Volume : 3 | Issue : 3 | March 2014 ISSN - 2250-1991

Research Paper Earth Science

Influence of DEM (Digital Elevation Model) Resolution in Geomorphological Modeling

* Samuele Segoni	Department of Earth Sciences, University of Firenze, Via la Pira 4, 52021, Firenze, Italy. *corresponding author
Sandro Moretti	Department of Earth Sciences, University of Firenze, Via la Pira 4, 52021, Firenze, Italy.

ABSTRACT

We investigate whether an improvement in spatial resolution of DEMs (Digital Elevation Models) always leads to an improvement in the results of geomorphological models. To this end, we selected a state-of-art model for the prediction of soil thickness and we applied it in a test area using input data derived from DEMs with a cell size of 5, 10 and 20 meters. Resulting soil thickness maps were validated and the differences were discussed and put in relation with the different spatial resolutions of the original DEM. We found that in our case a 10m resolution better constrained the morphological characteristics of the study area and provided better results. We conclude that in basin scale geomorphological modeling meso-scale DEMs could be conveniently used to account for the morphologic characteristics of the study area.

KEYWORDS Digital Elevation Model, DEM, soil thickness, geomorphology, resolution.

INTRODUCTION

The quality of the results of geomorphological models depends in part on the quality of the input parameters (Segoni et al., 2012) and among all input parameters DEMs (Digital Elevation Models) are among the most important, as they quantitatively represent the morphology of the study area.

The accuracy and the resolution of DEMs (intended here as the size of their cells) has greatly improved in recent years, as an instance airborne remote sensing techniques (Tofani et al., 2013) can be used to obtain high-detail DEMs with pixel resolution below one meter.

This manuscript investigates whether an improvement in spatial resolution of DEMs always leads to an improvement in the results of geomorphological models, and to which extent. To this end, we selected a state-of-art model for the prediction of soil thickness and we applied it in a test area using input data derived from DEMs characterized by different resolution (i.e. different size of the cells). The results were validated and the errors committed were statistically analyzed. The differences found in the characteristics of the errors were discussed and put in relation with the spatial resolution of the original DEM.

MATERIAL AND METHODS

The study area is the Armea catchment (38 km^2), Italy, a mountainous basin where altitudes range from 1298m to nearly the sea level (Figure 1). The bedrock is formed by Cretaceous and Eocenic flysches; the very steep mountainsides are shaped by active erosive processes that are responsible of thin layers of soils reaching the depth of some meters at the footslopes.

The state-of-art model for soil thickness used in this work is the GIST model (Catani et al., 2010), which can be considered quite consolidated as it has been used in several applications in the field of basin-scale geomorphological modelling (Segoni et al, 2009; Segoni et al., 2012; Rossi et al., 2013, Mercogliano et al., 2013).

GIST is an empirical model that correlates soil thickness with three morphometric attributes (namely curvature, relative position along the hillslope profile and slope gradient) derived from the DEM using GIS analyses. In addition, the correlations are differentiated based on peculiar geomorphological and lithological features encountered in the area. Further details can be found in Catani et al., 2010.

Figure 1: Test site (modified after Segoni et al., 2009).

In the Armea basin the GIST model was applied three times, using three DEMs at different resolution: the official 20m resolution DEM of the National Geographic Military Institute and 10m and 5m resolution DEMs derived from the digitalization of topographic maps at the 1:5,000 scale (Segoni et al., 2009).

Consequently, three spatially distributed soil thickness maps were obtained with the same spatial resolution of the original DEM.

RESULTS AND DISCUSSION

The three soil thickness maps were validated by means of a comparison between the soil thickness calculated by the models and the DTB directly measured in the field in 151 control points.

The errors committed by the GIST model (difference between modelled and real soil thickness) were calculated and we verified that the three applications showed noticeable differences. The sensitivity of the GIST model to the resolution of the original DEM is not surprising, since the model is based on three morphometric attributes derived from the DEM. Some basic statistical properties were derived to quantitatively compare the results of the three models at different resolutions (Tab. 1). Table 1 shows that the highest errors are obtained with the coarser resolution. However, the quality of the results does not increase accordingly to the spatial resolution: the better results in terms of mean and maximum absolute errors are obtained using the 10m resolution DEM.

TABLE – 1
Comparison of the errors of the model at different resolutions

DEM resolution	Maximum absolute error	Mean absolute error	Standard deviation
5 m	2.06 m	0.37 m	0.38 m
10 m	1.81 m	0.32 m	0.30 m
20 m	2.62 m	0.55 m	0.62 m

More in detail, figure 2 shows a comparison between the frequency histograms of the errors.

