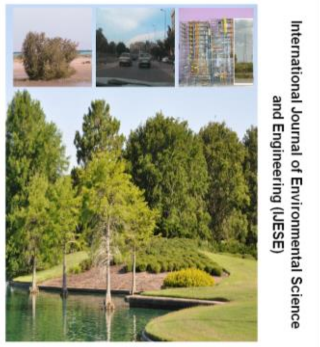
INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCE AND ENGINEERING (IJESE)
Vol. 7: 85- 93 (2016)
http://www.pvamu.edu/research/activeresearch/researchcenters/texged/international-journal
Prairie View A&M University, Texas, USA



Using GIS and Remote Sensing Approaches to Delineate Potential Areas for Runoff Management Applications in Egypt.

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ARTICLE INFO

Article History
Received:Sept.17, 2016
Accepted: Dec. 7, 2016
Available online: Feb.,2017

Keywords:
Satellite images,
GIS weighted,
overlay analysis,
runoff water,
Management,
Egypt

ABSTRACT

This study was carried out to delineate the potential areas of runoff in El Beheira governorate in Egypt, with the purpose of detecting locations where water is accumulated after heavy rainfall. A large rainstorm hit El Beheira in 4/11/2015, with precipitation ranged from 8 to 385 mm /day. The most important factors that influence the water runoff are: precipitation, land cover types, soil map types, and slope. Raster data describing these factors were: Integrated Multi-satellite Retrievals for Global Precipitation Measure (IMERG) in mm/hr units; Landsat Image for delineation of different land cover types; Digital Elevation Model (DEM) for delineation of slope raster data, in addition to the soil type map. All these raster layers were analyzed using Weighted Overlay Analysis tool under ArcGIS environment after sequential pre-processing steps. The delineated flood potential area was classified into four land cover types using K Mean algorithm, and from which water volume for each land cover type was calculated. The obtained values of water volume in million m^3/day for the most flooded areas in different land cover types were: 100.646 for 2270 km^2 of vegetation, and 129, 240 for 2823km^2 of bare soil, and 66.889 for 653.5 km^2 of a residential area. It can be concluded that potential regions of water runoff can be remotely delineated in effective and fast manner using approaches of GIS and remote sensing. This research study will help decision maker to put plan action for harvesting runoff water in delineated areas.

1. INTRODUCTION

Egypt is located in an arid- to semi-arid zone. The inhabited area of the country constitutes only 4% of the total area of the country (1 million km2), and the rest is desert. The main source of water, the River Nile, which provides more than 95% of all water available to the country (Abdel-Shafy and Aly, 2002). At present, the major challenge that Egypt has got to face is how to meet the increased future demands for water from all sectors with almost fixed amounts of water resources. The main (almost exclusive) source of water in Egypt is the Nile River which allocates 55.5 BCM/year. Rainfall in Egypt occurs only in winter in the form of scattered showers which is estimated to be 1.3 BCM/year.

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ISSN 2156-7530

Groundwater exists in Western Desert and Sinai in aquifers that are mostly deep and non-renewable. The most promising measures by MWRI are developing additional resources, making better use of the existing resources, and protecting health and environment (Water for the future, National Water resources plan 2017, 2005).

The Panel on Climate Change (IPCC) reported that there has been a very likely increase (probability 90–99%) in precipitation during the 20th century in the mid-to-high latitudes of the Northern Hemisphere (Groisman *et al*., 2001). Much of the increase in precipitation that has been observed worldwide has been in the form of heavy precipitation events (IPCC Working Group I, 2001; Easterling *et al*., 2000a, b, c).

Climate models are predicting a continued increase in intense precipitation events during the 21st century (IPCCWorking Group II, 2001). According to the Meteorological Society, a rain intensity of < 2.5 mm hr^{-1} is called light rain, while a rain intensity of > 7.5 mm hr^{-1} is referred to as heavy rain. Rain intensity between 2.5 and 7.5 mm hr^{-1} represents a moderate rainfall (Hussein A., Martin,R.,2010). The search for feasible solutions to sustain water resources is, therefore, gaining considerable momentum in Egypt and elsewhere (e.g. Adamowski *et al*. 2012; Haidary *et al*. 2013). Yet catastrophic flash flooding has recently become very common in some areas. More recently, Alexandria and Behiera Governorates areas in Egypt were hit by severe flash floods in November and December 2015,which led to loss of lives and damage to properties and cultivated crops, and left behind destruction in urbanized areas. Such run off areas should be identified to help decision maker to put plan action for harvesting runoff water in delineated areas.

