

Exploiting freely available imagery to improve land cover characterization and shallow landslide detection

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ABSTRACT

Natural hazards and land management issues can benefit nowadays from the increasing availability of free, high-resolution satellite imagery that opens the way to fine scale detailed investigations. In high elevation catchments the analysis of vegetation dynamics deserves particular attention since little climatic modifications can be amplified in such fragile systems. For the same reasons, the dynamic of instability phenomena as response to an input hydrological forcing, requires a meticulous spatial representation in order to better represent the active processes at catchment scale.

The present work focuses on the analysis of high-resolution freely available imagery (Microsoft® Bing Maps™ Platform) that enables the characterization of vegetation cover and the automatic mapping of shallow landslides in an alpine catchment. Semi-automatic detection of vegetation is carried out at the fine scale using both orthophotos and freely available satellite imagery. The analysis based on the satellite imagery showed a better accuracy in respect to the one based on the orthophotos. In particular, satellite imagery analysis showed high sensitivity and high specificity even in low illumination conditions, while, for the same circumstances, orthophotos-based analysis shows a significant wrong detection rate. In the framework of a long term, multi-temporal and high-resolution characterization of vegetation cover and for a rapid mapping of shallow instability phenomena, the effectiveness of the proposed approach can speed up the representation of the local conditions towards an improvement of land management strategies and hazard and risk assessment.

Keywords: Automatic detection, Vegetation patterns, Maximum Likelihood Estimation, headwater catchment, shallow landslides, Bing Maps™.

INTRODUCTION

Classification and mapping of vegetation is a key methodological issue for the management of natural resources (Xie et al., 2008). The increasing availability of free and high-resolution imagery dataset offers a great potential to leverage for a detailed and multi-temporal assessment of the vegetation dynamic.

Fine resolution vegetation cover assessment can help in setting up a correct soil properties parameterization for improved hydrological modelling (Oubeidillah et al., 2014). Furthermore, when focusing on uniform vegetated areas, the automatic detection of non-vegetated areas can be a good proxy of slope instability phenomena (Guzzetti et al., 2012).

With the above-mentioned conditions, the analysis of high-resolution, freely available imagery can improve intrinsic efficiency of the detection of vegetation cover and the automatic recognition of shallow landslides at increasing time frequency. In the long run and on the global scale the integration of such techniques with morphometric assessment of landscape features can pave the way towards an

improvement of land management strategies and hazard and risk assessment. In the following the effectiveness of the approach is validated in a study area.

DATA AND METHODS

The study area is the Rio Vauz catchment (1.9 km²), an headwater catchment located in the Dolomites, Eastern Italian Alps (Figure 1). The site ranges in elevations between 1847 m a.s.l. and 3152 m a.s.l.. Average, temperatures vary during the year from -5.7 °C in January to 14.1 °C in July. Mean annual precipitation is about 1220 mm, 49% is in form of snow. Spring and early summer snowmelt is frequently associated with high-flow conditions but summer thunderstorms and autumn precipitation determine important flood events as well. The upper part of the catchment is dominated by Dolomitic outcropping bedrock and debris whereas the central and lower part are vegetated by alpine grassland and sparse trees. The morphology of the study site is deeply influenced by the geo-structural setting, in particular in relation to the characteristics of structural discontinuities. The catchment is object of several measurements campaigns: the hydrological response is monitored since several years both in the rocky subcatchments of the upper part and in soil-mantled subcatchments of the middle and lower part of the catchment (Penna et al., 2015, 2016a,b) and morphometric characterizations of rocky areas and scree slopes have been also carried out (Marchi et al., 2015; Trevisani et al., 2009).

The first step of the analysis here proposed consisted in the mosaicking of the image tiles, downloaded at the maximum zoom level (with a pixel resolution of about 0.3 m) from Bing Maps™ (© 2016 Microsoft, © 2016 HERE, 2014 DigitalGlobe) satellite terrain imagery. The download was performed with GMapCatcher (<https://github.com/heldersepu/gmapcatcher>), a free, offline maps viewer that can display maps from many providers; GMapCatcher is written in Python 2.7 & PyGTK, can run on Linux, Windows and Mac OSX. The downloaded tiles were subsequently merged using a Matlab script. For the same area, a 0.15 m orthophoto dated 2006 was available. The satellite image was georeferenced in ArcGIS (ESRI, 2014) identifying common and stable features in the two images. The images were compared in terms of effectiveness in detecting the vegetation. To this purpose a common set of training areas has been selected for the two images; training areas were a priori classified among vegetation and no-vegetation classes. A Maximum Likelihood Estimation Classification (MLE) (Strahler, 1980) was then performed on the two images and an initial assessment of the effectiveness of the two outcomes was carried out.

