A wavelet-based DEM regularization methodology aimed at improving distributed rainfall-runoff modeling

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INTRODUCTION

The computation of some derived topographic properties from high resolution DEMs is characterized by daunting challenges caused by noise, pits and redundant information. Formation of several unconnected saturated zones is a particular case of such problems when TOPMODEL is employed for hydrological simulations. We propose a methodology which, by means of a soft-thresholding of the wavelet coefficients, provides a regularization of high-resolution DEMs oriented at hydrologic applications. The methodology is demonstrated using 1-m LiDAR data for the Elder Creek River basin in California.

SCALE EFFECTS ON TOPOGRAPHIC INDEX

The topographic index (TI) is defined as (Beven et al. 1995): $TI = Log\left(\frac{a}{\tan(b)}\right)$ where a is the drainage area and $\tan(b)$ is the slope.

By increasing the grid cell size, not only a positive shift in mean of TI distribution occurs but also higher order moments of the distribution change (Fig. 1). As the resolution decreases the spatial distribution of the topographic index becomes more regular (Fig. 2).

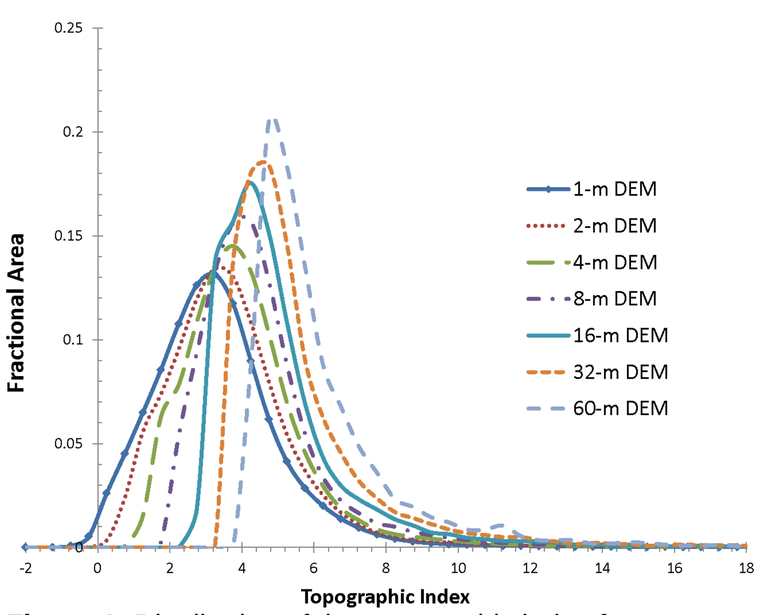


Figure 1: Distribution of the topographic index for different DEM resolutions

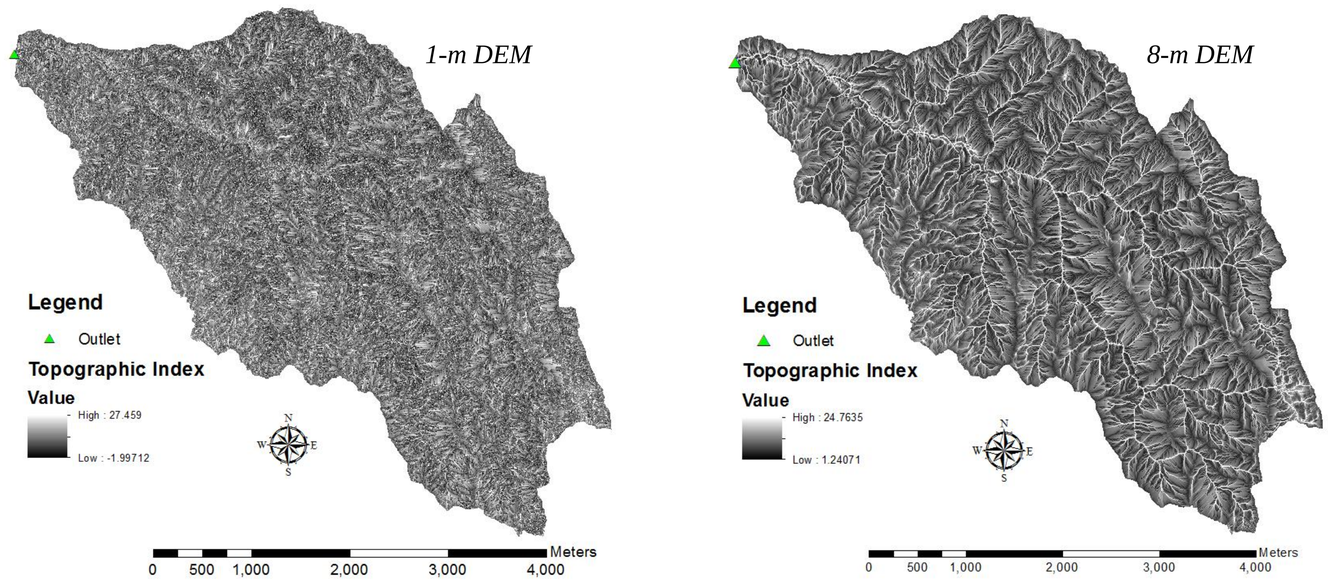


Figure 2: Spatial distribution of the topographic index extracted from the 1-m (left panel) and the 8-m (right panel) DEM of the Elder creek basin.

