

in pattern compared to storms with longer durations. Rainstorms in summer in China mainly arise from convective processes and cold fronts (Wang and Li, 2007). Convective rains characterized by shorter duration and heavier intensity tend to start suddenly and generate maximum rain in the first half of the storm, which may partly explain the variability in pattern of the Huff curves for China.

COMPARISONS ON THE QUARTILE-DURATION AND QUARTILE-SEASON RELATIONSHIPS

The quartile-duration relationships in this study were consistent with Huff (1967), which showed that first and second quartile storms most often had durations of less than 12 h, and third and fourth quartile storms occurred most frequently in the 12 to 24 h and greater than 24 h duration groups, respectively. Bonta (2004a) suggested that storms need to be categorized by month when quartile-duration relationships are analyzed due to different storm-duration characteristics in different seasons. In this study, the difference in quartile-duration relationships was that shorter-duration storms were more concentrated in quartiles I and II, and the difference in the effect of duration on the shapes of Huff curves between the summer season and the entire year combined was negligible. The main reason for this may be due to the fact that most erosive storms (56.4%) occurred in summer in the monsoon climate in the central and eastern parts of China, which resulted in the effect of duration on curves being dominated by summer storms. A significant effect of season on Huff curves was also shown by Bonta (2004a), which supported the idea that Huff curves should be developed for different seasons of the year.

CLIMATE CHANGE CONSIDERATIONS

The global hydrologic cycle has tended to be more active due to the increasing global surface temperatures over the 20th century (Dore, 2005; Groisman et al., 2005). Heavy precipitation has shown an increasing trend for many mid-latitude regions (IPCC, 2007). Some research has focused on the trends of intra-storm characteristics. For example, research conducted by Yin et al. (2011) demonstrated that the mean intensities and peak intensities have increased and the time to peak intensity has become earlier for short-duration events in the Haihe River basin in China during the last several decades. An increasing risk of urban waterlogging, local flooding, and soil erosion has emerged. The changing trends in intra-storm characteristics reflected by Huff curves in the context of climate change and their impacts on drainage design and soil erosion risk assessment are worth investigating. Calibrated hydrologic and erosion models could be used to determine how runoff and erosion amounts are affected by using different Huff curves as inputs to the models.

CONCLUSIONS

A total of 11,801 erosive events from 18 weather stations with 1 min resolution data were analyzed to generate Huff curves for the eastern and central parts of China. The following conclusions can be presented:

- On average, 38.3% of the storms were quartile I, followed by quartiles II (26.8%), III (22.4%), and IV (12.5%). More than half of the erosive events occurred in summer (June through August), with 40.8% of them being quartile I and 25.9% being quartile II.
- The curves for different stations shared similarities, and the station pairs near to each other did not show greater similarity of Huff curves compared to those far from each other. Regional Huff curves, including means and standard deviations based on a bootstrap scheme, were presented.
- Storms that had the maximum rainfall occurring in the first and second quartiles tended to be characterized by shorter duration and heavier intensity. The average duration for quartile I was about 3/4 of that for quartile IV, whereas the intensity indices for quartile I were 20% to 70% more than those of quartile IV. Huff curves derived from storms with shorter durations demonstrated more variability in pattern.
- Huff curves for Illinois, peninsular Malaysia, and Santa Catarina in Brazil reported in previous studies exhibited dissimilarities both in terms of the percentages of storms of various quartile classifications and the curve shapes compared with the Huff curves developed for China in this study. The reasons for this are due to both differences in data analysis methods and climate between locations.

The significant differences in rainfall characteristics among different types of rainfall suggest that more attention should be paid to rainstorm type and intra-storm characteristics when infiltration processes are considered and modeled. Huff curves reflect intra-storm temporal rainfall characteristics, and they can be useful for drainage design in urban areas as well as runoff and erosion simulations in rural areas.

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