RESULTS AND CONCLUSIONS

At catchment scale (Figure 1) the quality of the orthophoto is excellent in terms of resolution and color clearness, the only apparent limitation being related to the poor illuminating conditions, shadowed areas cover in fact significant part of the orthophoto. The satellite image shows instead an overall good quality both in terms of light and shadows conditions and as respects to the high resolution of the data.

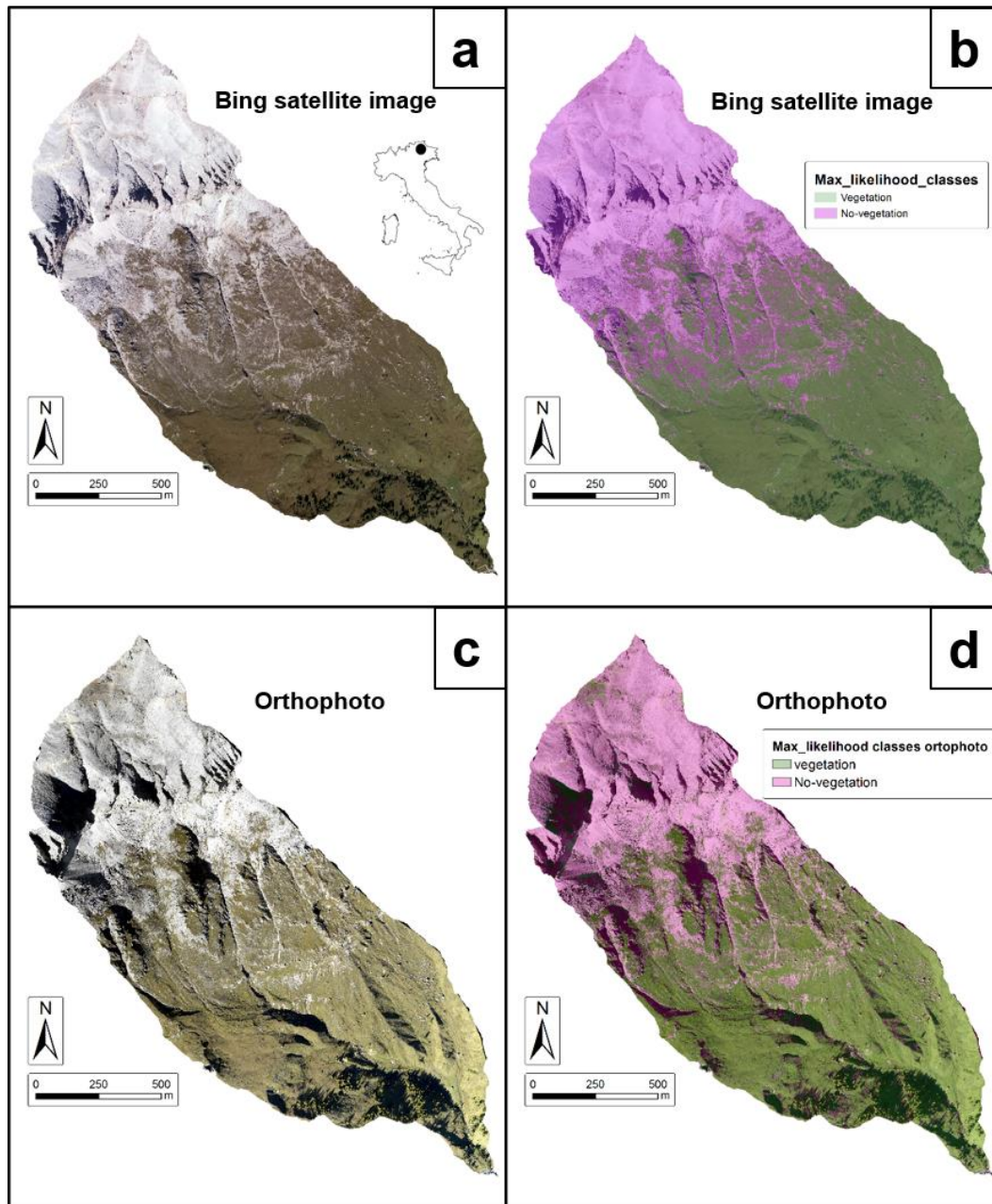


Figure 1. Study area with satellite terrain dataset (a) and orthophoto (c) and results of MLE classification on the presence or absence of vegetation at catchment scale using satellite image (b) and orthophoto (d)

A qualitative assessment of the georeferencing accuracy exhibits a good matching between the images with slightly higher distortion effects and uneven