SCALE EFFECTS ON TOPMODEL APPLICATIONS

In a high-resolution DEM, the high slopes result in very low (even negative) values of TI on steep slopes and facilitate the generation of isolated saturated areas (Fig. 5, left panel). These saturated areas will contribute to the quick surface runoff and artificially increase the overall basin discharge. Among the TOPMODEL parameters, the lateral saturated soil transmissivity, T_0, appears to vary noticeably as a function of different spatial distributions of the *TI* (Mendocino and Sole, 1997). As the DEM resolution decreases, the calibrated T_0 clearly increases (Fig. 3). While all the calibrated T_0's are valid in a functional sense, such optimized parameters may lead to unreasonable results when tested against internal field data.

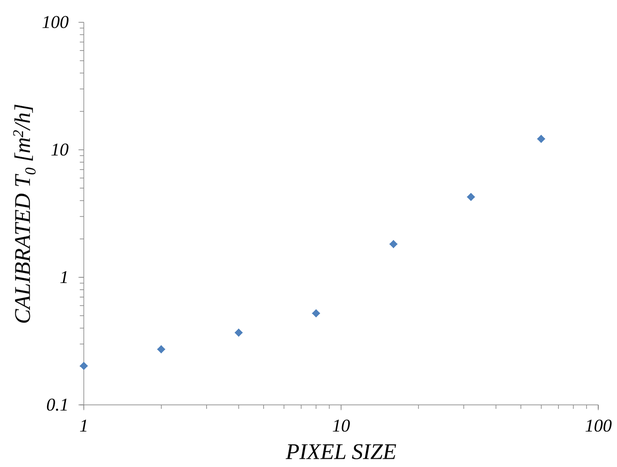


Figure 3: Calibrated transmissivity, T_0, as function of the pixel size

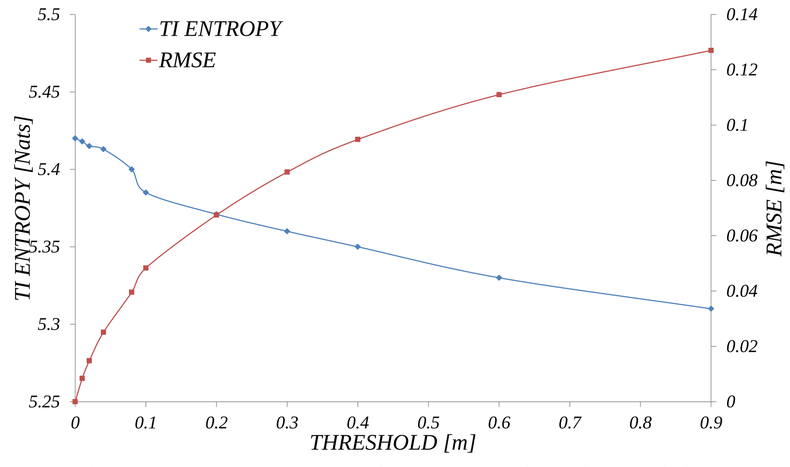
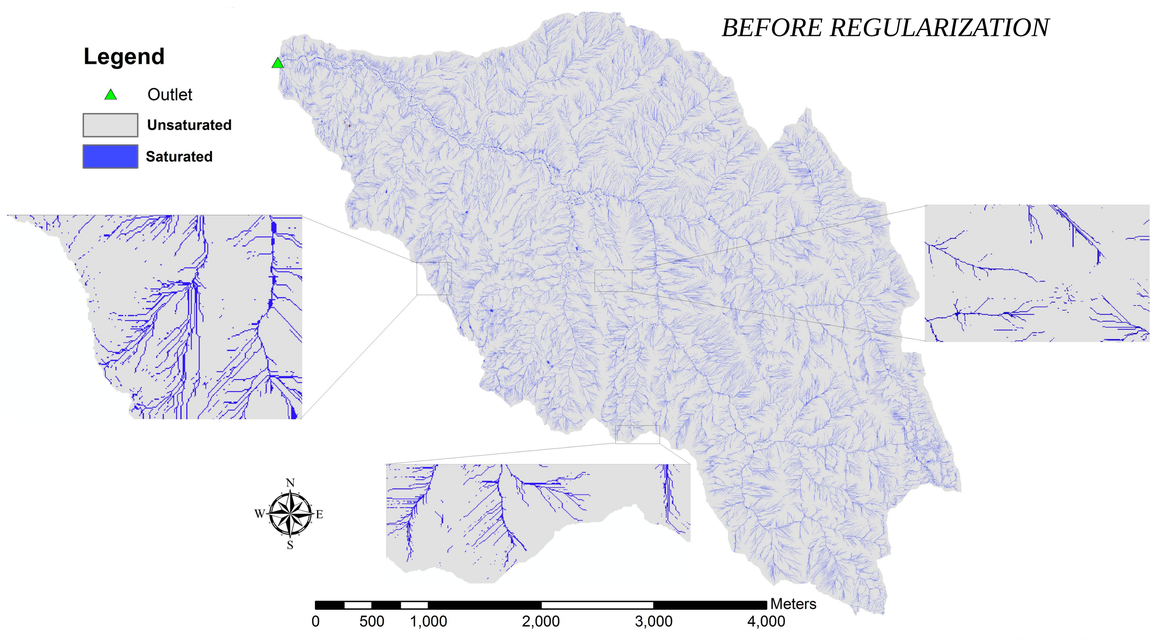


