Automatic Detection and Vulnerability Analysis of Areas endangered by Heavy Rain

ESA Living Planet Symposium, 9.–13.05.2016, Prague

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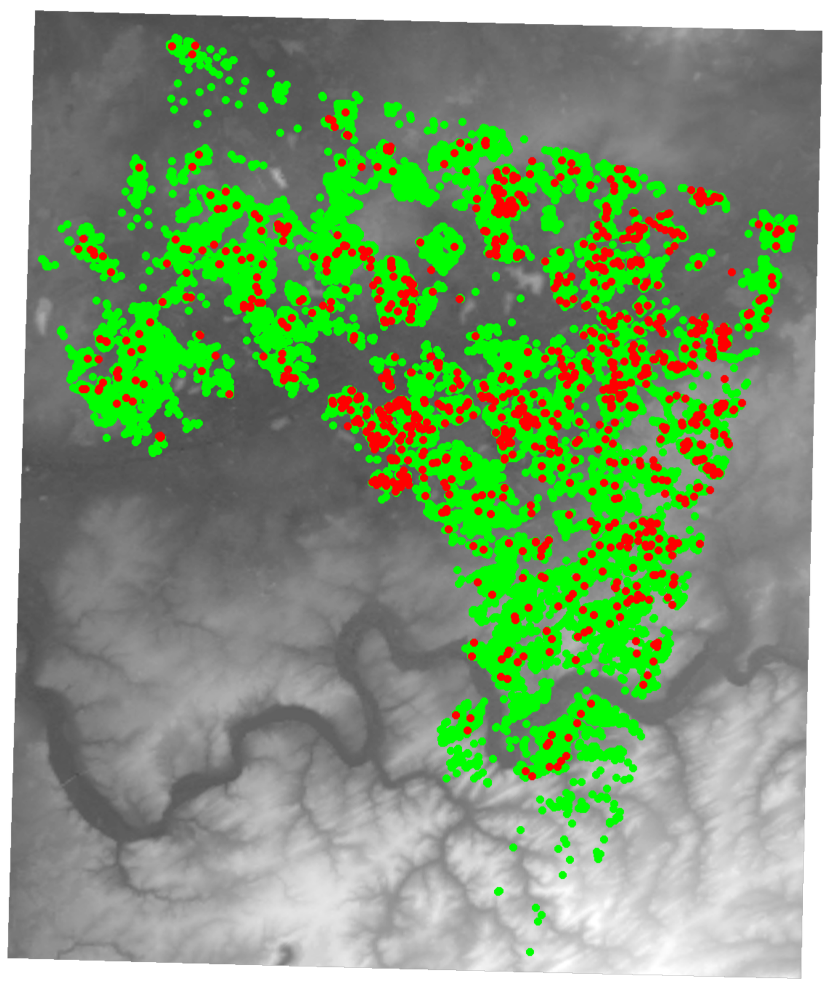
Introduction

In this study a method for automatic detection and vulnerability estimation for areas endangered by heavy rains was developed. The method relies simply only on digital terrain models like SRTM. The presented method for vulnerability analysis is based on different methods and was also applied to different types of DEMs like the freely available SRTM, a 25 m terrain model (DTM) from Germany down to 5 m surface models (DSM) which were derived from satellite images of the Indian Cartosat sensor. For validating the results anonymized data of an insurance company were available. The presented method is finally evaluated using this reference data.



SRTM DEM (Digital Elevation Model) of the area where reference data from an insurance company were available. Every **green** dot represents an insured household, every **red** dot a damage claim caused by water in the time span between June 2003 and September 2013.

The ellipsoidal heights range from 25 to 188 m. The test area is 30 km x 40 km, covering longitudes 6.85°E to 7.35°E and latitudes 51.30°N to 51.67°N.

