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## A geomorphometric approach to estimate soil volumes stored in agricultural terrace systems

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Geomorphometric information can be exploited to study the most extensive and common landforms that humans have ever produced: agricultural terraces. An understanding of these historical ecosystems can only be determined through in-depth knowledge of their origin, evolution, and current state in the landscape. These factors can ultimately assist in the future preservation of such landforms in a world increasingly affected by anthropogenic activities. High-resolution topographic (HRT) techniques allow the mapping and characterization of geomorphological features with wide-ranging perspectives at multiple scales. From HRT surveys, it is possible to produce high-resolution Digital Terrain Models (DTMs) to extract important geomorphometric parameters such as topographic curvature, to identify terrace edges, even if abandoned or covered by uncontrolled vegetation. By using riser bases as well as terrace edges (riser tops) and through the computation of minimum curvature, it is possible to obtain environmentally useful information on these agricultural systems such as terrace soil thickness and volumes. The quantification of terrace volumes can provide new benchmarks for soil erosion models, new perspectives for land and stakeholders for terrace management in terms of natural hazard and offer a measure of the effect of these agricultural systems on soil organic carbon (SOC) sequestration. This work aims to realize and test an innovative and rapid methodological workflow to estimate the minimum anthropogenic reworked and moved soil of terrace systems in different landscapes. This aspect of new technology and its application to terrace soil-systems has not been fully explored in the literature. We start with remote terrace mapping at a large scale (using

Airborne Laser Scanning) and then utilize more detailed HRT surveys (i.e., Structure from Motion and Terrestrial Laser Scanning) to extract geomorphological features, from which the original theoretical slope-surface of terrace systems were derived. These last elements were compared with in-field sedimentological recording obtained from the excavations across the study sites to assess the nature of sub-surface topographies. The results of this work have produced accurate DTMs of Difference (DoD) for three terrace sites in central Europe in Italy and Belgium. The utilization of ground-truthing through field excavation and sampling has confirmed the reliability of the methodology used across a range of sites with very specific terrace morphologies, and in each case has confirmed the nature of the reconstructed, theoretical original slope. Differences between actual and theoretical terraces from DTM and excavation evidence have been used to estimate the minimum soil volumes and masses used to remould slopes. Moreover, geomorphometric analysis through indices such as sediment connectivity permitted also to quantify the volume of sediment transported downstream, with the associated and mobilized C, after a collapsed terrace. The quantification of terrace soil volumes provides extremely useful standards for further multi-disciplinary analysis on the terrace sediments themselves, aiding physical geographers, geoarchaeologists, palaeo-environmentalists, and landscape historians in the understanding of terrace systems and the impact of agricultural processes on the landscape.