Remote sensing, GIS has been widely used to determine the sites for the flood vulnerability areas, and best water harvesting sites. The site selection criteria in most of these references are based on soil types and topographic suitability, land cover and precipitation. Most studies have focused on the selection of sites for rainwater harvesting in rural or urban areas such as the study conducted by Inamdar *et al*. (2013) to develop a robust GIS based screening methodology for identifying potentially suitable storm water harvesting sites in urban areas. Some study were carried out in Egypt about flash flood in general using GIS and remote sensing in different techniques, for specific areas (Fla FloM, 2009;Mohammed ,B.; Kevin w.; Ayman ,N., 2009).

This study aims to delineate the potential areas for rainwater harvesting system by analyzing the effective factors which cause runoff using weighted overlay analysis tool under Arc GIS environment, and to calculate water volume for these different types of land cover.

2. Study area

El-Beheira governorate lies in the West of the Nile Delta region in Egypt. It is bordered in the North by the Mediterranean Sea, in the East by Rosetta branch, in the west by Alexandria and Matrouh, and in the south by Giza and El-Menofia, with a total area of about 9826 km^2.The Beheira study area is located between latitude 29°54'25.281"N to 31°25'2.86"N and longitude 29°37'15.556"E to 30°49'9.164" E .The values of annual mean temperature, relative humidity, wind speed for Beheira governorate are: 21 °C, 57%, and 350 in (km/day) respectively. Rainfall (in mm /month) is between 9.6 and 24.8 for the period from November to February. Beheira is by far the largest governorate regarding the area of agricultural lands which are estimated as 1623.59 thousand feddans (including the Nubaria lands) (Fig. 1).

3. Methodologies

3.1 Precipitation

The precipitation raster data is Integrated Multi-satellite Retrievals for Global Precipitation Measure (IMERG) in mm/hr units. The products provide global high spatial resolution precipitation data, at 0.1-degree resolution (10 km). The data are archived in native HDF5 with Spatial Coverage: (90.0 N to 90.0 S; 180.0 E to 180.0 W) and Temporal Coverage: from 03-12-2014 until current. Temporal resolution is 30 minutes, so 48 raster data sets are required to obtain the precipitation data all over 24 hours of the day. This precipitation data is available for free from site: "http://disc.sci.gsfc.nasa.gov/uui/search/Precipitation".

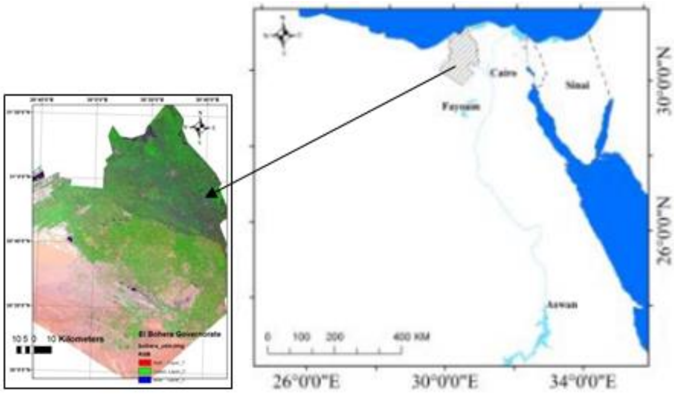

Fig. 1: The Study area; Beheira Governorate, Egypt.

Precipitation raster data in HDF5 format is need to be preprocessed first before analyzing ,as precipitation calibrated sub dataset was added into ArcMap , and the projection information was defined as WGS84, after that the image was oriented 90 degree counter clockwise rotation . Defining correct geo-reference longitude and latitude values were carried out, and finally wrap was performed using Table 1 with source and target control points were the information packed in the HDF5 file is not recognized by Arc GIS).

After precipitation raster data was corrected geometrically; it was resampled to 30 m and subset to the study area. These procedures where done for the 48 images. Finally, these 48 precipitation raster data were added together pixel by pixel values using raster calculator (Fig. 2).

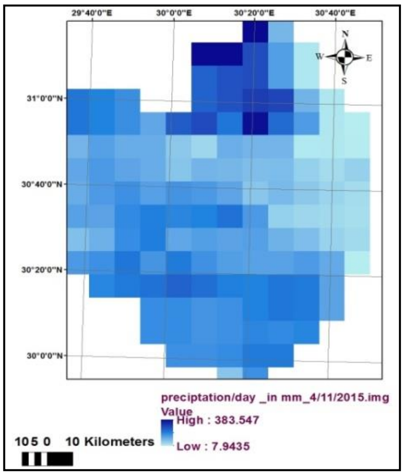

Fig. 2: Precipitation in El Beheira Governorate on 4/11/2015.

