EGU General Assembly 2017

Observation of geomorphological processes on steep slopes in Dalmatia by using TLS

Goran Vlastelica and Predrag Miščević,

University of Split, Faculty of Civil Engineering, Architecture and Geodesy, Split, Croatia (goran.vlastelica@gradst.hr)

UNIVERSITY OF SPLIT, FACULTY OF CIVIL ENGINEERING, ARCHITECTURE AND GEODESY

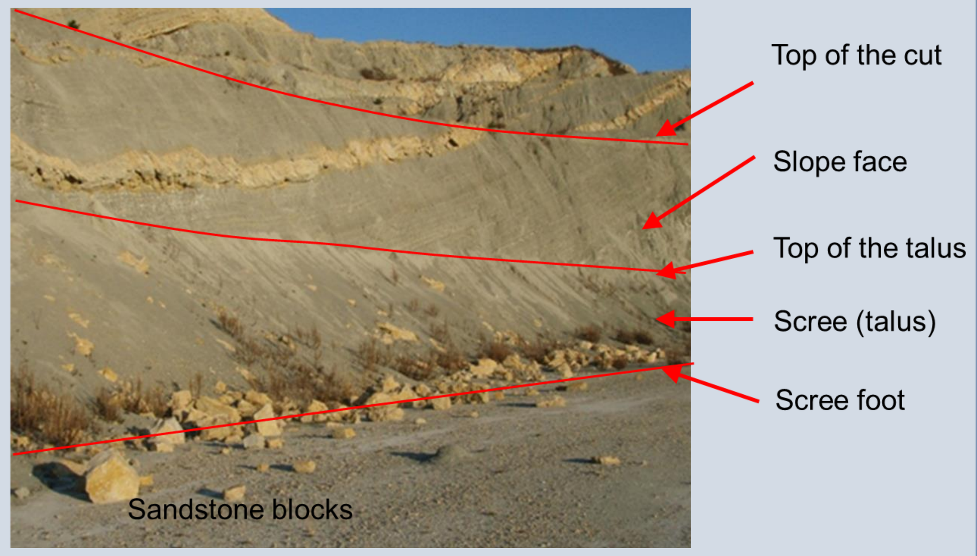
Introduction

Each year dozens of rockfalls and small landslides are recorded in Central Dalmatian region, while problems with erosion of the slope surface are an everyday occurrence. In addition, the geological settings are various, from predominantly flysch sediments in wider area of the city of Split, to the limestone massif in other parts of the coastline. Also, various Quaternary deposits in are also present. Therefore, it is often necessary to apply different types of slope stabilization, for which detailed geodetic survey is always necessary.

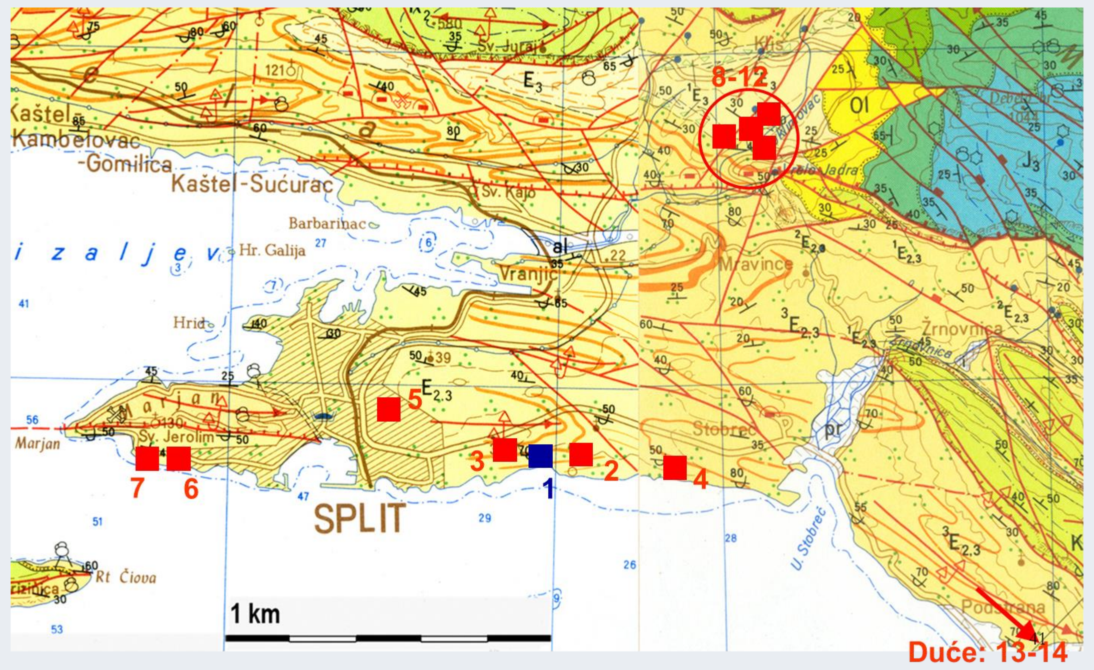
Flysch represents a complex geological and sedimentary environment made of different lithological components, whereas only few, depending on their mineral composition, are extremely susceptible to weathering and erosion. Precisely, the diversity of components in the flysch rock mass cuts emphasizes the issue of differential weathering and small scale rock falls. The existent cuts made in the wider area of the town Split are at the focus of this study.

