The Salerno University Geomorphological Informative Mapping System: the Licosa polygentic case study (Cilento European Geopark, southern Italy).

Guida D., Cuomo A.
Department of Civil Engineering
Salerno University
Fisciano Campus, Italy

Cestari A., Siervo V.
C.U.G.RI- interUniversity Consortium for Prevision and
Prevention of Great Risks,
Fisciano (SA), Italy

Dramis F.
Department of Geological Science,
Roma Tre University,
Rome, Italy

Palmieri V.
ARCADIS - Campanian Agency for Soil Defence,
Naples

Abstract— **The paper presents a specific application to a typical Mediterranean landscape (Punta Licosa headland) based on an advanced procedure of the hierarchical, multi-scale, object-based geomorphological mapping system in use at the Salerno University (Italy). The study area is a wide valley head characterized by shallow landslides and active stream erosion affecting Pleistocene landforms produced by diffusive processes (hollows, side-slopes, and noses). Based on simple geomorphometric parameters, from object-based geomorphological map obtained by supervised automatic landforms recognition, spatial analyses on target areas of the landscape have been performed. Results of the above analyses highlighted superposition landform components related to two distinctive morphogenetic controls. The proposed procedure allows the quantitative reconstruction of geomorphic events and scenarios in polygenetic/poly-chronologic landscapes, useful to assessing landslide and erosion hazard in a dynamic way.**

I. INTRODUCTION

Traditional geomorphological mapping, based exclusively on extensive field surveys, aerial photo analysis and symbol-based representation, is generally unable to provide a complete representation of landscape complexities at different scales and, therefore, is inadequate to fulfill all the scientific and practical needs of the modern society [1]. On the other hand, multiscale mapping, managed by Geographical Information System (GIS) [2] are easily readable and applicable to multidisciplinary landscape studies, such as geo-hazard zoning for risk mitigation, land conservation, inventory of geo-sites, soil mapping, hydrology, landscape ecology, environmental engineering, forestry and agronomy. Current advances in automated terrain analysis are based on geo-statistical and geo-morphometric concepts and procedures [3] [4] using both satellite imagery and Digital Elevation Models (DEMs), processed by GIS [5]. Automatic landform recognition is based both on supervised and unsupervised approaches. Supervised approach calibrates grid- or object-oriented mapping procedure by expert-judgement on training areas and extends the calibrated rules to the target areas [6] [7]. The unsupervised procedure can be based exclusively on grid segmentation and classification techniques, allowing the partitioning of DEMs or remotely sensed imagery by specific rule-sets into non-overlapping regions (segments), representative of geomorphic entities [8] [9]. Object-oriented geomorphological mapping is increasingly used both in the automatic and semi-automatic definition of landforms, with particular reference to those connected with hillslope and fluvial processes. The capacity of overcoming the ‘a-dimensional’ limitations related to symbol-oriented methods has progressively induced a widespread diffusion of this context [1] [9]. However, the transition to a full use of object-oriented geomorphological mapping is not simple and immediate. In fact, before reaching the goal of a reliable automatic recognition of landforms from DEM or remote sensing imagery, the ‘traditional’ symbol-oriented mapping system will continue to be used at least as the first operative step of the object-oriented methodology. DEMs are frequently used to extract surface morphology from elevation derivatives such as slope angle, plan and profile curvature, aspect, local drainage direction and upslope area [3] [10]. The basic concept in the automatic recognition and mapping of DEM-based landform is

---

In: Geomorphometry for Geosciences, Jasiewicz J., Zwoliński Zb., Mitasova H., Hengl T. (eds), 2015. Adam Mickiewicz University in Poznań
- Institute of Geoecology and Geoinformation, International Society for Geomorphometry, Poznań

that each landform should be associated to a distinctive geomorphometric signature, as a specific combination of elevation derivatives [3] [11]. In theory, a known training set of *geomorphometric signature dictionary'* could be used to compare extracted terrain objects with standard 'discrete landforms' for their spatial automatic recognition and classification [12]. Actually, however, most landscapes are the result of a polygenetic and poly-chronologic geomorphic evolution. Frequently, younger landforms due to active geomorphic processes may transform, at least in part, discrete terrain landforms into new features: *i.e*, a colluvial hollow stemming from diffusive soil transport during the last glacial period may be modified by post-glacial / periglacial erosional processes or superimposed by new landforms [13]. This implies that the statistical information provided by present-day land features may be also 'inherited' from earlier land features. Fuzzy classification of objects belonging to more than one class can be used to overcome this problem. This may lead to geomorphological maps linked to a spatial geodatabase in a GIS, as proposed by [14] and [15]. These proposals represent an advanced approach on how we can represent and organize geomorphological objects, but they do not overcome the issue of the spatial super-position of objects and then their temporal succession as morphogenetic events, both in the same and in different morpho-climatic regimes. In [1] is illustrated a new GIS-based, full-coverage, object-oriented geomorphological mapping system. This system, named "Geomorphological Informative System_Salerno University" (GmIS_UniSa), is in use at the Department of Civil Engineering and the CUGRI (Great Risks inter-University Consortium, Salerno University) for application in several engineering, landscape ecology and hydro-geomorphology projects [16]. Currently, are being introduced improvements in GmIS_UniSa in order to perform the automatic space-time recognition of landform typology and evolution. This will allow a 'non-subjective' and repeatable delineation of the landform changes in order to better pursue dynamic landscape analyses and support environmental scenarios. The paper discusses this issue.