matching related to the rock cliff areas. First results and visual interpretation on the semi-automatic detection of the presence or absence of vegetation in the study area show a very good performance in the case of satellite imagery analysis while the orthophoto based classifications seems to be characterized by a low specificity related to a high wrong detection rate.

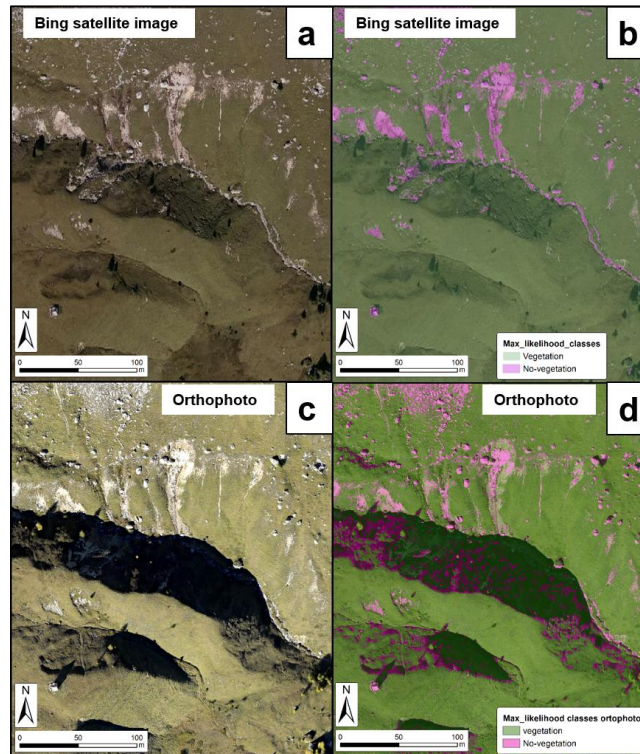


Figure 2. Shallow landslides within the study area: satellite image (a) satellite image-derived classification results (b), orthophoto (c) and orthophoto-derived classification results (d)

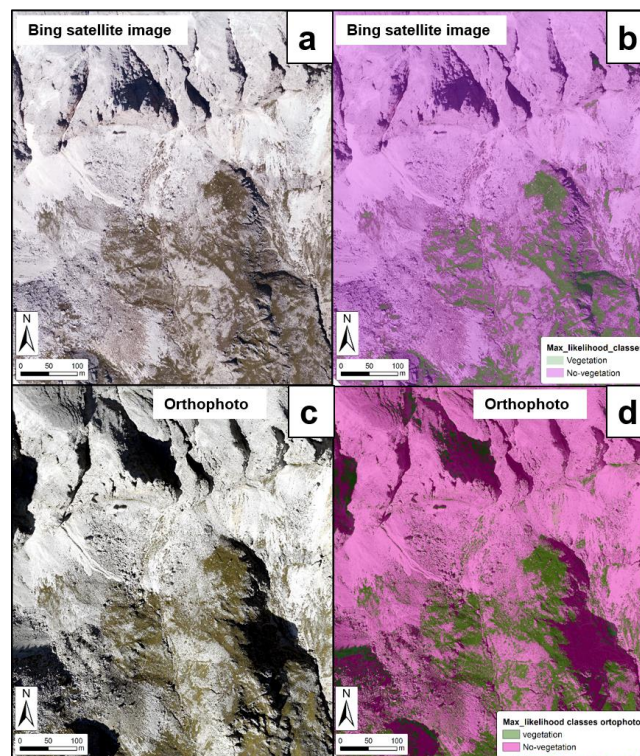


Figure 3. Dolomitic cliffs and sparse grasslands within the study area: satellite image (a) satellite image-derived classification results (b), orthophoto (c) and orthophoto-derived classification results (d)

