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| **Auteurs:** Authors: | Carl Gagnon-Ouellette, & Musandji Fuamba |
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Discussion of **Role of Watershed Geomorphic Characteristics on Flooding in Indiana, United States**

Kuk-Hyun Ahn1 and Venkatesh Merwade, DOI: 10.1061/(ASCE)HE.1943-5584.0001289.

Discussers:

CARL GAGNON-OUELLETTE[1] and MUSANDJI FUAMBA[2]

# Methodology Summary

The authors investigated the relationship between flooding and geomorphic characteristics in Indiana, United States, by using data at 94 streamflow gauging stations. They categorized the flood magnitude into three groups, including moderate, extreme, and severe. The flood in each group is related to geomorphic characteristics. Obtained results show that the extreme flooding is most affected by the watershed morphometry, particularly the watershed length, and the severe flooding by the watershed slope and land use type. It was also found that the geomorphic characteristics of the watershed have impact on the severity of flooding. Using the Kruskal-Wallis rank test when investigating the effect of the land cover type and the watershed size showed that the land cover type affects the occurrence of flooding even if its role may be relatively smaller compared with other variables. Additionally, flooding is been found to be affected by the watershed length than the watershed area for the watersheds. To quantify the significance of the flood, the Flash Flood Index (FFI) is calculated with the following equation

$$FFI = RK + RM + RTP + RIT \quad (1)$$

[1] M.A.Sc. student, Department of Civil, Geological and Mining Engineering, École Polytechnique de Montréal, 2500 Chemin de Polytechnique, Montreal, H3C 3A7, Canada. E-mail: carl.gagnon-ouellette@polymtl.ca

[2] Professor, Department of Civil, Geological and Mining Engineering, École Polytechnique de Montréal, 2500 Chemin de Polytechnique, Montreal, H3C 3A7, Canada. E-mail: musandji.fuamba@polymtl.ca, Ph.D, M.ASCE.

where RK is the relative rising curve gradient; RM the relative flood magnitude ratio, RTP the relative flood response time; and RIT the relative ratio with the rainfall intensity (Ahn and Merwade 2015) with more details in (Kim and Choi 2015).

Following are steps described by the authors to perform the suggested approach. First, the floods are ranked by percentile of FFI occurrences in the following categories: less than 70% for moderate, between 70% and 90% for severe and 90% for extreme. The results confirm that flooding is more severe in urban and mountainous areas. Second the authors suggested to find independent geomorphological variables that are most associated with the occurrence of floods by the simple correlation analysis and PCA rotated factor loading. Then the number of variables is strictly reduced from 36 to 14. The remaining variables are normalized to establish a multiple regression (stepwise) with the occurrence of severe and extreme flooding separately.

Third, land use effects are assessed using the K-mean clustering method. The created groups account for three uses of the soil: forests, farms and urban areas. The authors compared the effect of land use on the occurrence of floods by the rank test of Kruskal-Wallis and the Dunn test. The authors concluded that the land has less impact on the occurrence of flooding then the morphological characteristics of watersheds.

# Discussion and comments

Following are a few comments presented by the discussers:

1. As mentioned by the authors in accordance with the limitations of their study, the Thiessen polygon Method ignores the relief when allocating the rainfall intensity (Anctil et al. 2012). The authors stated that watersheds with higher flood occurrence are most of time in the mountainous regions of the case study. Moreover, the discussers question the sensitivity of the

RIT parameter in the calculation of FFI chosen by the authors. Indeed, this parameter depends directly on the rainfall intensity spread over the watershed.

2. In addition, the selection of the percentile rank for flood seems arbitrary. The authors clearly stated that the initiators of FFI had never regrouped the significance of flood in categories. However, they did not justify for establishing such occurrence thresholds of FFI values.
3. Before applying the multiple regression technique, the authors eliminated dependent variables incorporated in one of the two methods named above. The gradual introduction (stepwise) of the 14 variables allowed the authors to rule respectively to the extreme and severe floods and a 6 variables. Although the previously selected variables are considered insignificant after the use of the regression method, the authors should explicitly show detailed results allowing the removal. According to the way in which the variables were excluded, the results can change a lot with relatively low population data (Borcard 2009).
4. To validate the model proposed by the authors, one needs to use a data set that has not been used to determine the coefficients of the regression. Thus, the authors did not use a completely independent validation by comparing the predicted occurrences by the model to occurrences derived from the measured data. Knowing that only 5 years of data were available, it is understandable that the whole observation period was used. With validation data range, the authors would be able to decide on the robustness of the conclusions drawn from the model.

# A few suggestions

1. For the most rugged watershed, kriging may be appropriate to reflect the topography as well as being available on multiple software (Anctil et al. 2012). Several methods adapted to the interpolation of hydrological data have been developed over time (Baillargeon 2005). It is

reasonable to expect that the amended FFI is sensitive to the rainfall intensity value estimated for watersheds. The discussers state that the use of a method taking into account topography to determine the rainfall intensity on the watershed would impact the highest values of FFI which is located in mountainous areas according to the authors.

2. Related to the choice of percentiles to make difference between extreme floods, severe or moderate, the solution could be to combine the values of FFI to the potential damage or rarity of the event. For potential damage, the solution is not applicable because the FFI takes into account only the rainfall and its resulting hydrograph. In fact, two floods of the same FFI can cause very different damages if, for example, human occupation of watershed is different between the two floods.

However, due to the rarity of the event, the return period of an event related to a FFI could be fixed to determine the boundaries between moderate flooding, severe and extreme. Indeed, an earlier version of FFI has been associated with IDF curves to match the return periods to a FFI for a given watershed (Kim and Choi 2011). Also, according to the index used in the paper, the resulting intensity and magnitude of the hydrograph correspond to half of the calculation of FFI because it contains four terms as shown in Equation 1. The return period will necessarily correlate with the calculated value of FFI. Then, from the literature, it will be possible to establish a recurrence period beyond which a flood is seen as extreme or severe. Using the definition of the return period as follows

$$T = \frac{1}{p(FFI \geq x)} \quad (2)$$

Where T is the return period, p is the probability of occurrence that a value of FFI be larger than x and x is the threshold value of the FFI.

The thresholds for classifying occurrences of FFI may be established. At the end, it should be possible to take all events with a FFI higher than the threshold to constitute the data set leading to multiple regressions.

3. Although the list of variables of the study is already long, it would be interesting to add a new variable in relation to the prevalence of forest fires. Indeed, Smith (unpublished data, 2003) focuses on the importance of this variable in the lightning floods in the state of Utah (USA). His results show that this variable has some impact on flooding. The idea would be to check whether this impact is general to all projects or only selective. Moreover, it can be judicious to work with the change in time of variables linked to the use of soil.

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