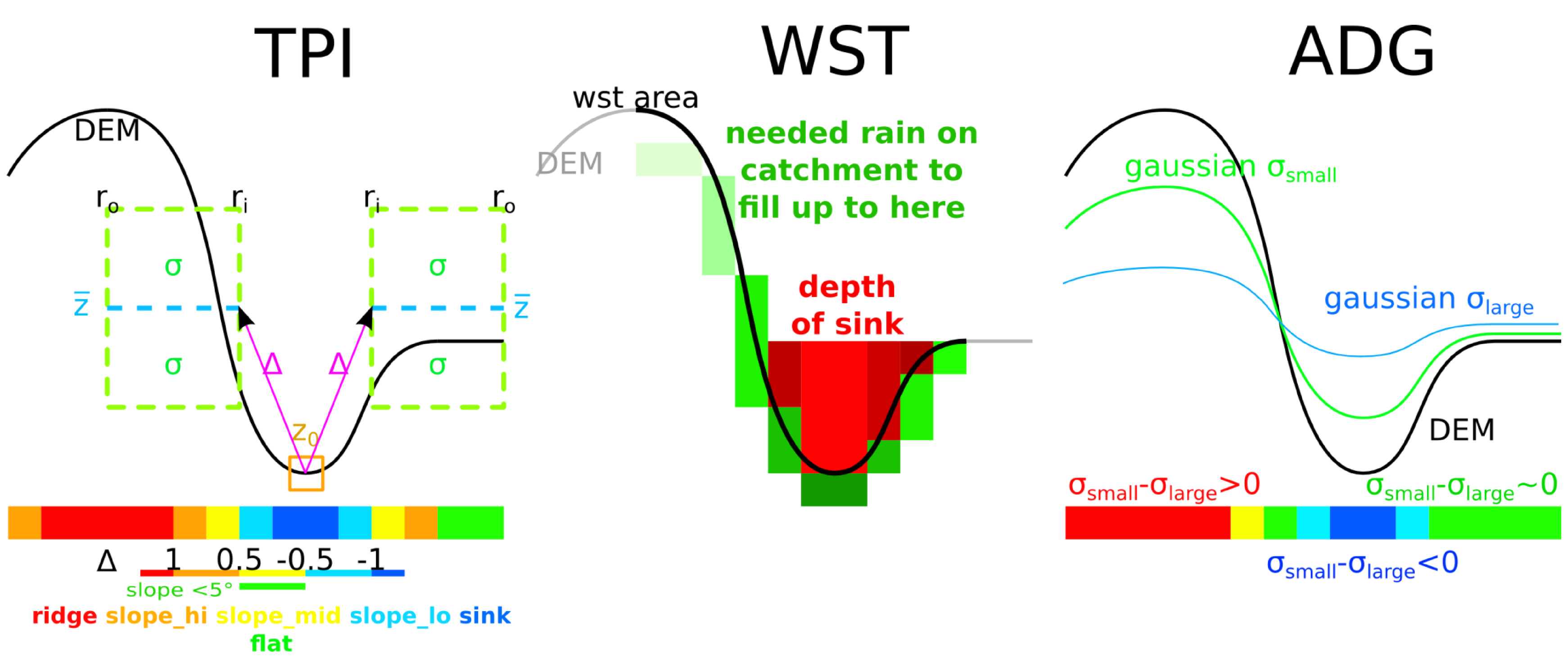
Method

Terrain Positioning Index TPI

In a first approach the so called terrain positioning index (TPI) is calculated. This index classifies a DEM based on the difference between the elevation of a cell z_0 and the average elevation $\bar{z}$ of a ring R ranging from an inner radius r_i to an outer radius r_o around the cell:

$$TPI = z_0 - \bar{z} \qquad \bar{z} = \frac{1}{N}\sum_{i\in R} z_i \qquad \sigma = \sqrt{\frac{1}{N-1}\sum_{i\in R}(z_i - \bar{z})^2} \qquad \Delta = \frac{TPI}{\sigma}$$

So the TPI is defined relative to the standard deviation of the heights in the ring and not using absolute height differences.



