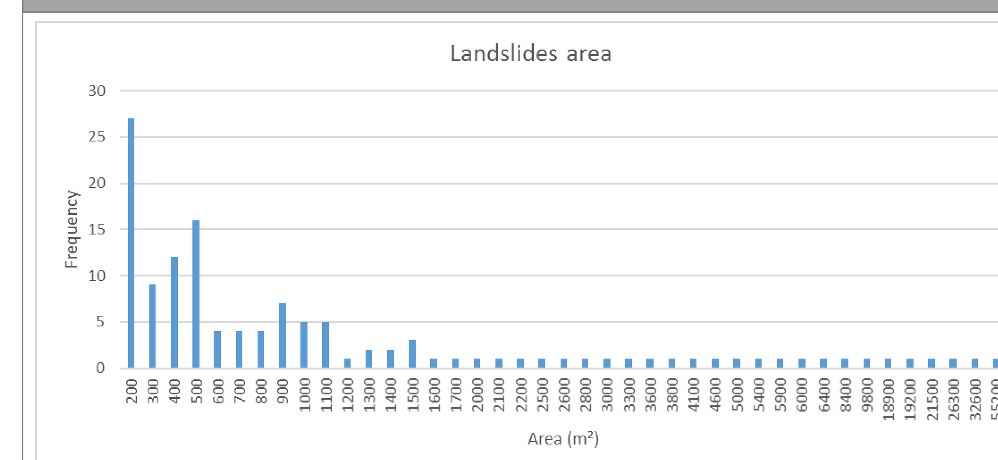


Figure 6: Histogram of joined pixels. 48 pixels corresponding each to 100 m^2 area, nearer than 15m from other pixels but not sharing common boundary, are excluded for a better understanding of the diagram. The total area affected by landslides is 322500 m^2.

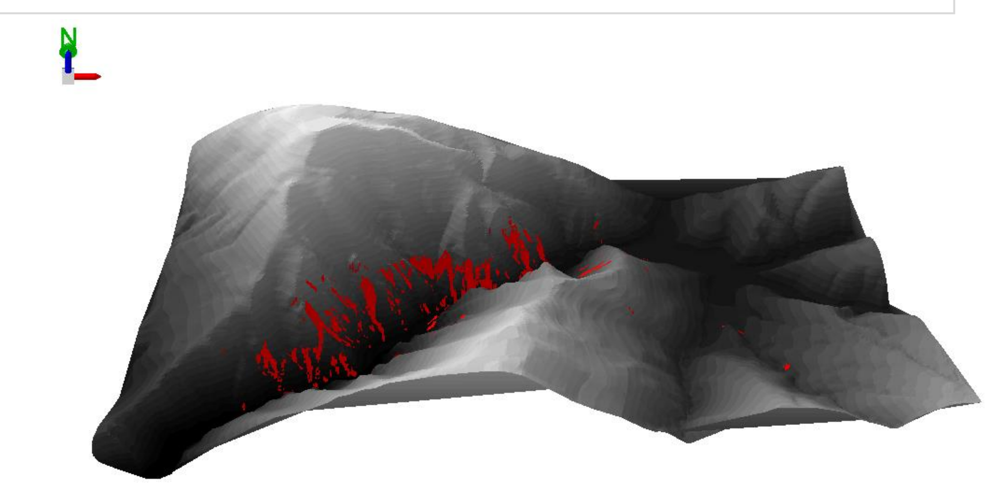


Figure 7: 3D rendering of the DEM done in ArcGIS, superimposing the areas affected by landslides (video sequence at https://photos.app.goo.gl/ygvueT4YrP1uFk7w5).

8. Conclusion

- **The goal of the study was to define the sensitivity of the sentinel 2 multispectral images in detecting landslides that followed the devastating earthquake of October 30, 2016 in Central Italy.**
- **The results are valid for any vegetated area with limestone geology. The geology enters the analysis as it defines the spectral contrast of the reflecting area before and after the landslide. For limestones at mid-latitudes, as in Central Italy, the red band is particularly responsive.**
- **Since landslides are typical for mountainous areas, the shadowing of topography is an effect that must be accounted for. We find that due to the seasonal variation of shadowing, comparison of images taken at the same day of the year, also if distant one or two years, is optimal for distinguishing landslides.**
- **The geology being a local factor, for hazard purposes it is recommendable that the spectral images are analyzed systematically for the entire mountainous territory, to define the most significant spectral bands characteristic for distinguishing exposed rock from vegetation.**

References

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