UNDERSTANDING FLOW DURATION CURVE SHAPES: A PROCESS BASED APPROACH

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1. INTRODUCTION

The flow duration curve is unique to a catchment and many studies have attempted to explain the relationship between its shape and catchment properties in order to advance predictions in ungauged basins (PUB, Sivapalan, 2003). Studies have attempted to explain the physical reasons for its shape, however, the limitations of these studies are the applicability to the studied catchments only because majority of the models were deeply rooted in empiricism. Therefore, the transition from highly calibrated and empirical models to process based understanding has recently been an initiative for concerned hydrologists. The process-based perspective has been made to address the challenges of PUB. This study seeks to understand the reason flow duration curves (FDC) are uniquely shaped to a catchment from a process-based perspective in perennial, intermittent and ephemeral catchments. It applies a data-based rainfall-runoff modeling approach which would have different dominant rainfall-runoff processes in each catchment.

2. METHOD

This study was done in three catchments Hanalei, Makaha and Kamananui in Hawaii as in Fig. 1. First, the number of dominant processes for each catchment was identified using the Hino and Hasebe (1984) hydrograph separation method. A tank model was then constructed according to this number of identified dominant processes. Secondly, for each dominant process (or component) of the tank, the storages were calculated using a simple linear storage estimation method by Chiba and Yokoo (2015). The process-based equations for the tank was developed and lastly the infiltration and return flows between each process was also identified. The FDC shapes were then explained in terms of identified dominant processes. The aridity indices and precipitation duration curves (PDC) were also identified for each catchment.

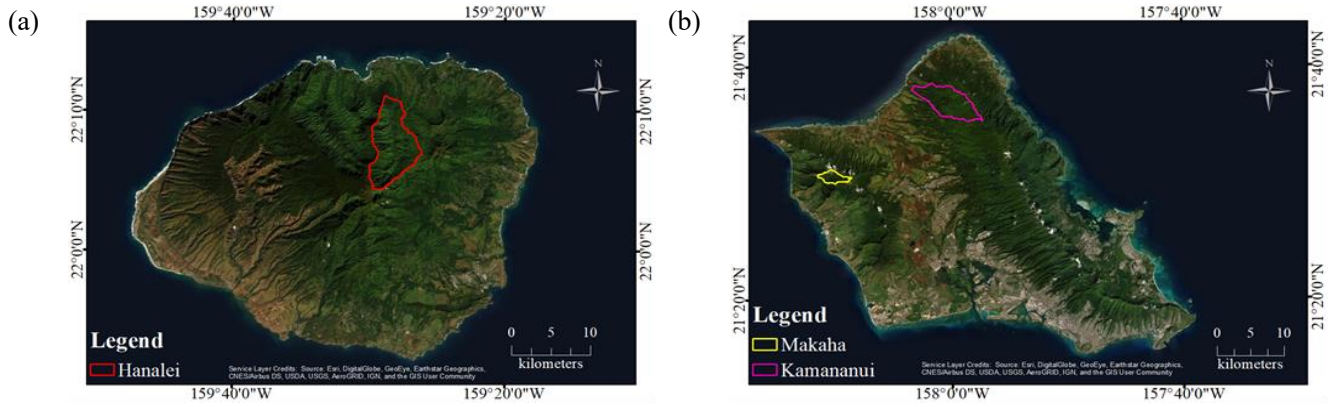

Fig. 1. The studied catchments in Hawaii. Hanalei on Kauai Island (a), Kamananui and Makaha on Oahu (b). The figure is partly taken from Leong and Yokoo (2019)

3. RESULTS

A tank model was constructed according to the number of separations for catchments as shown in Fig. 2. The hydrograph separation results for the three catchments showed that the Hanalei catchment has 4 separations, Kamananui has three separations and Makaha has two separations. Therefore, Hanalei, Kamananui and Makaha have four, three and two tank components, respectively. The figure also shows the PDC and the aridity indices (*AI*) for the catchments. The tank model results indicate that the perennial Hanalei catchment has more processes occurring in it as opposed to the Makaha ephemeral catchment. Other results suggest that as a result of favorable climatic conditions such as adequate precipitation with low aridity index, more processes occur in the catchment and therefore the more the chance that the catchment will be perennial. In contrast to a catchment with unfavorable climatic conditions such as inadequate precipitation and high aridity index, the catchment has less occurring processes and is quickly forced to become ephemeral.

4. CONCLUSION

The reasons for the different shapes of the FDC was interpreted from a process-based modeling approach under different climatic conditions. The study showed that a catchment with a combination of humid climate with lower aridity index has a greater number of dominant processes occurring slowly in it, which would cause perennial flow. In contrast to

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a combination of a catchment with a dry climate with high aridity index will have a smaller number of dominant processes occurring at a faster rate which will cause ephemeral runoff. The results from this study should contribute to predictions in ungauged basins initiatives by estimating FDCs in ungauged catchments from climatic conditions. This study used climatic conditions and recognizes that other catchment properties such as catchment size, soils, geology etc. can contribute or have an effect on the current results. Therefore, these will be tested as part of a future study.