The exogenous processes that take place (weathering, surface layer erosion, localized slides, and rock falls. . .) have causal effect on the security, and maintenance costs of the objects situated at the foot of the slope, and the stability of objects at the top.

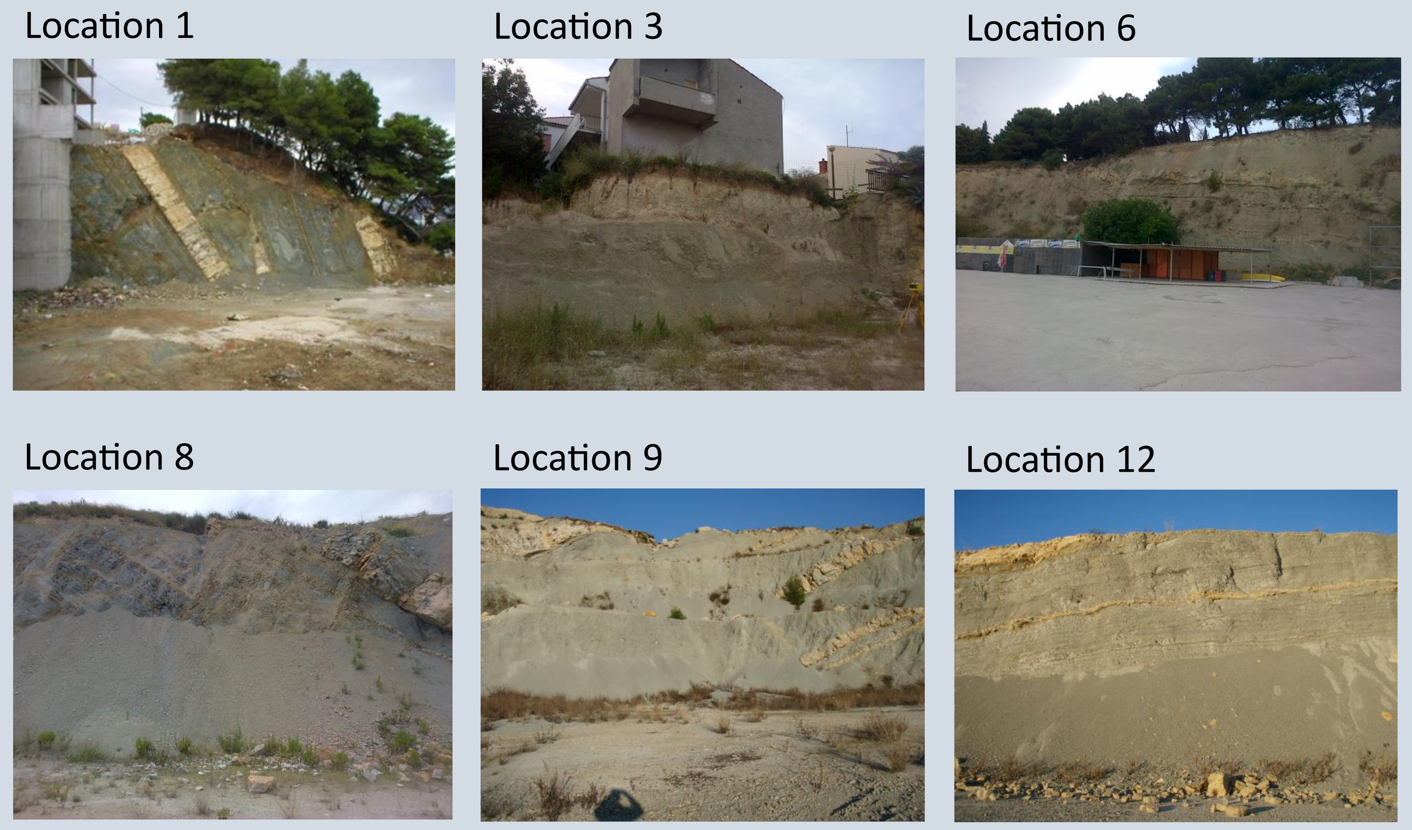
Field observations were carried using terrestrial laser scanner (TLS) on selected pilot locations. Data collected by TLS can be analysed for the entire surface of the slope to give a 3D insight into the development of the geomorphological processes such as: rockfall, sliding, toppling, etc.