II. CASE STUDY OF THE SALERNO UNIVERSITY GEOMORPHOLOGICAL INFORMATIVE MAPPING SYSTEM

In order to enhance the above improvements in a real landscape, has been carried out an application on the Licosa Headland study area (Cilento European Geopark), a coastal landscape of the southern Tyrrhenian borderland (Fig. 1). Our aim was to recognize the space superposition and time succession of landforms in this typical Mediterranean polygenetic landscape by applying further geomorphometric procedures to the GmIS_UniSa [1]. The attention was focused on the objective landform mapping produced by present-day processes acting on Pleistocene landforms, such as active channels and shallow landslides on terraced alluvial fans, marine terraces, talus slopes and colluvial hollows.

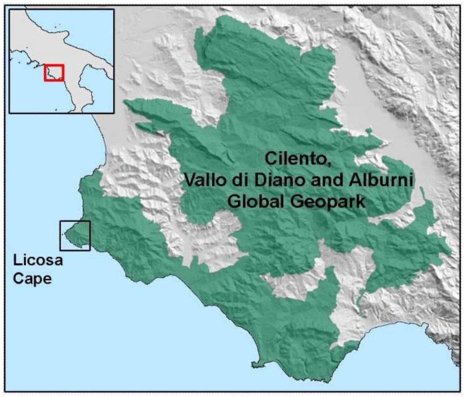

Figure 1. Location of the study area.

The new procedure includes an expert-driven spatial analysis on the traditional four steps of the GmIS_UniSa [1]. Step 1 concerns the 'traditional' field-surveyed, symbol-based geomorphological mapping and Step 2 "translates" the previously mapped landforms into a bounded, full coverage geomorphological map, delimiting and coding the geomorphological features as geomorphological units in a geodatabase. At the end of Step 2, specific "training landform units" are been selected among the most representative polygenetic landforms in the landscape. Step 3 manages the "training landform units" of Step 2 using a recursive procedure by rule-sets in a usual grid-based landform recognition, starting from a 5x5 m DEM and obtaining a new map by a first objective spatial validation of the previous subjective boundaries (Fig. 2). Step 4 performs the object-based procedure by *e-Cognition* package (Trimble Inc.) using the same 5x5 m DEM. The procedure includes: 1. grid-based pre-processing (Fig. 2a) of significant parameters (i.e. curvature, slope, flow accumulation, etc.; 2. segmentation of objects based on discriminant parameters with different weights (Fig. 2b); 3. supervised classification of the training landform components (Fig. 2c) and, finally, 4. fuzzy membership classification on target landform components having maximum likelihood in respect to the training ones (Fig. 2d). In order to improve the spatial relationships of the above illustrated objective mapping of over-posed landforms with different ages (herein event-based mapping), a sample procedure has been applied to the zero order basins or ZOB's (Fig. 3a), located as Fig. 2d. A distributed statistical analysis has been performed by using the plan and profile curvature as discriminant geomorphometric parameters, on the ZOB's components over the entire study area: hollow,

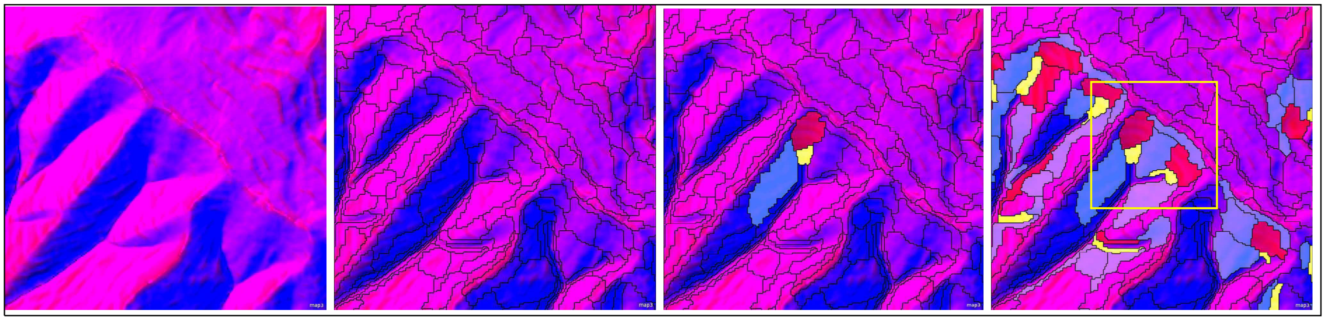

Figure 2. a) Grid –based pre-processing; b) Object segmentation; c) Training object classification; d) target object extension to the study area.