3.2 Soil types map

Soil types and texture are very important factors in determining the water holding and infiltration characteristics of an area and consequently affect flood susceptibility (Nyarko, 2002). Some soil types can cause very rapid runoff even in dry conditions (National Oceanic and Atmospheric Administration, 2010). Soil association map of Egypt was downloaded from the site http://esdac.jrc.ec.europa.eu/resource-type/datasets, and it was geo-referenced to

UTM WGS 84 projection and resampled to 30m (SRTM DEM resolution), and it was subset to the study area. Vector layer was digitized accordingly to each soil type value and, hence its infiltration rate values relevant to each soil type were added as attribute column in its table. Infiltration rate was determined according to Black (1982) and FAO (1976) (Fig. 3).

3.3 Landsat Image was used to delineate different land cover types

Two Landsat 8 images with paths/rows: (177/38), (177/39) were acquired in 8/2015 (the images were free downloaded from: http://earthexplorer.usgs.gov). Initial images processing were carried out, a sub-image of El Beheira governorate cut after a mosaic processing, layer stacking, and geometric correction. The image was classified using (K-means algorithm) into 36 classes ,comprises four different land cover types (built-up, bare soil ,vegetation, and water) ,and every land cover was extracted as a single layer to calculate the area of each, and hence calculate water runoff volumes for all layers (Fig. 4).

3.4 Digital Elevation Model

The elevation of the study area is nearly flat and ranges between 0and >26m above mean sea level (Fig. 5).

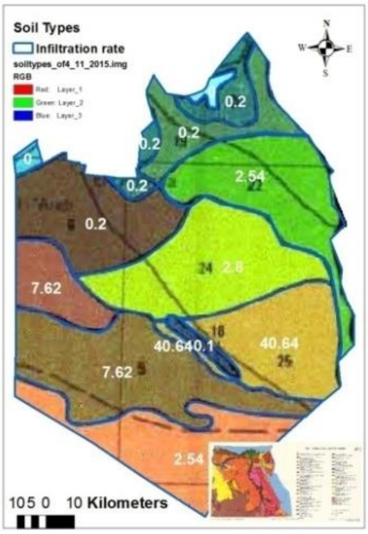

Fig. 3: Soil type map with relevant infiltration rate values (in mm/ hr) .Cartographic preparation by the Soil Survey Institute, Wageningen, the Netherlands.

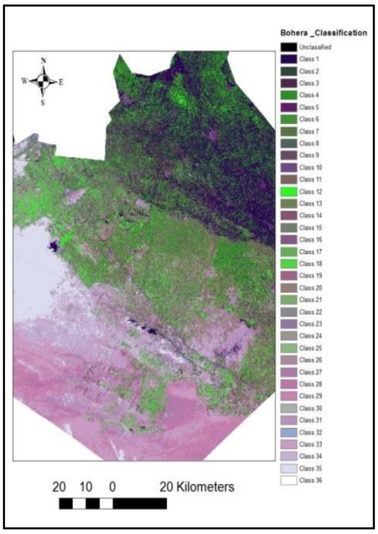

Fig. 4:Resulted Landsat image classification

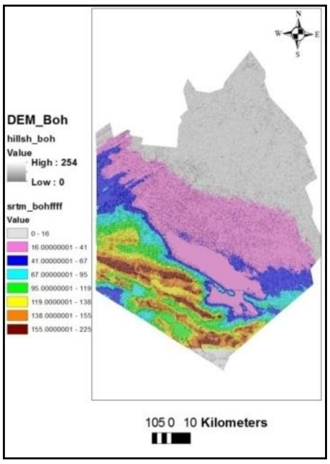

Fig. 5: DEM for El Beheira Governorate, Egypt.

4. RESULTS AND DISCUSSION

Two aspects were applied in this study to manage the runoff potential areas. The first aspect analyzes effective factors that cause runoff by using weighted overlay analysis tool to determine the flood potential areas, which is considered as the most suitable areas to harvest water from, and determine the volume of water for these potential areas. Volume calculations are dependent on land cover type, so classification of the satellite image of the study area is necessary. The second aspect demonstrates a review study on water harvesting and purification.

4.1 Weighted Overlay Analysis

The Weighted overlay tool allows the calculation of a multiple-criteria analysis between several raster's data. Some of the important causative water analysis is: rainfall (precipitation), slope, and the type of soil and its relevant infiltration rate. The input raster data have been reclassified to a common measurement scale, where (Low infiltration + relatively low slope + high precipitation) corresponds to high flood potential areas. Each raster layer data is assigned as percentage influence (weight). Weight is assigned as 60% for precipitation, 20% for each of the slope and infiltration rate .The cell values for each raster data are multiplied by their weights, and the results are added together to create the output weighted raster data. The output areas (Fig. 6) were consistent with the areas that were almost flooded by the rainstorm in 4/11/2015. Some of these areas are: Kafr El-Dawar, Abo-Homos, Damanhour, Kom El Basal in the North, and Wadi El-Notron in (El-Efona village) in the south.

