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Potentiality of rainwater harvesting for an urban community in Bangladesh

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SUMMARY

Due to cost effectiveness, rainwater harvesting (RWH) systems are practicing already in some rural parts of Bangladesh but very few in urban areas. This paper aimed to evaluate the potentiality of RWH systems in the South Agrabad in Chittagong city with an average annual precipitation of 3000 mm, experiencing both water scarcity and urban flooding in the same year. The adopted approach was Analytic Hierarchy Process (AHP) based multicriteria decision analysis technique, and the evaluation criteria were roof area, slope, drainage density and runoff coefficient. Geospatial Hydrologic Modeling Extension supported hydrologic model viz. HEC–HMS used to simulate the precipitation-runoff process, the model outcomes showed RWH potentiality which could minimize stagnant storm water up to 26% through supplementing city water supply annually up to 20 liter/person/day. Then, assigning suitable weightage to the evaluation criteria with their associated features in ArcGIS 9.3, the study area was reasonably divided into three potential zones i.e. good, moderate and poor covering 19%, 64% and 17% of the total area respectively. Thus, this is envisaged AHP using HEC–HMS could provide important guidance to the decision supporting system not only for urban areas but also for the wide sub-basin/basin context.

1. Introduction

Since 4500 B.C. rainwater harvesting (RWH) has been practicing around the world (Verma and Tiwari, 1995), and due to cost effectiveness and easy maintenance, this becomes the most common alternative water source in developing countries. The rooftop RWH technology usually involves small-scale structures to collect runoff for either domestic usage (Evans et al., 2006; Handia et al., 2003; Mwenge Kahinda et al., 2007; Villarreal and Dixon, 2005a), or groundwater recharge (Kumar et al., 2006; Wang et al., 2014). On the other hand, in developed countries about one third domestic water spends for water closet or toilet, and this placed a query whether this is right to flush toilet using drinking-quality water (Fewkes, 1999; Leggett et al., 2001; Vaes and Berlamont, 1999)? Understanding this scenario, RWH systems were adopted worldwide to save potable water viz. Beijing, Berlin, parts of Jordan, different regions of Brazil, Tokyo, Norrkoping and Nottingham showed water supply saving efficiency as 25% (Zhang et al., 2009), 70% (Nolde, 2007), 0.27–19.7% (Abdulla and Al-Shareef, 2009), 48–100% (Ghisi, 2006), 59% (Zaizen et al., 2000), 33–44% (Villarreal and Dixon, 2005b) and 4–100% (Fewkes, 1999) respectively. These experiences also showed that, the actual water saving efficiency depends on rainfall intensity, per capita water consumption, household size, roof properties (i.e. material, pitch and area), economic capability of the household and design period. Thus utilisation of urban RWH to supplement main water supply, overall water usage can be reduced along with water bills reduction and also deduce excess storm water which might place additional loads on existing drainage network (Mahmoud et al., 2014; Sample et al., 2012; Walsh et al., 2014). In this context, potentiality of urban RWH has evaluated by different researchers using different methods, for example: United States Natural Resources Conservation Services (US-NRCS) method, (Mahmoud et al., 2014), behavioural models to simulate a long-term water balance of the harvesting tank (Campisano and Modica, 2014; Palla et al., 2012; Villarreal and Dixon, 2005b), a two-step cluster analysis based on rainfall

Abbreviations: AHP, Analytic Hierarchy Process; BBS, Bangladesh Bureau of Statistics; BMD, Bangladesh Meteorological Department; CDA, Chittagong Development Authority; DEM, Digital Elevation Model; DoE, Department of Environment; GIS, Geographic Information System; HEC-GeoHMS, Hydrologic Engineering Center–Geospatial Hydrologic Modeling Extension; HEC-HMS, Hydrologic Engineering Center–Hydrologic Modeling System; PET, Potential Evapotranspiration; RWH, Rainwater Harvesting; RWHPI, Rainwater Harvesting Potential Index; SCS, Soil Conservation Service; TIN, Triangular Irregular Networks; WLC, Weighted Linear Combination; WSP, Water and Sanitation Program.

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level characteristics and spatial continuity (Cheng and Liao, 2009); also commercial numerical models i.e. U.S. Environmental Protection Agency's (USEPA) Storm Water Management Model (SWMM) (Walsh et al., 2014), Storage and Reliability Estimation Tool (SARET) (Basinger et al., 2010), hydrological-based precipitation Runoff model viz. RWIN (Herrmann and Schmida, 2000) and IHACRES (Kim and Yoo, 2009), Rainwater harvester simulation model (Jones and Hunt, 2010); and furthermore some watershed based models.

Very few attempts were made to explore commercial RWH possibilities in Bangladesh, except the published example for Sylhet city by Alam et al. (2012). However, due to the tropical monsoon associated with wide range of rainfall cycle, an evaluation is needed in regards to large scale RWH in Bangladesh. RWH traditionally practiced in Bangladesh, for example: in high water scarcity parts (hilly zone), highly saline prone areas (south part of the country), and as an alternative source in iron or arsenic prone areas. These are mostly belongs to rural parts, but no published research focused on potentialities of urban RWH systems. A GIS supported Hydrologic Engineering Center–Hydrologic Modeling System might be a useful model to simulate the precipitation-runoff process of an urban catchment system through featuring in an integrated environment (Scharffenberg, 2013). In this connection, the Geospatial Hydrologic Modeling Extension can support to present the geospatial hydrologic phenomena for the studied area. This model is widely used by the researchers and practitioners due to the simplicity and suitability with wide range of geographic areas and also with minimum data availability (Zhang and Pan, 2014).