transient channel, first order channel and side slope. In the plot of Fig. 3b the results of the analyses are shown and two main fields can be clearly observed, each representing the geomorphometric signature of landform components due to two distinctive morphogenetic controls.

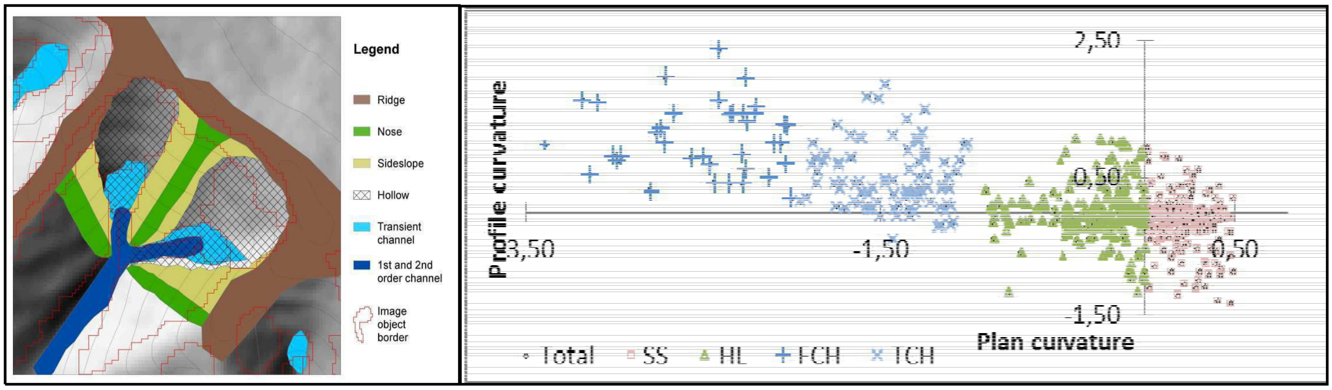

Figure 3. a) ZOB Landform Component map by automatic (red lines) and expert recognition; b) Plan vs Prof Curvature plot showing, on the right, the geomorphometric signature of landform components resulting from Pleistocene dominant diffusive processes (Side-slope – SS- and Hollow – HL); the left field shows landform components produced by Holocene dominant advective processes: transient channel – TCH - and first-order channel – FCH.

On the right, a very dense cluster of points defines both side slope (SS as pink squares), having PlanCurvature values > 0 and ProfCurvature values spanning between 1.00 and -1.00, and hollow (HL, green triangles) having PlanCurvature <0 up to -1.0 and the ProfCurvature having the same values intervals of SS. On the left, a more sparse cluster having a PlanCurvature < -1.0, spreads toward positive values in ProfCurvatures. The first field indicates the geomorphometric signature of the landform components resulting from diffusive hillslope processes, dominant during late Pleistocene stadial and inter-stadial stages. The second one results from dominant Holocene advective processes, as sapping erosion in the transient channel (TCH) and gully erosion along the first-order channel (FCH), both involved in debris flow initiation and transport, where boundary conditions are prone to trigger these processes.

III DISCUSSION AND CONCLUSION

Object-based spatial analyses performed by the GmIS_UniSa on the study area demonstrate their capability to perform the quantitative reconstruction of geomorphic events in polygenetic and poly-chronologic landscapes. Detailed field surveys confirmed the consistence between geomorphometric distribution of landforms and their long-term geomorphic evolution, revealing a mid-term geomorphic competition at the hollow toe, between gully retreat and colluvial filling by soil creep from side slopes. Downstream, the V-shaped channel indicates that the upstream collected runoff causes the initial and subsequent, progressive incision of the gully. This geomorphic path can evolve into flow-like transport, where saturation of colluvial soil and associated sapping erosion induces multiple, shallow soil slips, represented by narrow, elongated U-shaped scars. Finally, the reconstruction of the pre-existent hollow boundaries, modified by Holocene linear erosion, was obtained by means of specific geomorphometric rule-sets based on flow accumulation, topographic wetness index and flow direction, having down-valley terminations at the first to second order channel junctions (gridded in Fig 3a). Objective space-time discrimination between present-day erosional and gravitational hillslope processes, acting on previous landforms could be definitely useful for both objective and dynamic assessment of geomorphological hazards, such as landslides and erosion.