A detailed analysis of the results focusing on an area where several shallow landslides are affecting the slope and a sparse trees are present in the lower portion (Figure 2 and Figure 4), highlights the effectiveness of the satellite image-derived classification not only considering the correct interpretation of shadowed areas but also in relation to the more precise boundary detection of the instability phenomena. The same behavior is shown when considering the upper portion of the catchment (Figure 3), characterized mainly by dolomitic cliffs and sparse herbaceous vegetation or even when focusing on an anthropic structure in the middle-lower part of the catchment. Markedly wrong classifications emerge in relation to the orthophoto-based classification both in shadowed areas in the upper part of the catchment and under medium illuminating condition in the middle-lower portion. Satellite image-based classification is instead very precise also in the above-mentioned conditions without significant wrong classification neither in the rocky headwater catchments, nor close by the anthropic structure. In all the analyzed cases, in shadowed areas, a clear different behavior between the two images emerged (Figure 2 to 5). This discrepancy in behavior is partially related to the Red, Green and Blue (RGB) pixel values of the two images especially in shadowed conditions. RGB bands show similar values between shadowed areas under vegetation and shadowed areas close by rocky cliffs in the orthophoto, while different values are observed, for the same two settings, in the satellite image. This discrepancy is likely ascribed to the different spectral bandwidth acquired by the two technologies, with a finer spatial resolution panchromatic band associated to the satellite images.

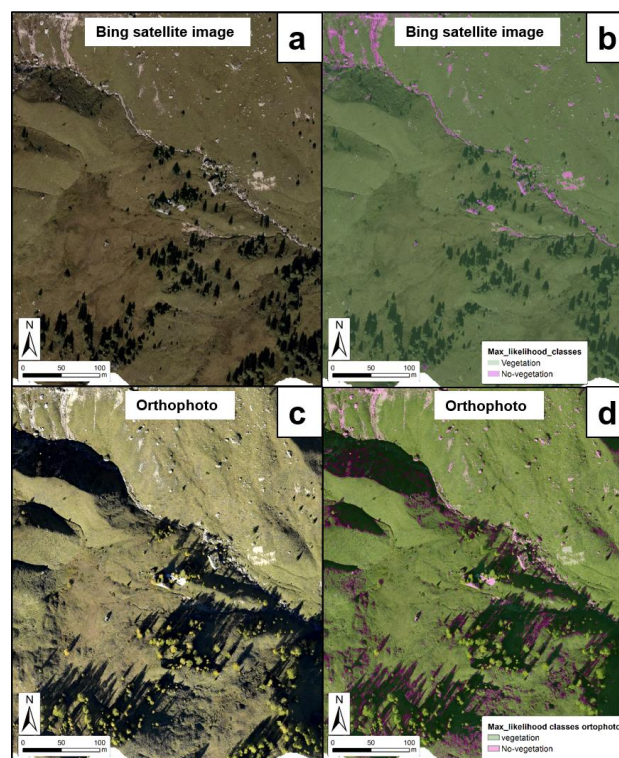


Figure 4. Shallow landslides and sparse forest within the study area: satellite image (a) satellite image-derived classification results (b), orthophoto (c) and orthophoto-derived classification results (d)