On the other hand, Geographic Information System (GIS) has been using as a potential tool to enrich Decision Support System (DSS). Applications of GIS were found in: potential site identification (Mbilinyi et al., 2007), in association with Pitman model for evaluating RWH users adaption (Mwenge Kahinda et al., 2009), exploring artificial recharge using Remote Sensing (Jasrotia et al., 2009; Jha et al., 2014), RWH Suitability Model (RSM) development (Kahinda et al., 2008), and also RWH suitability ranking method in Australia (Inamdar et al., 2013). For multi criteria evaluation, 'weighted sum' method is used as 'Weighted Linear Combination (WLC)' method in the GIS environment. This method usually involves standardization of the suitability maps through assigning the weights on relative importance to these maps, and then combining the weights to obtain an overall suitability score. Although WLC is used for land suitability analysis, Analytic Hierarchy Process based multicriteria decision analysis (Saaty, 1980) along with the WLC technique in GIS was successfully applied by many researchers for different aspect of RWH (Jasrotia et al., 2009; Jha et al., 2014) and this seems a useful means to explore the urban RWH potentialities in Bangladesh.

Considering city water supply shortage in dry season compare to the stagnant storm water during rainy season in the same year, this paper aimed to acquire the potential zones for RWH systems in an urban area using a multicriteria decision analysis along with a hydrological model.

2. Materials and methods

2.1. Study area

The South Agrabad located in south-western part of Chittagong city, the second largest city of Bangladesh (Fig. 1). In a typical year

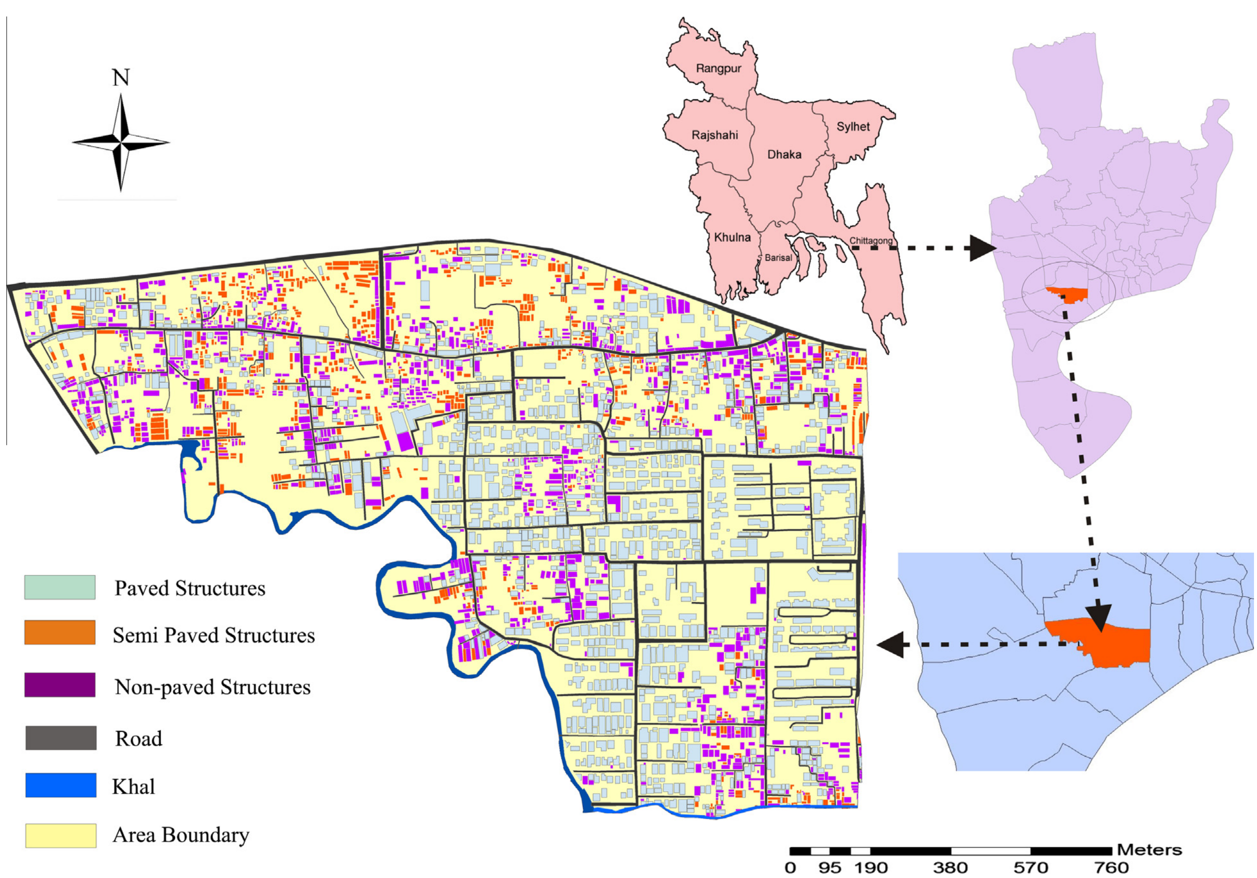

Fig. 1. Location map of the study area.