In conclusion, the procedure applied to the zero order basins seems to demonstrate an effective capacity of improving the time-spatial relationship of landforms in the object-based mapping procedure. Moreover, the topological relations of superposition and substitution between geomorphological objects, introduces the perspective of transforming the present-day object-based mapping into event-based mapping.

ACKNOWLEDGMENT

Authors are grateful to CUGRI for technical and Cilento Geopark for financial support to research activities.

REFERENCES

[1] Dramis, F., Guida, D. and Cestari, A. (2011). Nature and Aims of geomorphological mapping. In: Smith, M.J., Paron, P. and Griffiths J.S. (Eds.), Geomorphological mapping: Methods and applications, pp. 39-73, Elsevier, Amsterdam.

[2] Mark, D. and Smith, B. (2004). A science of topography: from qualitative ontology to digital representations. In: Bishop, M. and Shroder J. (Eds.), Geographic Information Science and Mountain Geomorphology, pp. 75-100,, Springer-Verlag, Berlin.

[3] Mìnar, J. and Evans, I. (2008). Elementary forms for land surface segmentation: The theoretical basis of terrain analysis and geomorphological mapping. Geomorphology, 95, 236-259.

[4] Smith, M.J. (2011). Digital mapping: visulisation, interpretation and quantification of landforms. In: Smith, M.J., Paron, P. and Griffiths J.S. (Eds.), Geomorphological mapping: Methods and applications, pp. 225-251, Elsevier, Amsterdam.

[5] Oguchi, T., Hayakawa, Y. and Wasklewicz, T. (2011). Data sources. In: Smith, M.J., Paron, P. and Griffiths J.S. (Eds.), Geomorphological mapping: Methods and applications, pp. 189-224, Elsevier, Amsterdam.Pike, R., Evans, I. and Hengl, T. (2008). Geomorphometry: a brief guide. In: Hengl, T. and Reuter, H.I. (Eds.), Geomorphometry: Concepts, Software, Applications, pp. 1-28, Elsevier, Amsterdam.

[6] Molenaar, M. (1989). Single valued vector maps. A concept in Geographic Information Systems. GIS, 2(1), 18-26.

[7] Schmidt, J. and Hewitt, A. (2004). Fuzzy land element classification from DTMs based on geometry and terrain position. Geoderma, 121(3-4), 243-256.

[8] Drăgut, L. and Blaschke, T. (2006). Automated classification of landform elements using object-based image analysis. Geomorphology, 81, 330-344.

[9] Anders, N., Seijmonsbergen, A. and Bouten, W. (2011). Segmentation optimization and stratified object-based analysis for semi-automated geomorphological mapping. Remote Sensing and Environment, doi:10.1016/j.rse.2011.05.007.

[10] Pike, R., Evans, I., & Hengl, T. (2008). Geomorphometry: a Brief Guide. In T. Hengl, & H. I. Reuter, Geomorpho-metry: Concepts, Software, Applications. (Vol. 33, p. 1-28). Elsevier.

[11] Wood, J.K. (1996). The geomorphological characterisation of digital elevation models. PhD thesis, Department of Geography, University of Leicester, Leicester, UK, (http://www. soi.city.ac.uk/~jwo/phd/). Accessed 12th September 2008.Gallant, J.C., and M. F. Hutchinson, 2009. "A Differential Equation for Specific Catchment Area", In Geomorphometry 2009 Conference Proceedings, Edited by: Purves, R., Gruber, S., Straumann, R. and T. Hengl, University of Zürich, Zürich.

[12] Anders, N. and Seijmonsbergen, A. (2008). Laser altimetry and terrain analysis. A revolution in geomorphology. GIM international, 36-39.

[13] Guida, D. (2003). The role of Zero-Order basins in flowslides-debris flows occurrence and recurrence in Campania (Italy). In: Picarelli, L. (Ed.), Conference on Fast Slope Movements-Prediction and Prevention for Risk Mitigation, vol. 2, pp. 255-262. Napoli, Patron Editore, Bologna.

[14] Van Asselen, S. and Seijmonsbergen, A. (2006). Expert-driven semi-automated geomorphological mapping for a mountainous area using a laser DTM . Geomorphology, 78, 309-320.

[15] Gustavsson, M. and Kolstrup, E. (2009). New geomorphological mapping system used at different scales in a Swedish glaciated area. Geomorphology, 110, 37-44.

[16] Cuomo, A. (2012). The contribution of hydro-geomorphology in the evaluation of flood discharge in the Campania region. PhD Thesis, University of Salerno, Italy.