Some pictures were acquired in this storm day they were demonstrated in the Figure below (Fig. 7).

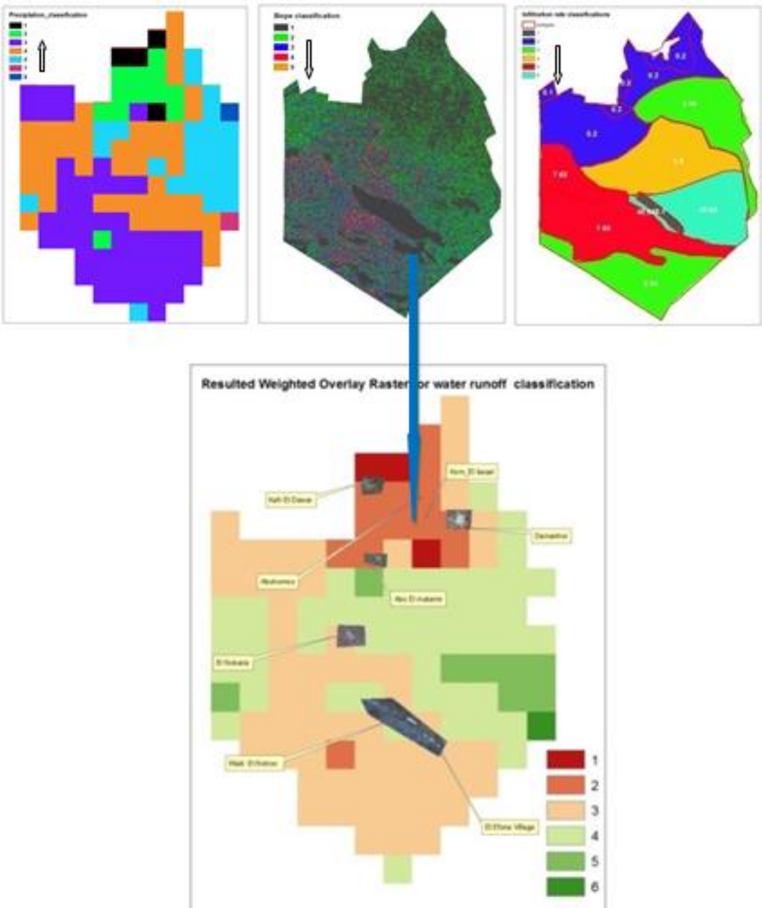

Fig. 6: The output flooded areas that resulted from weighted overlay analysis.

Fig. 7: Images of some areas in Al Beheira Governorate that were hit by a large Rain storm in 4 /11/2015 (El-Ahram newspaper on 6/11/2016).

The runoff areas, with different levels of intensity were delineated. It can be seen that the most flooded areas were distributed in the north and west south zones. The lands covers of these areas comprise buildup, vegetation, and bare soil ones (Fig. 8).