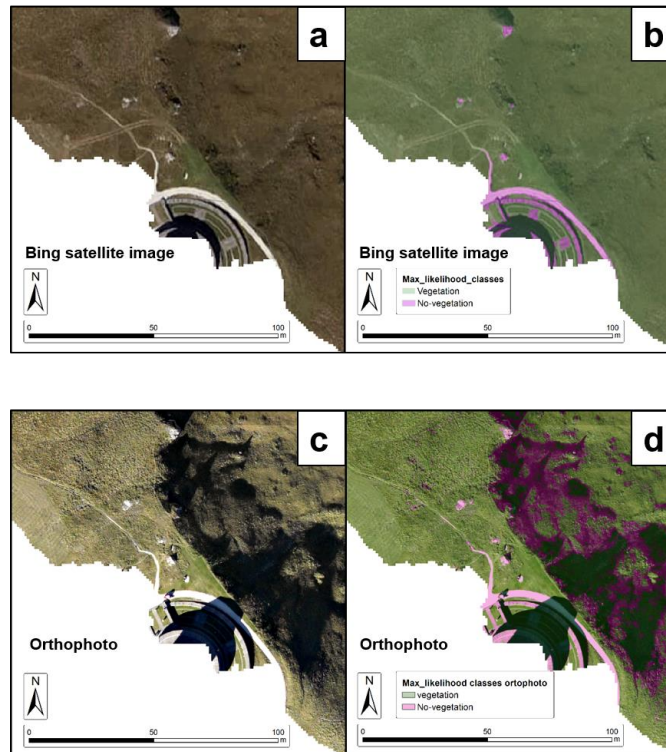


Figure 5. Artificial structure within the study area: satellite image (a) satellite image-derived classification results (b), orthophoto (c) and orthophoto-derived classification results (d)

In conclusion, an overall good performance of the satellite analysis emerged and, when sticking on vegetation-covered slopes, the semi-automatic detection of areas without vegetation could be a useful instrument for a first characterization and mapping of shallow landslides.

REFERENCES

- ESRI, 2014. ArcGIS Desktop: Release 10.3. Redlands, CA. Environmental Systems Research Institute.
- Guzzetti, F., Mondini, A.C., Cardinali, M., Fiorucci, F., Santangelo, M., Chang, K.-T., 2012. Landslide inventory maps: New tools for an old problem. *Earth-Sci. Rev.* 112, 42–66. doi:10.1016/j.earscirev.2012.02.001
- Marchi, L., Cavalli, M., Trevisani, S., 2015. Hypsometric Analysis of Headwater Rock Basins in the Dolomites (Eastern Alps) Using High-Resolution Topography. *Geogr. Ann. Ser. Phys. Geogr.* 97, 317–335. doi:10.1111/geoa.12067
- Oubeidillah, A., Kao, S.-C., Ashfaq, M., Naz, B., Tootle, G., 2014. A large-scale, high-resolution hydrological model parameter data set for climate change impact assessment for the conterminous US. *Hydrol. Earth Syst. Sci.* 18, 67–84. doi:10.5194/hess-18-67-2014
- Penna, D., Mantese, N., Hopp, L., Dalla Fontana, G., Borga, M., 2015. Spatio-temporal variability of piezometric response on two steep alpine hillslopes. *Hydrol. Process.* 29, 198–211. doi:10.1002/hyp.10140
- Penna, D., Van Meerveld, H.J., Zuecco, G., Dalla Fontana, G., Borga, M., 2016a. Hydrological response of an Alpine catchment to rainfall and snowmelt events. *J. Hydrol.* 537, 382–397. doi:10.1016/j.jhydrol.2016.03.040

- 143 Penna, D., Zuecco, G., Crema, S., Trevisani, S., Cavalli, M., Pianezzola, L., Marchi, L., Borga, M., 2016b.
- 144 Response time and water origin in a steep nested catchment in the Italian Dolomites. Submitted
- 145 to Hydrological Processes.
- 146 Strahler, A.H., 1980. The use of prior probabilities in maximum likelihood classification of remotely
- 147 sensed data. Remote Sens. Environ. 10, 135–163. doi:10.1016/0034-4257(80)90011-5
- 148 Trevisani, S., Cavalli, M., Marchi, L., 2009. Variogram maps from LiDAR data as fingerprints of surface
- 149 morphology on scree slopes. Nat Hazards Earth Syst Sci 9, 129–133. doi:10.5194/nhess-9-129-
- 150 2009
- 151 Xie, Y., Sha, Z., Yu, M., 2008. Remote sensing imagery in vegetation mapping: a review. J. Plant Ecol. 1,
- 152 9–23. doi:10.1093/jpe/rtm005
- 153