RAINWATER HARVESTING AS AN ADAPTATION MEASURE TO CLIMATE CHANGE: A CASE STUDY OF MAMORA BEACH AREA, EGYPT

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ABSTRACT

Egypt's water resources are under threat and could have a severe water crisis unless its finite resources are managed in a sustainable manner. Climate Change (CC) is an additional threat that puts more pressure on already stressed water resources and its impacts are already visible. In Egypt, high intensity rainstorms with a short duration events have become more frequent during the last two decadesresulting inundation in urban areas such as Alexandria city. Rainwater harvesting (RWH) is listed as one of the adaptation measures of CC and could cope with the water scarcity and inundation problems in urban areas. In this research, assessment the potentiality of RWH for urban area was carried out by taking Mamora beach area in Alexandria governorate as a case study. Rainfall data from Alexandria rainfall station for the period 1868–2014 was used. HYFRAN software was utilized to calculate the design rainfall from 1 to 3 years return periods. Rooftopand roads areas were estimated manually by digitization recent high resolution satellite image from Digital Globe data using Arc GIS software. The water volume of RWH was estimated using rational method. Water demand for domestic use was assumedfor different consumptions levels from 10- to 122- liters/capita/day for drinking and up to full supply for sanitation requirement, respectively. The results showed that the designed rainfall for the different return periods were ranged from 97 to 222 mm/year. Total roof and roads areas within the district was found to be 242,000 m^2. There is a potentiality of RWH to increase the water supply of the area up to30,000 m^3 and 31,000 m^3 for domestic supply and irrigating landscape areas, respectively. RWH from buildings only could support annually 8240and 675 persons for drinking and full supply, respectively. Roof areas have a range of 15-4,500 m^{2}which can harvest 2-575m^3/year. Storage tank reservoir was suggested as a RWH technique to store water during the rainy season and to be used in the dry period. Socioeconomic and engineering analyses should be conducted for implementing such RWH technique. The proposed plan would certainly minimize the effects of water inundation problem in urban areas and could be used as an adaptation measure to water scarcity and CC in addition to achieving Sustainable Development Goals'(SDG)goals.

Keywords: Rooftop, Rainwater harvesting, Climate Change, Adaptation measures, Egypt.

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1 INTRODUCTION

Climate Change (CC) and global warming are serious issues that may threaten the places, species and people's livelihoods. The phenomenon is already responsible for changes in precipitation and heavy rains causing flash floods and increasing intensity and duration of drought (Trenberth, 2011).The rainfall in arid and semi-arid regions is characterized by high seasonality and annual totals which are sometimes exaggerated by occurrence of a few high rainfalls (Elagib and Addin Abdu, 1997). In Egypt, high intensity rainstorms with a short duration have become more frequent during the last two decades (i.e. in years 2000, 2003, 2004, 2005, 2010, 2012, 2015 and 2016) resulting inundation in urban areas such as Alexandria city (Baldi et al., 2017; Zevenbergen et al., 2017).

The increase of population and urbanization in developing countries, coupled with the recent evidence of CC, may result in insufficient water to meet the urban population demand (Amin et al., 2013). Water resources, which are already very few in this arid region, will be further stressed due to predicted CC. The Egyptian water resources is no exception asseveral studies showed that there will be hyper-sensitive to Ethiopian rainfall and increasing in temperature and evapotranspiration rates due to CC (Conway, 2017). As a result, the Nile River flow, represents 95% of total water resources of Egypt, will be reduced by 15% on average by 2100 only due to CC using 17 bias-corrected Global Circulation Models (GCMs) (Elshamy et al., 2009). McCartney and Girma (2012) concluded that the flow of the Blue Nile will be reduced by 22% at the Ethiopia–Sudan border as a consequence of CC in combination with upstream water resource development. The Ethiopian Grand EthiopianRenaissance Dam (GERD) wouldalso reduce the quantities of the delivered water to Egypt.It is estimated that losing one BCM of Nile Water will resulting in losing 200,000 acre of cultivated land and about one million people will lose their jobs (The telegraph, 2017). Rainfall water supply of Egypt consists of 3.5% from the precipitation only at the coastal areas. The direct exploitation of rainfall should not be ignored (Liaw and Tsai, 2004)to meet the needs of the people in the coastal areas.Rainwater harvesting (RWH) is listed as one of the adaptation measures of CC (Ferrandet al., 2015; Ojwang et al., 2017). It is also stated in the Intergovernmental Panel on Climate Change (IPCC)Fourth AssessmentReport that rainwater harvesting as an important adaption measure for water supply either for drinking or supplementary irrigation (Bates et al., 2008). This could cope with the water scarcity and water inundation problems in urban areas of Egypt to achieve the sustainable development goals (SDGs).This research proposes the RWH as a specific adaptation measure to cope with future CCfor urban areas in the coastal zones in Egypt by taking Mamorabeach area in Alexandria governorate of Egypt as a case study.

