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Summary

In Bangladesh, about 18% of the total rice is produced in the north-eastern part of the country. Several large bowl-shaped depressed areas, locally called *"haors"* are located in this region. Flash floods during the premonsoon season (January to May) are identified as the top-ranked hazard that severely affects agriculture in the Sunamganj district. The Bangladesh Water Development Board has constructed earth-made submersible embankments (SEs) since the 1960s, to prevent flash floods of 10-year return period from flowing into haors until May 15. However, the past massive crop damage indicated that the current SE height for 10-year flash floods is not adequate.

The objective of this study is to develop a methodology for identifying cost-effective strategies to prevent boro crop damage and increase economic benefits in the haor areas of Bangladesh. This research proposes and assesses three selected strategies: embankment height increasing, retention area outside the haor, and retention area inside the haor, to minimize crop damage due to flash floods in the haor areas. A two-dimensional hydrodynamic model, namely the Rainfall-Runoff-Inundation (RRI) Model, was used. River water overtopping phenomena in three different haors: Matian, Shanir, and Mohalia Haors, located in Sunamganj, were investigated. The effectiveness of the three selected strategies was investigated using cost-benefit analysis (CBA).

The investigation results of the role of SE showed that if there had been no SE, the river overflow would have entered the Matian Haor 3 days, 22 days, and 9 days before the flash flood events in 2004, 2010, and 2016, respectively. In the same way, the river overflow would have entered the Shanir Haor 7 days and 23 days before the flash floods in 2004 and

2010, although the SE would have successfully stopped the event in 2016. The results using the rainfall pattern of 2004 as the design rainfall also implied that the present embankment levels (i.e., 6.3 m at Matian and 6.1 m at Mohalia) would not be effective to withhold 10-year RPWL and that the SE should be elevated by approximately 60 cm for both haors. To prevent the river water from entering into the haors with respect to 10-year, 15-year, 20-year, and 30-year RPWL, the SE level should be elevated to approximately 6.90 m, 7.00 m, 7.10 m, and 7.20 m for the Matian Haor and to 6.70 m, 6.80 m, 6.95 m, and 7.05 m for the Mohalia Haor, respectively.

The effectiveness of the retention area outside and inside the haors to retain flash-flood waters was also investigated. The results showed that the outside retention area could delay the river-water overtopping in the Matian Haor for 3 days with respect to 10-year and 15-year RPWL. It was also found to reduce the safe embankment height by 7 cm with respect to 10-year RPWL for the Matian and Shanir Haors. The required excavated area was estimated to be 526.5 ha with a soil volume of 36.2 Mm^3. The inside retention area requires an excavation of 500.3 ha (soil volume 32.1 Mm^3) and 545.5 ha (soil volume 26.8 Mm^3) inside the Matian and Shanir Haors with respect to 15-year RPWL, respectively.

The CBA analysis revealed that the benefit-to-cost ratio decreased as RPWL increased. The benefit-to-cost ratio of the mixed-type embankment (soil and concrete) with respect to 10-year, 15-year, 20-year, and 30-year RPWL were 4.19, 3.7, 3.41, and 3.08 for the Matian Haor while 9.44, 7.99, 7.05, and 6.24 for the Shanir Haor, respectively. Due to the high excavation cost, the retention area outside the haor and the retention area inside the haor were found to be not cost-effective.

These results will support policy makers to design effective solutions against flash floods. The methodology introduced in this study can be utilized for formulating effective policies to manage flash flooding in other haors in this region as well.