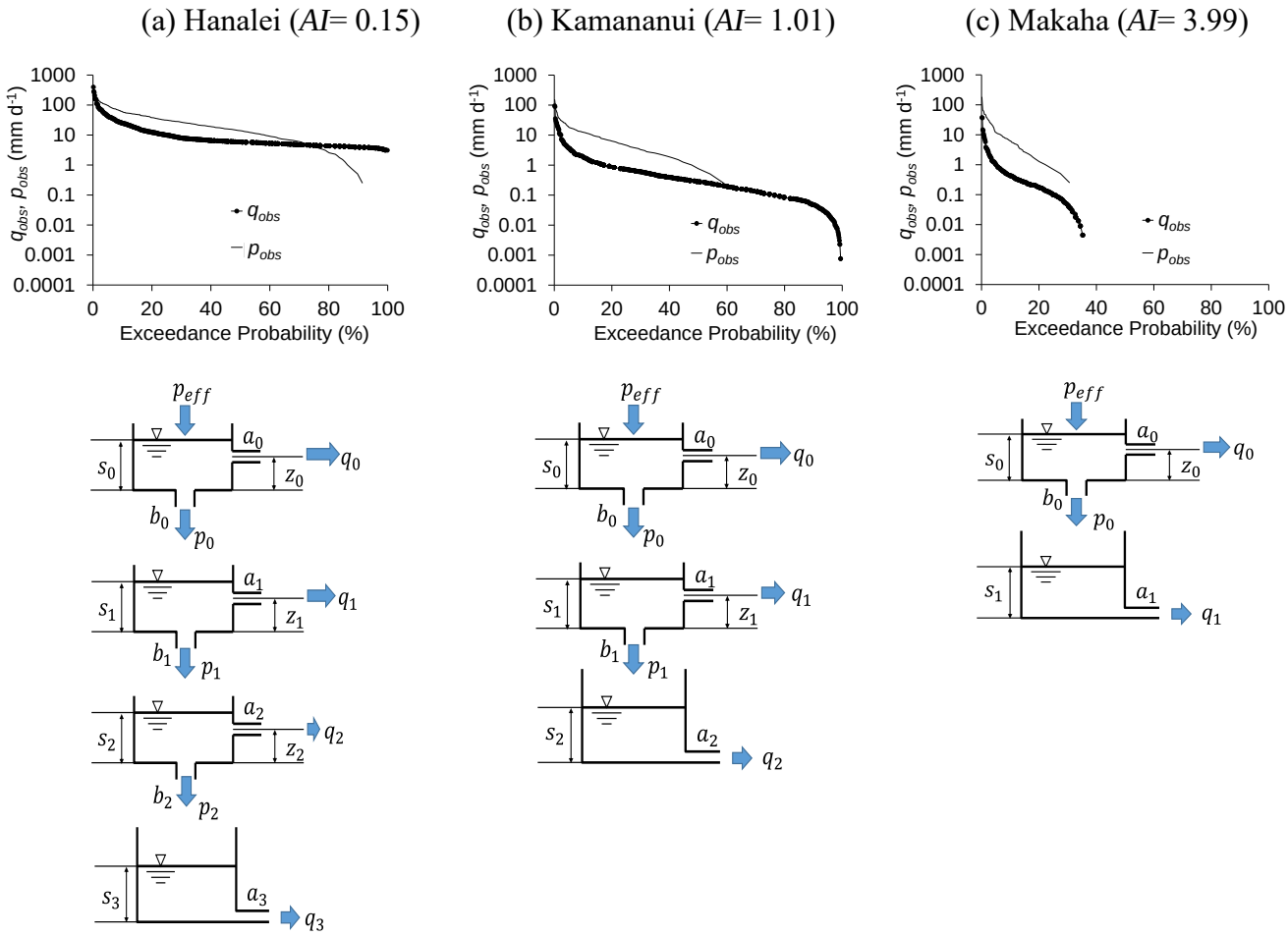

Fig. 2. Flow duration curve (q_{obs}) and precipitation duration curves (p_{obs}) combined with the process-based tank model structure. p_{eff}, q_i, z_i s_i, p_i, a_i and b_i are effective precipitation, runoff, height of runoff hole from the infiltration hole, storage height above infiltration hole, infiltration, runoff coefficient, infiltration coefficient respectively. 'i' denotes the tank number. The figure is partly taken from Leong and Yokoo (2019).

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