Pilot locations



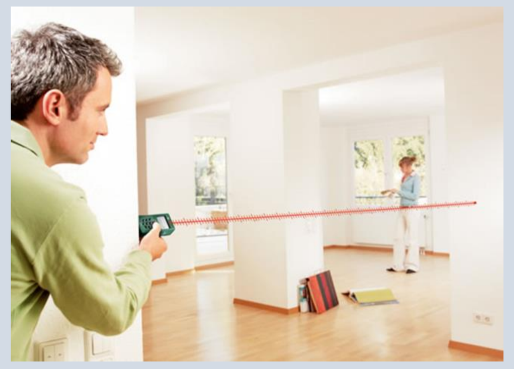
Official geological map of an area around town of Split (made by Croatian Geological Survey). Legend: (al) – alluvium, (pr) – proluvium, $E_{2,3}$ – Flysch: marl with intercalations of silicified calcareous sandstone, ${}^{1}E_{2,3}$ – Breccias with fragments of foraminiferal limestone, ${}^{2}E_{2,3}$ – Thin-bedded calcarenite, ${}^{3}E_{2,3}$ – Flysch: sandstones alternating with marls; lenses of limestone and calcirudite, E_3 – Breccias and conglomerate with insertions of limestone and marl, Ol – poorly sorted limestone breccias, K_2^3 – bulky or layered limestone and dolomite, J_3 – thick-bedded dolomitic limestone (OGK 1:100.000, Split and Omiš sheet)



In order to determine the rates of erosion of the cuts, 14 locations in the area of Split are selected. Locations have different geological settings, as well as orientations of cuttings and layering.

Methodology

Terrestrial laser scanning



x

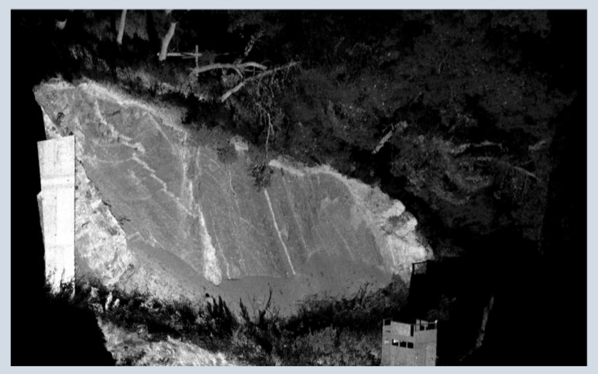
repetition rate

3000 Hz

=

Result:

Cloud of points with app 4 million points (Pilot location „Žnjan 1")



Valuable results:
(x, y, z) and Intensity of return-beam

Comparison of point clouds from different epochs

The first collection of data (Cloud of points, TIN) → 3D comparisons

... The new epoch of measurement (New cloud of points, After 6 months, 1 year, ...) → 3D comparisons

The initial geometric characteristics required for modeling → Define necessary input parameters (c, $R_{y,s}$ ili $R_{g,s}$) → 2D models (Mathematical models)

The change in morphology of cuts is carried out by comparing the point clouds from different epochs using the following methodology (Vlastelica et al. 2016):

- Obtaining a reference point cloud (Combine multiple point clouds in case of more scanning positions. Preferably georeferencing is done to determine spatial orientation of a cut).
- Creating a Triangle Irregular Network (TIN) model of the surface of the cut - reference surface (S_0).
- Obtaining new point cloud after a certain period (PC_1, PC_2, ..., PC_n)
- Preparing the data for alignment between the multiple epochs.
- Comparing of the PC_i with the S_0.
- Calculating the difference for each different epoch.
- Creating cross-section for comparison or directly comparing point cloud with S_0 in 3D.

