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1 Discussion of **Role of Watershed Geomorphic Characteristics on Flooding in Indiana, United**

2 **States**

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

4 Discussers:

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

6 Methodology Summary

7 The authors investigated the relationship between flooding and geomorphic characteristics in

8 Indiana, United States, by using data at 94 streamflow gauging stations. They categorized the flood

9 magnitude into three groups, including moderate, extreme, and severe. The flood in each group is

10 related to geomorphic characteristics. Obtained results show that the extreme flooding is most

11 affected by the watershed morphometry, particularly the watershed length, and the severe flooding

12 by the watershed slope and land use type. It was also found that the geomorphic characteristics of

13 the watershed have impact on the severity of flooding. Using the Kruskal-Wallis rank test when

14 investigating the effect of the land cover type and the watershed size showed that the land cover

15 type affects the occurrence of flooding even if its role may be relatively smaller compared with

16 other variables. Additionally, flooding is been found to be affected by the watershed length than

17 the watershed area for the watersheds. To quantify the significance of the flood, the Flash Flood

18 Index (FFI) is calculated with the following equation

19
$$FFI = RK + RM + RTP + RIT \quad (1)$$

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20   where RK is the relative rising curve gradient; RM the relative flood magnitude ratio, RTP the

21   relative flood response time; and RIT the relative ratio with the rainfall intensity (Ahn and

22   Merwade 2015) with more details in (Kim and Choi 2015).

23   Following are steps described by the authors to perform the suggested approach. First, the floods

24   are ranked by percentile of FFI occurrences in the following categories: less than 70% for

25   moderate, between 70% and 90% for severe and 90% for extreme. The results confirm that

26   flooding is more severe in urban and mountainous areas. Second the authors suggested to find

27   independent geomorphological variables that are most associated with the occurrence of floods by

28   the simple correlation analysis and PCA rotated factor loading. Then the number of variables is

29   strictly reduced from 36 to 14. The remaining variables are normalized to establish a multiple

30   regression (stepwise) with the occurrence of severe and extreme flooding separately.

31   Third, land use effects are assessed using the K-mean clustering method. The created groups

32   account for three uses of the soil: forests, farms and urban areas. The authors compared the effect

33   of land use on the occurrence of floods by the rank test of Kruskal-Wallis and the Dunn test. The

34   authors concluded that the land has less impact on the occurrence of flooding then the

35   morphological characteristics of watersheds.

36   Discussion and comments

37   Following are a few comments presented by the discussers:

38   1. As mentioned by the authors in accordance with the limitations of their study, the Thiessen

39   polygon Method ignores the relief when allocating the rainfall intensity (Anctil et al. 2012).

40   The authors stated that watersheds with higher flood occurrence are most of time in the

41   mountainous regions of the case study. Moreover, the discussers question the sensitivity of the

42   RIT parameter in the calculation of FFI chosen by the authors. Indeed, this parameter depends

43   directly on the rainfall intensity spread over the watershed.

44 2. In addition, the selection of the percentile rank for flood seems arbitrary. The authors clearly

45   stated that the initiators of FFI had never regrouped the significance of flood in categories.

46   However, they did not justify for establishing such occurrence thresholds of FFI values.

47 3. Before applying the multiple regression technique, the authors eliminated dependent variables

48   incorporated in one of the two methods named above. The gradual introduction (stepwise) of

49   the 14 variables allowed the authors to rule respectively to the extreme and severe floods and

50   a 6 variables. Although the previously selected variables are considered insignificant after the

51   use of the regression method, the authors should explicitly show detailed results allowing the

52   removal. According to the way in which the variables were excluded, the results can change a

53   lot with relatively low population data (Borcard 2009).

54 4. To validate the model proposed by the authors, one needs to use a data set that has not been

55   used to determine the coefficients of the regression. Thus, the authors did not use a completely

56   independent validation by comparing the predicted occurrences by the model to occurrences

57   derived from the measured data. Knowing that only 5 years of data were available, it is

58   understandable that the whole observation period was used. With validation data range, the

59   authors would be able to decide on the robustness of the conclusions drawn from the model.

60 A few suggestions

61 1. For the most rugged watershed, kriging may be appropriate to reflect the topography as well

62   as being available on multiple software (Anctil et al. 2012). Several methods adapted to the

63   interpolation of hydrological data have been developed over time (Baillargeon 2005). It is

64   reasonable to expect that the amended FFI is sensitive to the rainfall intensity value estimated

65   for watersheds. The discussers state that the use of a method taking into account topography

66   to determine the rainfall intensity on the watershed would impact the highest values of FFI

67   which is located in mountainous areas according to the authors.

68   2. Related to the choice of percentiles to make difference between extreme floods, severe or

69   moderate, the solution could be to combine the values of FFI to the potential damage or rarity

70   of the event. For potential damage, the solution is not applicable because the FFI takes into

71   account only the rainfall and its resulting hydrograph. In fact, two floods of the same FFI can

72   cause very different damages if, for example, human occupation of watershed is different

73   between the two floods.

74   However, due to the rarity of the event, the return period of an event related to a FFI could be

75   fixed to determine the boundaries between moderate flooding, severe and extreme. Indeed, an

76   earlier version of FFI has been associated with IDF curves to match the return periods to a FFI

77   for a given watershed (Kim and Choi 2011). Also, according to the index used in the paper,

78   the resulting intensity and magnitude of the hydrograph correspond to half of the calculation

79   of FFI because it contains four terms as shown in Equation 1. The return period will

80   necessarily correlate with the calculated value of FFI. Then, from the literature, it will be

81   possible to establish a recurrence period beyond which a flood is seen as extreme or severe.

82   Using the definition of the return period as follows

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

84   Where T is the return period, p is the probability of occurrence that a value of FFI be larger

85   than x and x is the threshold value of the FFI.

86 The thresholds for classifying occurrences of FFI may be established. At the end, it should be

87 possible to take all events with a FFI higher than the threshold to constitute the data set leading

88 to multiple regressions.

89 3. Although the list of variables of the study is already long, it would be interesting to add a new

90 variable in relation to the prevalence of forest fires. Indeed, Smith (unpublished data, 2003)

91 focuses on the importance of this variable in the lightning floods in the state of Utah (USA).

92 His results show that this variable has some impact on flooding. The idea would be to check

93 whether this impact is general to all projects or only selective. Moreover, it can be judicious to

94 work with the change in time of variables linked to the use of soil.

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111