Watershed transformation WST

The second method applied is the so called watershed transformation. This operation segments a DEM to areas with a common sink. Since DEMs contain mostly much small noise before applying the WST the DEM is filtered using a gaussian filter. Afterwards the height h_{min} of the lowest point on the border of each segment (=catchment area) is derived and the sink (heights≤h_{min}) depth calculated (**red**). Also the needed rain volume on the catchment area for reaching each pixel is derived (**green**).

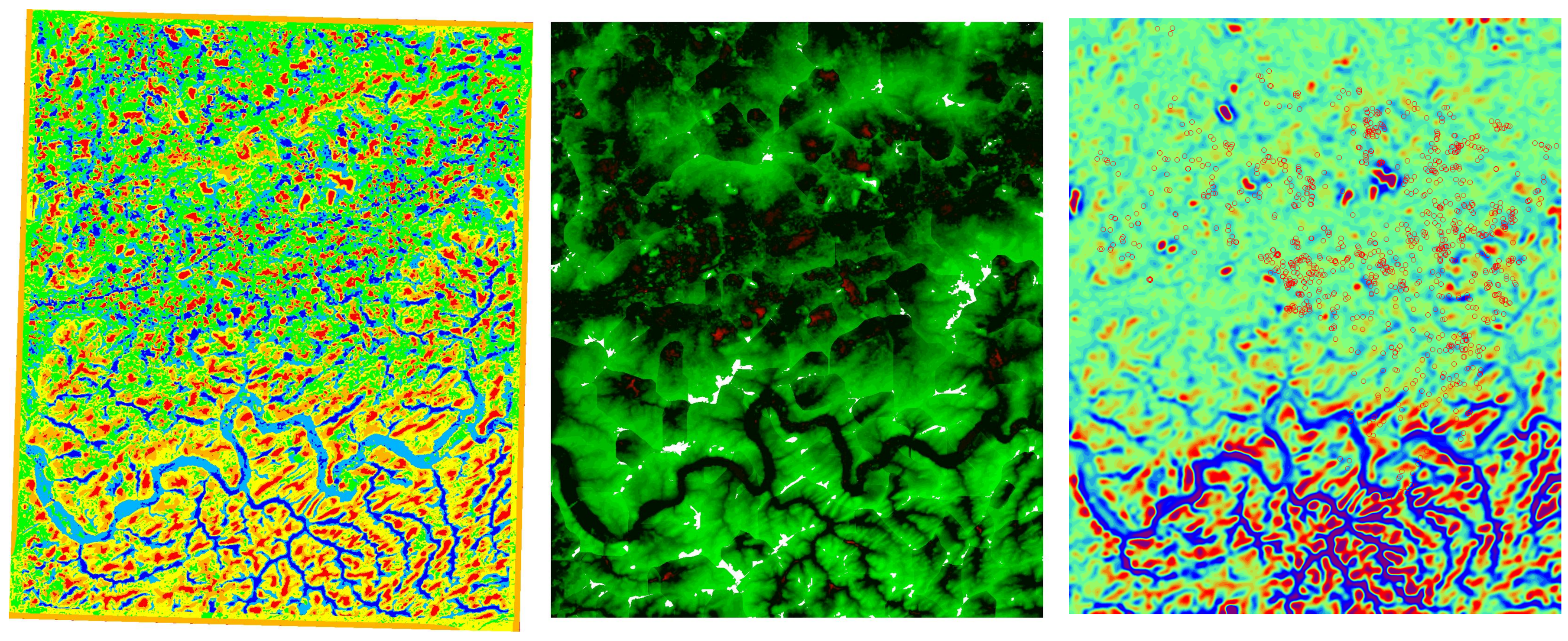
Absolute Gaussian Filter Differences ADG

In the third method applied to the DEM data two gaussian filters with different filter radii (small and large) are calculated and the difference of these filtered DEMs is taken as measure:

