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Identification of potential soil water retention using hydric numerical model at arid regions by land-use changes

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Abstract

Assessment of soil water retention in arid region is an input required parameter in precision water management at large scale. Investigations were carried out in Tanta catchment in the middle Nile Delta, Egypt (30° 45 N, 30° 55 E), where collecting soil samples covered different hydrological soil groups and land-uses. Based on the natural resource conservation service curve number model (NRCS-CN), CN approach was used to investigate the effect of spatio-temporal variations of different land-uses on soil water retention. Potential soil water retention from 1990 to 2015 was reduced by 118.1 m^3 per hectare with decreasing cropland area. Urbanization encroachment from 1990 to 2015 was increased by 2.13% by decreasing cropland with 15.3% (5300 ha in 2015). This resulted in losing the potential soil water retention by 625,968.42 m^3 water for the whole catchment area. Impact of land degradation was pronounced, where 2.65%, 29.35%, and 1.11% of the initial crop land-use in 1990 were converted to bare soil, fallow, and urban area, respectively in 2015. Implementation of (S) value of the NRCS-CN model with GIS technique provides useful measure to identify land-use changes of potential water storage capacity at catchment scale.

Keywords: Curve number model; Land-use; Potential water retention; Spatio-temporal variations

1. Introduction

Land-use changes are important parameters in the runoff process as they affect water storage capacity in the Mediterranean regions. These changes resulted from agriculture intensification, people relocation in urban areas, grazing abandonment inland, and explosion in urbanization (Brandt & Thornes, 1996; Drake & Vafeidis, 2004). Monitoring these changes required accurate spatio-temporal land-use/land cover (LULC) mapping over large areas that become operationally available by multispectral satellite data. In fact such data sets facilitate monitoring processes of LULC and urbanization change studies due to its accurate spectral resolution. Land degradation reflects

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the well-tendency of soil to surface runoff (Sharma, 1998; Kosmas, Danalatos, & Gerontidis, 2000). Removing vegetation covers with increasing urbanization leads to an increase in overland flow and surface runoff. Surface runoff, a subsidiary parameter of soil degradation, was determined using natural resource conservation service—curve number model (Hawkins, Ward, Woodward, & Van Mullem, 2009). Due to its simplicity, curve number (CN) model was used by the hydrologists of US Soil Conservation Service (SCS) to identify the direct surface runoff in ungauged agricultural basins and for non-agricultural watersheds (Ponce & Hawkins 1996; Mishra & Singh, 2006). CN is a dimensionless value, which has been identified experimentally for a variety of different soil, land-use, land management situations, and hydrologic conditions for small scale catchments in US. In addition, CN is related to the retention soil water potential (*S*) and the curve number model considers many factors including land-use change, soil type, land management, treatment, antecedent soil moisture condition, and surface condition (Hawkins, 1993; Michel, Andréassian, & Perrin, 2005). Therefore, this methodology is well-grasped and well established in documenting the environmental features (Chow, Maidment, & Mays, 1988; Romero, Castro, Gomez, & Fereres, 2007; King, & Balogh, 2008). Although CN model was mainly developed for identifying runoff in agricultural basins, it is adopted for several land-uses as well as urbanized watersheds (Mishra & Singh, 2006), and its scope extended to be an integral parameter of complex and simulation water retention models (Lyon, Walter, Gerard-Marchant, & Steenhuis, 2004; Zhan & Huang, 2004; Mishra, Geetha, Rastogi, & Pandey, 2005; Soulis & Dercas, 2007; Geetha, Mishra, Eldho, Rastogi, & Pandey, 2008; Singh, Bhunya, Mishra, & Chaube, 2008). CN has experimentally been identified for different LULC situations for small catchments to determine the actual and/or potential water retention and direct surface runoff (Romero et al., 2007; Hawkins et al., 2009). In addition, Mantey and Tagoe (2013) reported that the hydrologic soil groups (HSGs), land use and DEM were the main parameters used to generate curve number value. Geographical information system (GIS) was performed as an efficient technique for preparation of input date required by the SCS curve number model (Latha, Rajendran, & Murugappan, 2012, 2012). Curve number value can be established from remote sensing digital data by correlating generalized LULC with hydrologic soil groups and the tables that were presented by the SCS and experimentally identified (Zhan & Huang 2004). In addition, remote sensing immensely helps in rapid identification of LULC that is used as an input tool in the SCS model (Kumar, Tiwari, & Pal, 1991; Chen, Wang, Pollino, & Merrin, 2012).

Water requirements in Nile Delta are continuously rising due to population growth and enhancing standards of living (Mohamed & Belal, 2015). Annually, agricultural sector that consumes the largest component of total water demand, exhausts more than 85% of Egypt's portion of the Nile water. Water issue in Nile Delta is rapidly considering alarming proportion, that by the year 2020, Egypt will lose 20 percent more water of its share. With this loosening grip on Egyptian Nile portion, water scarcity would endanger the country’s stability (MWRIE, 2014), resulting in land degradation processes, that has widely been recognized (Kosmas et al., 2000). This phenomenon resulted from drought, poor agricultural practices, deterioration of vegetation cover, soil organic matter losses, and reduction of its soil water storage that would result in soil desertification (Thornes, 1985).

The objective of this work is to integrate soil, remote sense data, GIS and hydrological model to map soil water retention in arid region for precision water management. Specific objectives included study of spatio-temporal variations of LULC and their effects on the potential water retention in a Nile Delta region.

2. Material and methods

2.1. Experimental site

Investigations were carried out in the middle of Nile Delta at the catchment area of Tanta (30° 45′ N, 30° 55′ E), that was aligned by Damietta and Rosetta branches as shown in Fig. 1. The catchment area is 34,650 ha and has a maximum altitude of 40 m above sea level (asl). The studied area is characterized by Mediterranean climatic conditions with seasonal and spatial variations of rainfall and high oscillations in daily temperatures. Climatic data of Tanta Meteorological Station (TMS, 1960–2010) indicate 45.1 mm annual rainfall for Tanta city that falls mainly in the winter seasons. Mean of annual and maximum temperature was 20.1 and 45.7 °C. Central part of Nile Delta is classified by sedimentary non-consolidated deposits belonging to the quaternary area that is differentiated into four different deposits: young deltaic, Fluvio-marine, young Eolian, and old Eolian.