11th World Congress on Water Resources and Environment (EWRA 2019)
"Managing Water Resources for a Sustainable Future"
Madrid, Spain, 25-29 June 2019

DEM-resolution control on rainfall-triggered landslide modeling within a triangulated network-based model.

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Introduction

Catchment slope distribution significantly controls rainfall-triggered landslide modeling, in both direct and indirect ways. Slope directly determines the soil volume associated with instability. Indirectly, it affects the subsurface lateral redistribution of soil moisture across the basin, which in turn determines the water pore pressure conditions that impact slope stability. It is thus clear that the accuracy in reproducing slope distribution may be crucial in slope stability analysis.

The resolution of Digital Elevation Model (DEM) regulates the description of topography. The correlation between raster resolution and landslide model outputs has been investigated in literature, both in terms of landslide susceptibility (Arnone et al., 2016) and landslide dynamics (Tran de Viet et al., 2017; Keijsers et al., 2011; Tarolli and Tarboton, 2006). Results demonstrate that the optimal DEM resolution may not necessarily exclude the use of coarser DEMs.

This study evaluates the influence of DEM resolution on the slope stability analysis by using a distributed eco-hydrological-landslide model, which implements a Triangulated Irregular Network (TIN) to describe the topography; as well, the model is capable of evaluating vegetation dynamics and predicting shallow landslides triggered by rainfall.

Materials and methods

We used the distributed eco-hydrological and landslide model, the tRIBS-VEGGIE-Landslide (Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator - VEGetation Generator for Interactive Evolution) (Lepore et al., 2013). The study area is the Mameyes Basin, which is located in the Luquillo Experimental Forest (Puerto Rico), where numerous landslide analyses have been carried out (Lepore et al., 2013

Grid-DEMs at 20, 30, 50, and 70 m resolution were resampled from the available 10 m Grid-DEM, and were used to derive the corresponding hydrologically-significant TINs (Vivoni et al., 2004) (Table1), for a total of 5 configurations. As the Grid-DEM resolution increases, the DEM-to-TIN ratio required to preserve topographic attributes increases (Table 1). The corresponding voronoi meshes are then derived by tRIBS-VEGGIE. The model inputs (meteorological forcing, soil properties, model parameters) come from Lepore et al., 2013.

Table 1. *Number of DEM cells, TIN nodes, and Voronoi cells for each Grid-DEM resolution. Because some nodes are used as catchment boundaries, the final number of Voronoi cells is lower than the TIN nodes*

GRID-DEM Resolution [m]	DEM Cells	TIN Nodes	DEM to TIN Ratio	Voronoi Cells
10	169,615	6,974	4%	6,276
20	42,400	3,605	9%	3,131
30	18,837	2,603	14%	2,190
50	6,782	2,274	34%	1,908
70	3,462	2,416	70%	2,177

Results and concluding remarks

Application of a TIN-based hydrological-landslide model to different DEM-derived resolutions showed that: irregular mesh reduces the loss of accuracy in the derived slope distribution when coarser resolutions are used; at 'steady' state (either at dry or saturated conditions), soil moisture dynamics through the resolutions are almost invariant; in the transient, the different topography leads to slightly different soil moisture patterns; predicted failure area decreases with resolution, but statistics of slope at failure are almost invariant (Figure 1). In fact, the finer the resolution, the larger the area affected by landslide (Figure 1a); whereas only the 70 m case shows lower median and smaller range in the statistics (Figure 1b).

Overall, the use of the irregular mesh reduced the loss of accuracy in the derived slope distribution when coarser resolutions were used. The impact on soil moisture patterns was significant only when the lateral redistribution was considerable, depending on hydrological properties and rainfall forcing. In some cases, the use of different DEM resolutions did not significantly affect the model output, in terms of landslide locations and values of slope and soil moisture at failure (Arnone et al., 2013; Dialynas Y.G. 2017).

In conclusion, as many other studies in literature, our results suggest that the optimal DEM resolution may not necessarily lead to the best landslide modeling.

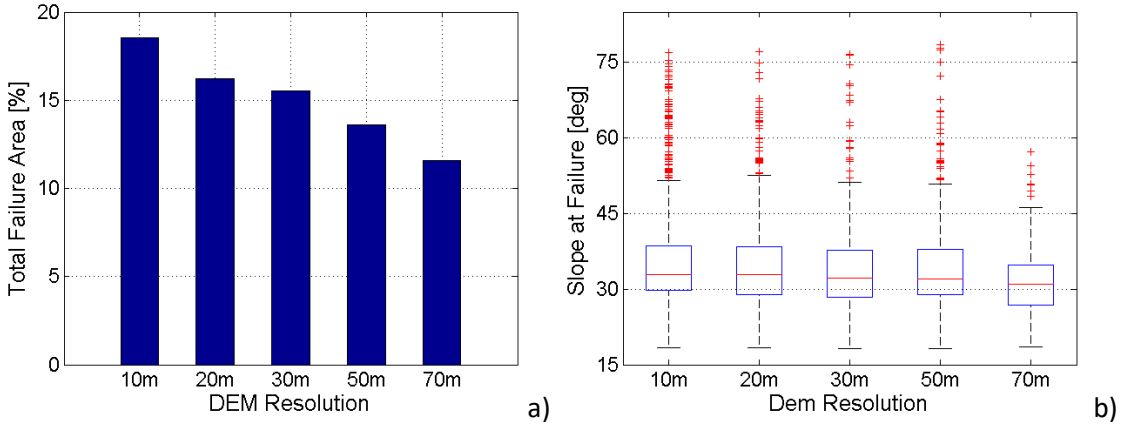

Figure 1. Total failing area at different resolutions (a). Box plots of slope values at slope for the five resolutions (b).

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