Figure 4: TI entropy and RMSE as functions of the wavelet threshold

REGULARIZATION PROCEDURE

In the wavelet domain, most of the noise of the DEM tends to be represented by the smaller wavelet coefficients. To regularize the DEM we therefore remove these smaller coefficients using a soft-thresholding criterion, which not only removes the coefficients below a threshold, but also reduces the remaining coefficients by the threshold value. Fig. 4 shows how the root mean square error (RMSE) between original and regularized DEM as well as the TI entropy vary with the threshold. While RMSE increases "regularly" the entropy shows a step-wise trend. This allows for an automatic definition of a threshold that is already embedded in the DEM signal. After regularizing the Elder creek 1-m DEM, the application of the TOPMODEL (for a particular storm event), results in a significant reduction of unconnected saturated areas (Fig. 5, right panel).



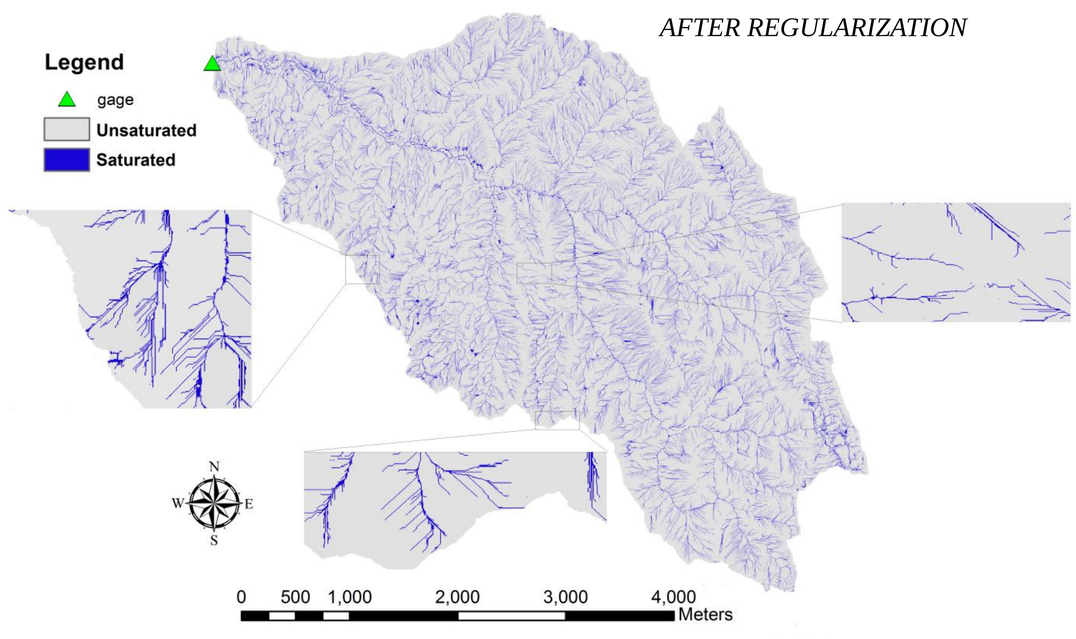


Figure 5: Spatial distribution of the saturated areas from the application of the TOPMODEL. Left panel and right panel refer to the un-regularized and regularized DEM, respectively.

CONCLUSIONS

- We propose a regularization method for pre-processing high resolution DEM based on the wavelet decomposition.
- The method is "hydrologically meaningful" in that the regularization criterion is based on the distribution of the topographic index.
- The application to the Elder creek shows how TI entropy has a characteristic pattern, which allows to automatically identify a suitable threshold for the regularization procedure.
- The TOPMODEL application shows how the method significantly reduces unconnected saturated areas.