2 METHODOLOGY

2.1 Study area

Alexandria is the second largest city and an important Mediterranean port in Egypt. There are two distinguishedareas as urban and rural. The urban areas are located in the northern part of the city and share the beach of the Mediterranean Sea. Around 98.7% of the total population live in the urban part (CAPMAS, 2017).Mamorabeach, as shown in

Figure 1, is a popular beach place with an area of 771,000 m². It is located east of Montaza's royal gardens and administrated by the Governorate of Alexandria. It is considered as one of the main tourist attractions in the city for its beach and parks.

Figure 1. Location of the Mamora beach area and the digitized landuse map

2.2 Rainwater harvesting for urban areas

Water harvesting is defined as the collection of concentrated rainfall,e.g., from buildings, rock catchments, and land or road surfaces, for its beneficial use (Critchley et al., 1991).RWH can support the water supply in almost any place either as a sole source or by reducing stress on other sources through water savings (Ojwang et al., 2017).For urban areas, water can be harvested from rooftops, roads and landscape areas. There are three basic subsystems for such RWH technique: 1) a catchment system (roofor road), 2) a delivery system (filters and gutters), and 3) a storage system (Liaw and Tsai, 2004).Climate characteristics(rainfall, evapotranspiration, etc.), catchment characteristics(slope, materialused, etc.) and, most significantly, the socioeconomic conditions of the community of the region should be considered when implementing RWH techniques(Critchley et al., 1991).

Rational method commonly used to calculate the amount of water from urban catchments (Ojwang et al., 2017). However, this method calculates discharge for given rainfall intensity. Many researchers (e.g. Farreny et al., 2011) suggested to calculate the potential RWH volume (V) in m^3 from the inspiration of the rational method, presented in Equation 1, as follow:

$$V = C \times R \times A \quad (1)$$

where C is runoff coefficient (unitless), R is the design rainfall (meter), and A is the different catchment areas in m^2 (e.g. rooftop and roads). C represents the percentage ofrainfallthatbecomesrunoff. According to Chow et al. (1988), the C for rooftops and asphalt streets have the range of 0.75-0.95. In this research, the values of 0.8 and 0.85 were assumed for both rooftops and asphalt streets catchments based on a field visit to the area. However, actual measurements of C should be carried out until a representative value is obtainedbefore any larger construction project starts (Critchley et al., 1991).

Rainfall characteristics are important factors in applying RWH techniques for an area. For RWH, the Ris defined as the total amount of rain which could providewater users (e.g. human or plant)with water requirement during the dry season (Al Zayed et al., 2013).R is determined by means of a statistical probability analysis of annual rainfall time series data with a range of 67-90% and 33%-67% probability of occurrence with 1.5-1 and 3-2 year of return periods for domestic uses and landscape irrigation, respectively. Rainfall data from Alexandria rainfall station for the period 1868–2014 was used. HYFRAN software utilized to fit statistical distributions and calculate the design rainfall.

To estimate A, land uses were estimated manually by digitization using the ArcGIS software (ESRI, 2017). All the features, which have the potentiality to capture and collect the rainwater, were considered such as rooftops, roads, parking spaces, bare lands and vegetation areas. The Digital Globe satellite image captured in 2017, provided by ArcGIS Map Servicewith high spatial resolution, was used to identify each type of the various land uses within the study area.

For human water demand, the World Health Organization (WHO) recommended 15 to 20liters/capita/day (l/c/d)as minimum water quantitiesfor drinking, food preparation, personal hygiene and laundry (Howard and Bartram, 2003). For developed areas such as Germany, average domestic consumption is 122 l/c/d (Badran et al., 2010). Alexandria Water Company estimated the average water consumption by 230 l/c/d (Jaweesh, 2010). With the fears from CC and water shortage for the Nile water, reducing average domestic water consumption should take place. In this research, water demand for domestic use was assumed for different consumptions levels from 10- to 122- l/c/d for drinking and up to full supply for sanitation requirement, respectively.

3 RESULTS AND DISCUSSIONS

3.1 Design rainfall amount

The annual rainfall data were analyzed using many methodsin order to determine the design rainfall amount. Weibull distributiongave the best fit for the data and the probability of occurrence curve for the observed and predicted data was derived as shown in

Figure 2.