Preparation of data for comparison (4th bullet) between the series of measurements is defined by alignment matrix of the new point cloud with the reference surface.

The alignment matrix is defined by using a fixed object in the environment (buildings near of cuts or geological members which are not subject to weathering in engineering time scale), in following four steps:

- Identification of the stable part of the cut or an object in vicinity of the cut.
- Removal of the part of the point cloud where the changes take place (detachment and deposition) and any unwanted measurements (vegetation, moving objects, etc.).
- Alignment of the chosen stable part using Iterative Closest Point (ICP) algorithm, which defines the alignment matrix of the point cloud.
- Using the alignment matrix on the original point cloud.

Distance of each point in PC_i and S_0 is calculated using the "Data vs. Reference comparison", (Polyworks v12), wherein the direction of comparison is determined by the direction of the vector perpendicular to the reference plane S_0. For the purpose of comparison of the data it is not necessary to execute georeferencing.

PC_0

↓

S_0

↓

PC_1 Δt_1

PC_2 Δt_2

⋮ ⋮

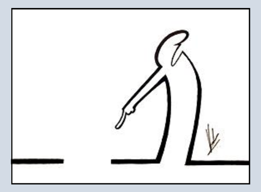
PC_n Δt_{n-1}

↓

PC_i vs S_0

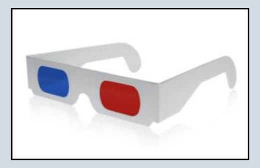
↓

2D



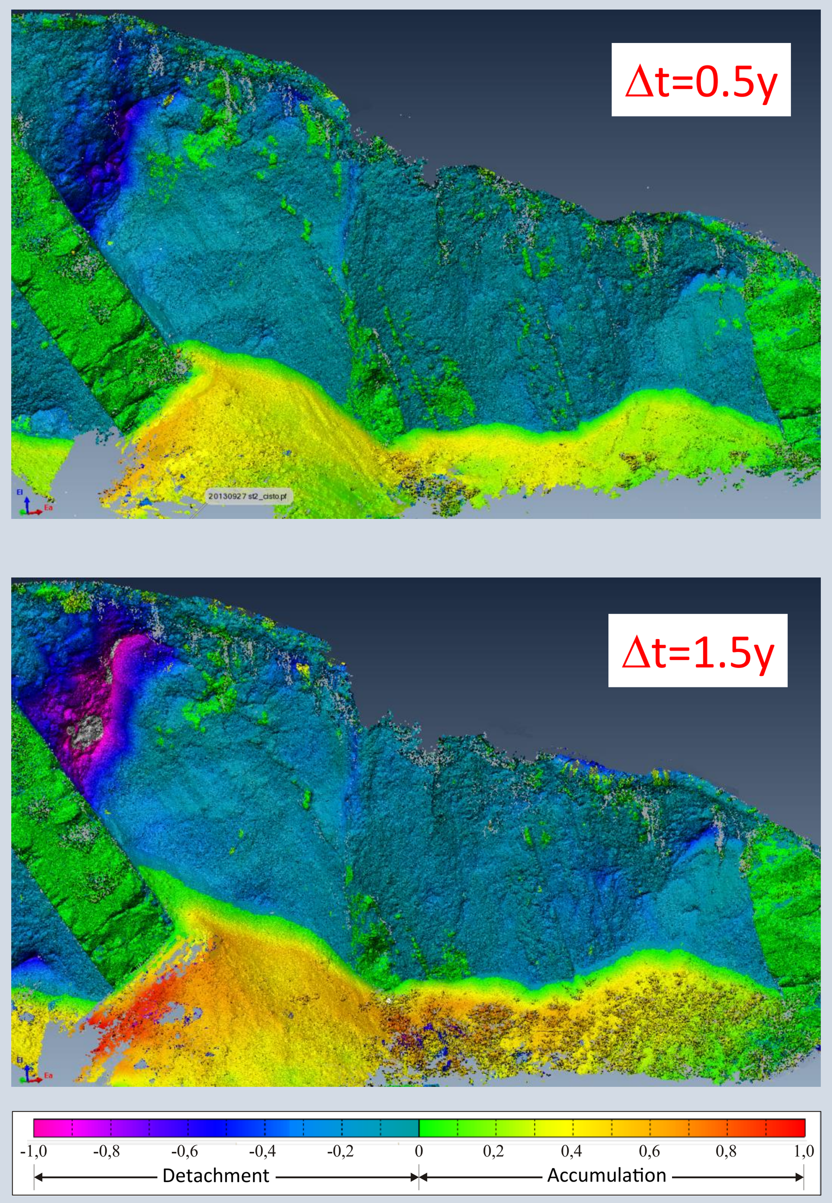
or

3D

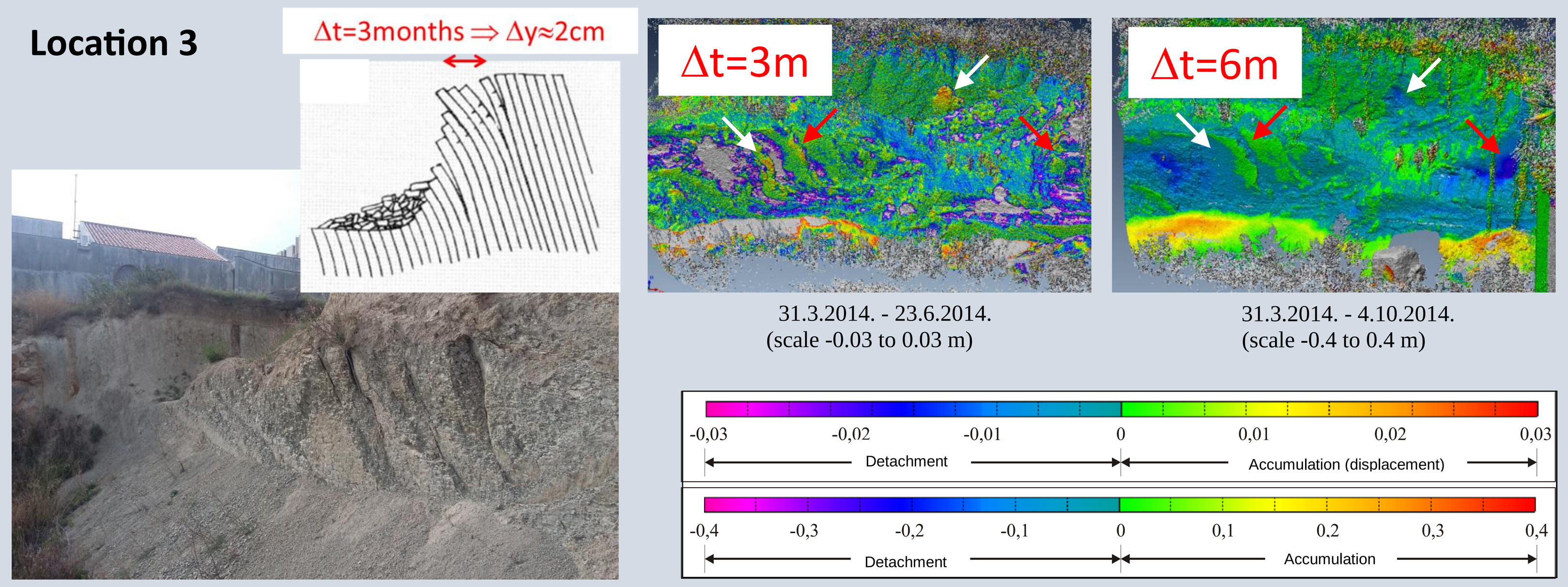


Results

Location 1

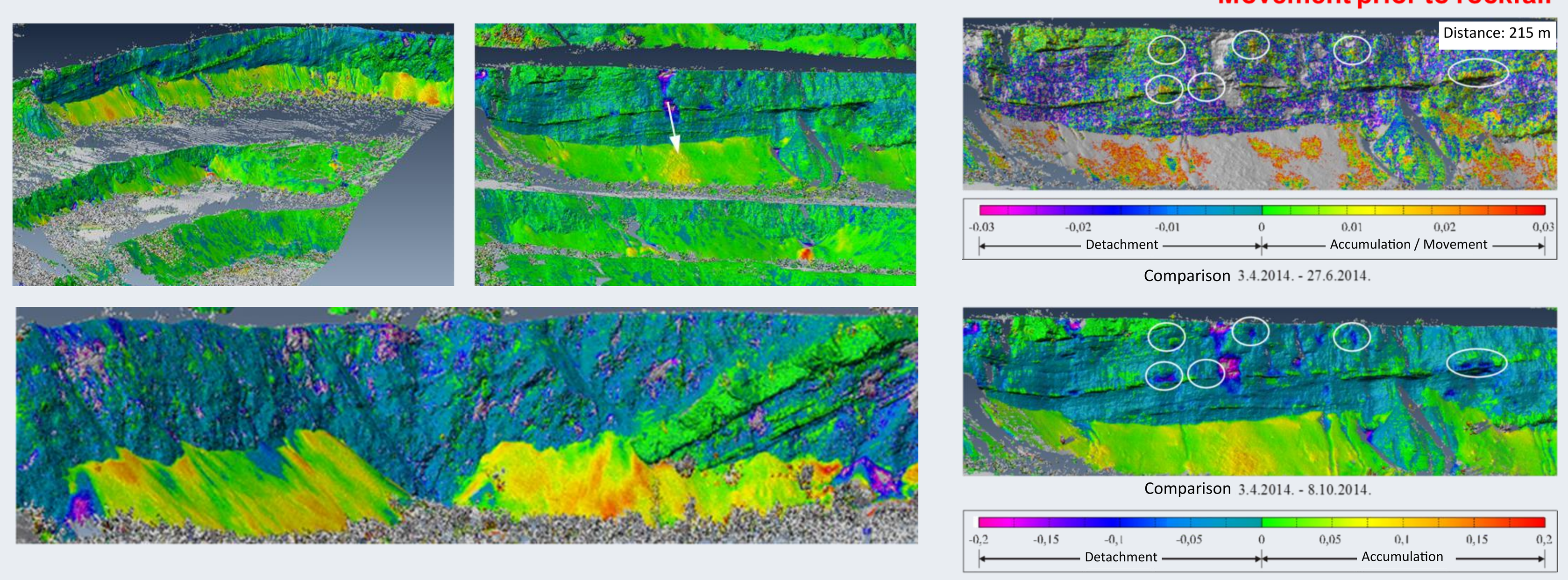


Location 3



Location 12

Movement prior to rockfall



Conclusions

- It is possible to detect the change of morphology in short time intervals (3, 6 or 12 months).
- Annual erosion rate (R) and coefficient c for 2D mathematical models can be determined even by short time monitoring (couple of years).
- Useful for forecasting and retrograde analysis.
- With shorter time intervals between scans – rockfall forecasting possible.

References and additional information:

- Miščević, P., Vlastelica, G. (2014) „Impact of weathering on slope stability in soft rock mass", Journal of Rock Mechanics and Geotechnical Engineering, Volume 6, Issue 3, Pages 240–250.
- Vlastelica, G. (2015): „The Influence of Weathering on Durability of Cuts in Soft Rock Mass". Split: University of Split, Faculty of Civil Engineering, Architecture and Geodesy. PhD thesis.
- Vlastelica, G., Miščević, P., Fukuoka, H. (2016): „Monitoring of vertical cuts in soft rock mass, defining erosion rates and modelling time-dependent geometrical development of the slope" . Rock Mechanics and Rock Engineering: From the Past to the Future. Eds.: Ulusay, R. et al., CRC Press / Taylor & Francis, London, pp. 1249-1254.
- Vlastelica, G., Miščević, P., Fukuoka, H. (2014): „Rockfall Monitoring by Terrestrial Laser Scanning - Case Study of the Rock Cliff at Duće, Croatia // *Landslide and Flood Hazard Assessment, Proceedings of the 1st Regional Symposium on Landslides in the Adriatic-Balkan Region with the 3rd Workshop of the Japanese-Croatian Project "Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia"* / Mihalić Arbanas S. ; Arbanas Ž. (ur.). Zagreb : FMGPE, University of Zagreb and FCE, University of Rijeka, pp. 51-55.