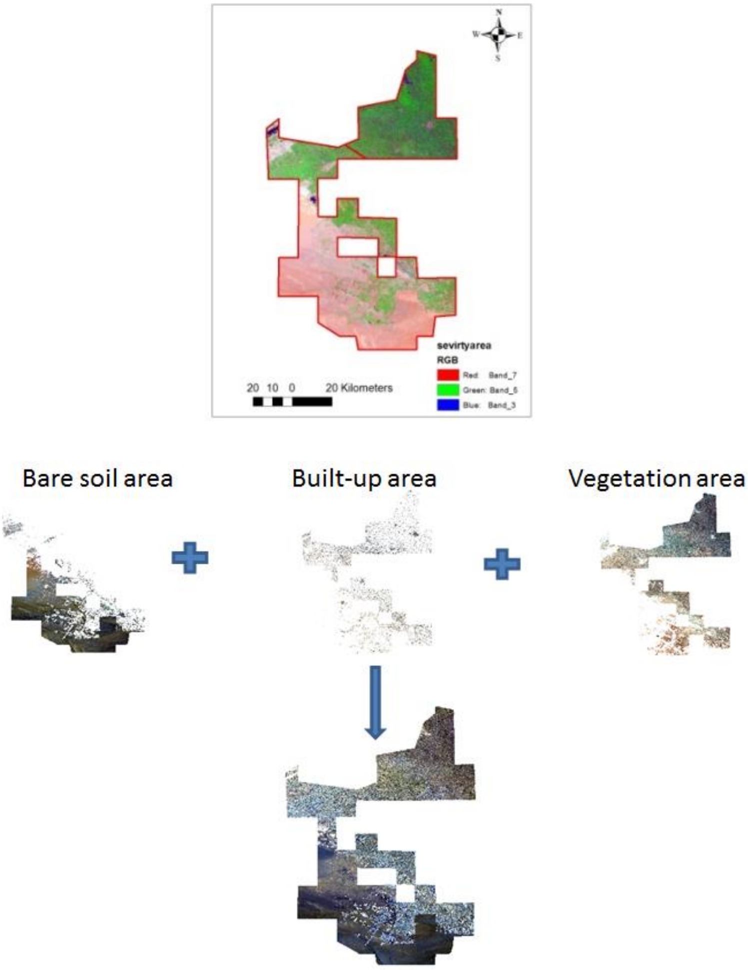

Fig. 8: Runoff areas for different land cover types

4.2 Calculation of water runoff volume for different land covers types in Beheira Governorate.

Estimating the volume of runoff for different land cover types for rainwater harvesting depend on three factors:

a-Catchment Area: the area in which rain directly falls on different land cover type staking into consideration that all buildings roofs inside the buildup land cover area treated as rectangle shapes for approximation.

b-Runoff Coefficient: the average percentage of rainfall that will run off a particular surface (depending on land cover types) , and the applied Runoff coefficient values were the average values which deduced by Mahmoud (2014), using a GIS, estimated PRC values varying from 0.03 to 1.0 for different regions of Egypt based on their hydrologic soil group (HSG), land use, slope, and measured runoff volume and the values used for El-Bohera Governorate specifically are ranged between .3 to .9.

c- Rainfall intensity: Net runoff volume was calculated using equation 1 for the previous three land cover types using field calculator tool under Arc GIS environment. Table 1 demonstrates the catchment areas in km^2, and the resulted runoff volumes.

Table 1: The calculated volumes for each land cover types

Land cover Types	Catchment areas in km^2	Runoff Coefficients	Runoff water Volume in million m^3/day
Vegetation	2270.0	0.3٠	100.646
Bare soil	2823.85	0.45٠	129.240
residential area	653.5	0.85٠	66.889

Catchment area (m^2) * rainfall (mm/day) * runoff coefficient = net runoff volume in (m^3/day) (Brad Lancaster, 2006).

The volume of the collected should be treated before use for both health of the users and maintenance of the system. The level of treatment will depend on the intended use of the water. For example, water used for landscape drip irrigation would not need the same level of treatment as water used for potable indoor purposes. Different types of water treatment such as filtration can remove microorganisms, sediment, metals, and other organic matter. However, the high costs associated with runoff water treatment facilities for small cities and villages in the near future will prevent its establishment, unless more technologies that are inexpensive are introduced such as wetland.

Wetlands are one of nature's most efficient and common ways to clean runoff water. It is a technique for the amelioration of wastewater using aquatic macrophytes. The ability of aquatic weeds to purify water varies from one species to the other and there are also great variations among the varieties of the same species (El falaky *et.al.* 2003). Thus choosing the suitable weed to be grown is very important .Other mechanical factors for successful wetland include the type of media and water flow rate. Constructed wetlands mimic the natural process that is both economical and environmentally sound because they rely on natural methods such as vegetation and gravity flow\which are both energy efficient and environmentally sound. Less air pollution is realized because electricity from coal and oil fired generation plants are not used. Unlike traditional water treatment systems, chemicals are not needed for the process. A small home or business wetland can be as small as one cell (7 meters X 7 meters X 1.5 meters). A larger one for that can filter 28390.6 to 94635.3 liters a day will have 3 to 4 cells .Such types of these wetland could be established anywhere in small to medium sized communities and larger business and sporting clubs and schools with 3785412 liters or less of waste water a day.

5. CONCLUSION

In this research, effective factors causing water runoff for the study area in El-Behera governorate were analyzed using GIS weighted overlay analysis tool. The potential areas for water harvest of rainwater flood were delineated. These delineated output were in consistent with the areas in El-Behera that were flooded by the rain storm in 4/11/2015. The volume of water for these potential areas under different land cover type was calculated .The obtained values in million m^3/day were: 100.646, 129.240 and 66.889 for vegetation, bare soil, and buildup areas respectively. Hence, remote sensing tool was proven a reliable method for detecting the areas of runoff water.

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