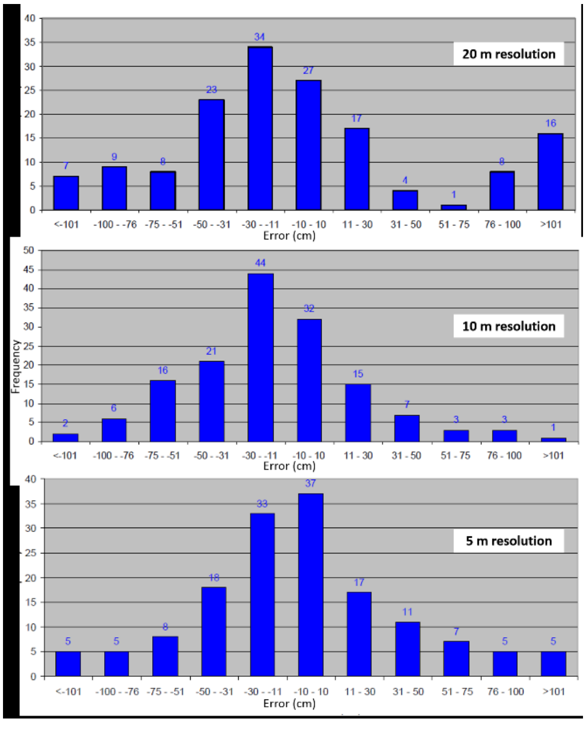

Figure 2: Frequency histograms of the errors committed by the GIST model at different spatial resolutions.

In case of the 20 m resolution, we can observe a bimodal distribution with a peak corresponding to moderate underestimations and another one corresponding to relevant overestimations of soil thickness. The other two histograms have a distribution more similar to a Gauss curve centered on low errors, highlighting a more balanced performance of the model. Even if the frequency peak at the 5 meters resolution is centered on negligible errors (lower than 10 cm), the histogram tails highlight that high and very high errors are more frequent than in the 10 meters resolution. Consequently, it can be concluded that the model obtains the best performance at the 10 meters resolution.

In a study area characterized by a high energy of relief, a coarser resolution (20m) does not adequately represent the morphology: reliefs are smoothed, slope gradients could be averaged, hydrographic network not adequately represented in narrow valleys and erosive and depositional landforms non adequately represented. That brings to an approximate definition of the topographic parameters used by the morphological models, and reflects on the results, which are affected by relevant errors.

A resolution finer than the optimal one is able to model the landforms in great detail, but this can bring to errors nevertheless: a very high detail can overestimate the importance of the micro variations of morphology, which not necessarily have a relevant importance from a geomorphological point of view. In addition, these micro-scale variations can hide the meso-scale landforms, which are of interest in catchment scale geomorphological modelling.

CONCLUSIONS

The same geomorphological model (namely the GIST model - Catani et al., 2010) for the distributed modelling of soil thickness produced different results depending on the spatial resolution of the original DEM used to account for the morphology of the study area. We demonstrated that an improvement in the resolution does not necessarily lead to an improvement of the quality of the results. Indeed, the 10 meters resolution produced lower errors than the 20 and 5 meters resolutions: on one hand, a 20 m resolution is too coarse to adequately represent the landforms of a study area characterized by a relevant energy of relief; on the other hand, in case of the finest resolution, the meso-scale landforms resulted shaded by high-frequency variations of the topography that have limited importance in basin-scale geomorphological modelling.

This outcome is important because very detailed DEMs are generally less widespread and more expansive to produce: their affordability does not limit the possibility of performing basin scale geomorphological modelling when limited economical budgets constrain research programs.

REFERENCES

Catani, F., Segoni, S., and Falorni, G. (2010), "An empirical geomorphology-based approach to the spatial prediction of soil thickness at catchment scale". Water Resour. Res., 46, W05508, doi:10.1029/2008WR007450. | Mercogliano, P., Segoni, S., Rossi, G., Sikorsky, B., Tofani, V., Schiano, P., Catani, F., and Casagli, N. (2013), "Brief communication: a prototype forecasting chain for rainfall induced shallow landslides". Nat. Hazards Earth Syst. Sci. 13, 771–777. | Rossi, G., Catani, F., Leoni, L., Segoni, S., and Tofani, V. (2013), "HIRESSS: a physically based slope stability simulator for HPC applications". Nat. Hazards Earth Syst. Sci., 13, 151–166. | Segoni, S., Leoni, L., Benedetti, A. I., Catani, F., Righini, G., Falorni, G., Gabellani, S., Rudari, R., Silvestro, F., and Rebora, N. (2009), "Towards a definition of a real-time forecasting network for rainfall induced shallow landslides". Nat. Hazards Earth Syst. Sci., 9, 2119–2133. | Segoni, S., Rossi, G., and Catani, F. (2012), "Improving basin scale shallow landslide modelling using reliable soil thickness maps". Nat. Hazards, 61, 85–101. | Tofani, V., Segoni, S., Agostini, A., Catani, F., and Casagli, N. (2013), "Technical Note: Use of remote sensing for landslide studies in Europe". Nat. Hazards Earth Syst. Sci., 13, 299–309. |