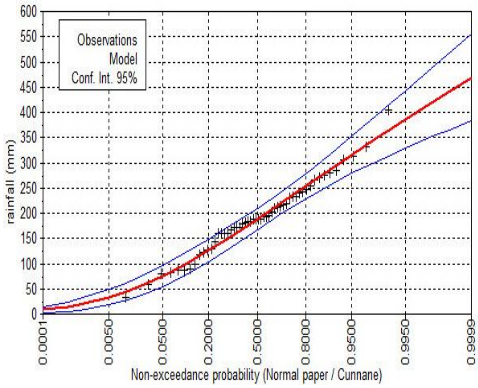

Figure 2. Probability of occurrence of annual rainfall data of Alexandria (1868–2014)

Rainfall events with a probability of 33%–90%, equivalent to annual rainfall of 222–97 mm, can occur every 1–3 years. The R valueswere found to be 97mm and 156mm for domestic uses, which will be met or exceeded (on average) every year or 1.5 year, respectively. For agricultural landscape areas, a design rainfall of 222mm (3-year return period) can be utilized.

3.2 Estimation of different landuse catchment areas

Eight different landuse classes were digitized for the area as can be seen in

Figure 1.For domestic use, it is recommended to utilize the catchment areas only from rooftop which covers ≅241,000 m^2, to collect water. The catchment areas of roads and parking space have an area of 165,000 m^2 and can harvest water to be used as supplementary irrigation for agricultural landscape areas (≅140,000 m^2).

3.3 Potential rainwater harvesting

There is a potentiality to increase the water supply of Mamora beach area with up to 30,000 m^3 for domestic supplyand 31,000 m^3 for irrigating landscape areasby RWH from roads and parking spaces.

Figure 3 shows the spatial distribution of potential water volume from RWH of Mamora beach area. Roof areas have a range of 15-4,500 m^{2}which can harvest 2-575 m^3/year of water for the design rainfall.

Figure 3. Spatial distribution of potential water volume(m^3) from RWH of Mamora beach area

The RWH from buildings could support annually a number of 8240 and 675 persons for drinking and full supply, respectively. The spatial distribution of number of people to utilize RWH of Mamora beach area only for drinking purposes is shown in

Figure **4**.

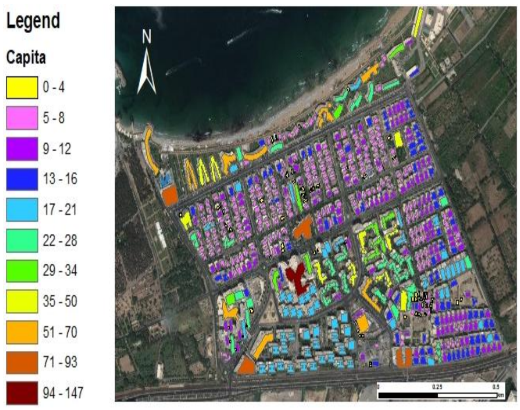

Figure 4. Spatial distribution of the potential number of people who could utilize RWH of Mamora beach area only for drinking purposes

CONCLUSIONS

In this study Mamora beach is selected as urban area case study. Different tools and models are used to compute the potential amount of water to be harvested. Water resources of the area would be increased by up to 30,000 m^3 and 31,000 m^3 for domestic supply and irrigating landscape areas, respectively, when utilizing such RWH techniques. It is obvious that the total amount of water that can be collected from roofs in the study area is not enough to fulfil the total water demand for the full supply. Since Egypt's water resources are under water stress with addition to the threat of CC, all stakeholders should recognize that the future depends on the way of management of the precious and finite water resources. It might still be worthwhile to construct a rainwater harvesting system at least for drinking purposes. Storage tank reservoir is suggested to store water during the rainy season and to be used in the dry period. Information on the construction and maintenance of rainwater harvesting systems should be tested through pilot project area.

Socioeconomic and engineering analyses should be conducted for the local people and implementing such technique, respectively. In addition, quality of rainwater should be tested to meet the World Health Organization (WHO) drinking water guidelines for chemical, physical, and biological parameters to meet the Egyptian drinking water standards.It is recommended such technology in the agricultures urban areas especially in Delta region in order to fill the deficit in irrigation water, especially at the ends of the canal system. The proposed plan will certainly minimize the effects of water inundation problem in urban areas. In addition, the harvested water could be used as an adaptation measure to CC. this water can also be integrated with ground water for sustainable development.

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