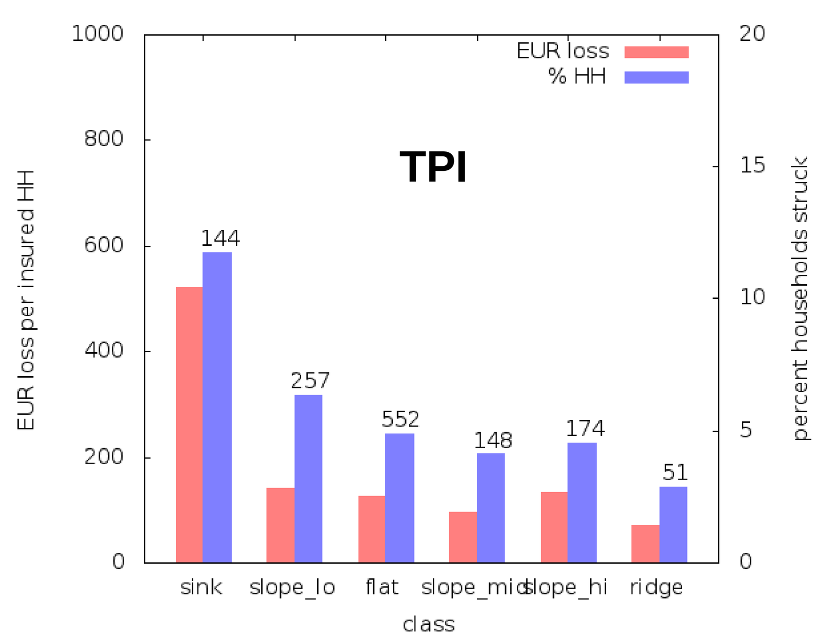
$$G_s = \gamma_s(DSM) \qquad G_l = \gamma_l(DSM) \qquad ADG = G_s - G_l$$

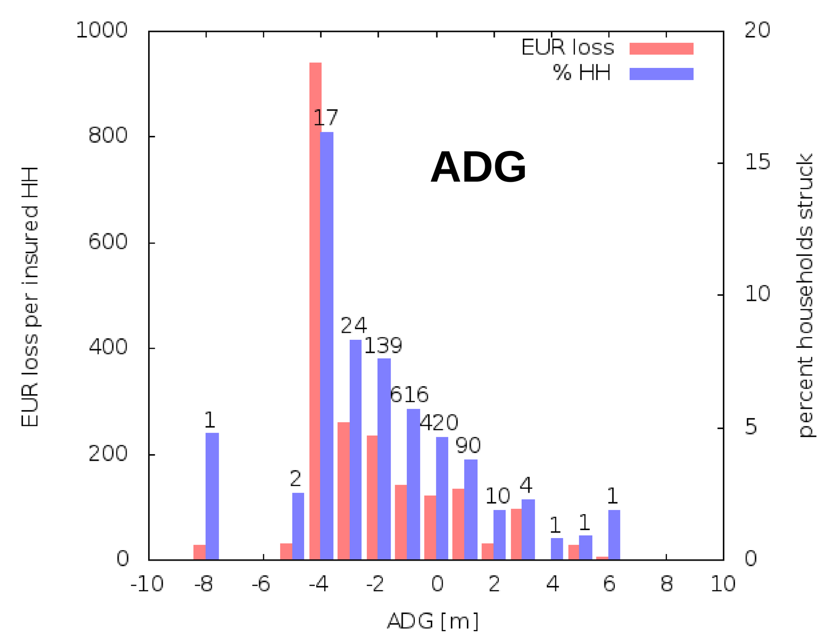
Data Evaluation

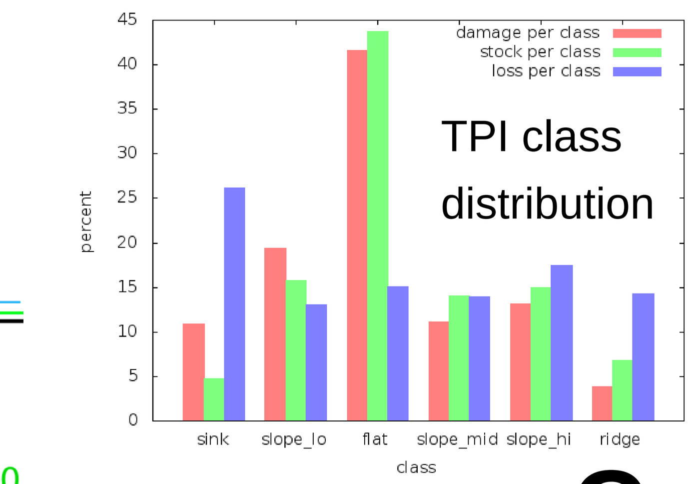
For the test area the three presented operations where applied to the DEM and the results analyzed using the insurance data. First the **TPI** was calculated for a set of inner radii r_i ranging from 30 to 270 m and outer radii r_o from r_i+30 m up to 1100 m. Calculating the losses per insured household for each class and from these the largest variance over the classes show the optimum for r_i=90 m and r_o=750 m. Also applying the TPI to different DEMs shows overall nearly an complete independence from the resolution of the DEM. It's only important to use a terrain model (DTM) and no surface model.

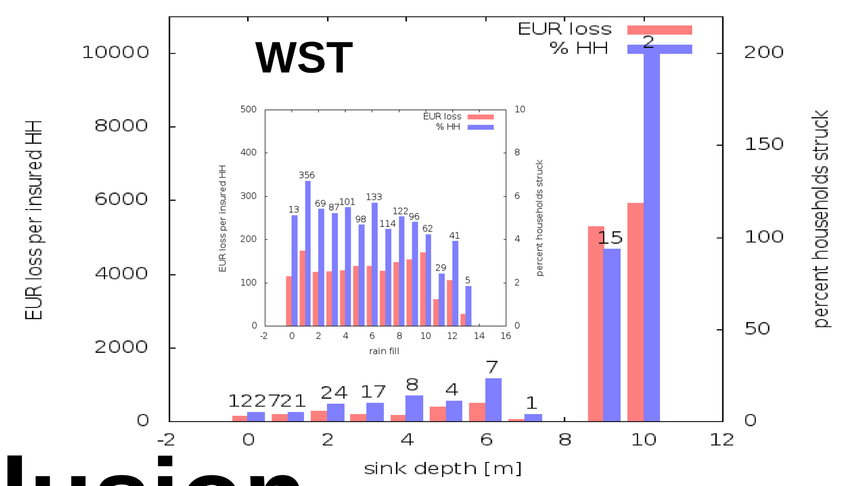


Second the **WST** sink-depths and fill-heights are calculated for different sizes of the gaussian filter. The results are not as meaningful as these based on the TPI. Third the classification following the **ADG** shows again significant differences between classes. Best results can be found for filter sizes σ of 240 and 330 m – nearly as good as the TPI results.









Conclusion

In this work we show that a reliable vulnerability analysis for areas endangered by heavy rain can be prepared from only a using a digital terrain model and applying the Terrain Positioning Index TPI or the calculation of the Absolute Gaussian Differences ADG. The TPI yields best results using an inner radius of 90 m and an outer radius of 750 m whereas the ADG performs best using a small filter of σ=240 m and a large filter of σ=330 m. The results where validated using available insurance data. The probability of being affected by a damage caused by heavy rain is for the derived classes (sinks for TPI or ADG<-3 m) at least 2 times higher as in other classes – the monetary damage even 3 times or more.

Knowledge for Tomorrow

[1] Weiss, A.-D. (2001). Topographic position and landforms analysis. Poster Presentation, ESRI Users Conference, San Diego, CA.
[2] Zevenbergen, L. and Thorne, C. (1987). Quantitative analysis of land surface topography. Earth Surface Processes and Landforms 12(2), pp. 47-56

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