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Identification of Potential Runoff Harvesting Sites in Wadi Elrawakeeb-Alsayal Watershed

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Abstract**—** *To identify the suitable areas for potential runoff harvesting in Wadi Elrawakeeb and Wadi Alsayal desertified watershed, spatial suitability analysis was applied considering three major factors; potential surface runoff, inhabited sites, sites planted with field crops, and two additional factors; sub-basins average runoff and outlet locations of sub-basins. Obtained results showed that; most, middle and least suitable areas for water harvesting in the studied watershed are located at the sub-basins outlets, which are formed by the longest flow paths of both Wadis.*

Keywords**— water harvesting, runoff potential, spatial suitability analysis.**

I. INTRODUCTION

The United Nations Environment Program (UNEP) defines water harvesting as the collection of rainwater from the surface and storing it to meet the needs of humans, animals and plants for water when needed (Ahmed, 2018[1]). With limited resources and rapidly increasing demands, sustainable development of Wadi systems is becoming increasingly important, which is a difficult goal to be achieved. Watershed management of Wadi systems leads to the improvement of these resources. Although Wadis in Sudan have high runoff potential, they have been suffering from lack of data that can be used to manage and evaluate them, which calls for an urgent initiative to evaluate this precious water resource. There is a need in Sudan for technologies such as RS, GIS, GPS, and Hydrological Modeling Systems (HMS) to help provide reliable, useful and timely data for water resource management (Alhassan, 2011[2]; Salih and Ghanim, 2002[3]; Wheater and Alweshah, 2002[4]). Weighted Overlay Analysis is one of the overlay analysis tools included in the Spatial Analyst Extension of ArcGIS; it is often used to solve complex problems. Spatial Suitability Analysis aims to test a suitable spatial location to perform a specific function by applying the specific conditions for how to choose, and it is one of the most important functions of GIS technology (Dawood, 2012[5]). Wadi Elrawakeeb and Wadi Alsayal watershed is located at Elrawakeeb Area at western Omdurman which is located in semi-arid region as shown in Figure (1) and which suffer from severe land degradation such as sand encroachments. Wadi Elrawakeeb and Wadi Alsayal share one watershed with a total area of 257 km^2 and one outlet. The average annual rainfall in the region is about 121.4 mm, mostly falling in July and August; the actual annual rate of evaporation is about 850 mm; the average daily potential evaporation is about 7.7 mm, and the average relative humidity values are 38% and 23%, respectively. The average annual temperature is about 29º C; the average daily maximum and minimum temperatures are 37º C and 21.6º C, respectively (Ahmed, 2020[6]). Wadi Elrawakeeb and Wadi Alsayal have been suffering from a lack of rain-runoff data that can be used to manage and assess them. The sudden and fluctuating nature of precipitation at their watershed makes the process of rain and runoff gauging rather difficult due to the topographical variation in the region. On the other hand, achieving an adequate scientific understanding of Wadi system in arid and semi-arid regions is a challenging task, for this reason the study had directed attention for the hydrological parameters estimation and rainfall-runoff modeling of this vital resource which is expected to assist in management and evaluation of these systems and leads to better use of Wadi systems to meet current and future demands. The study mainly aimed to identify suitable areas for runoff harvesting at Wadi Elrawakeeb and Wadi Alsayal desertified watersheds, using a GIS-based approach that incorporates hydrological and socioeconomic criteria's for selecting sites.

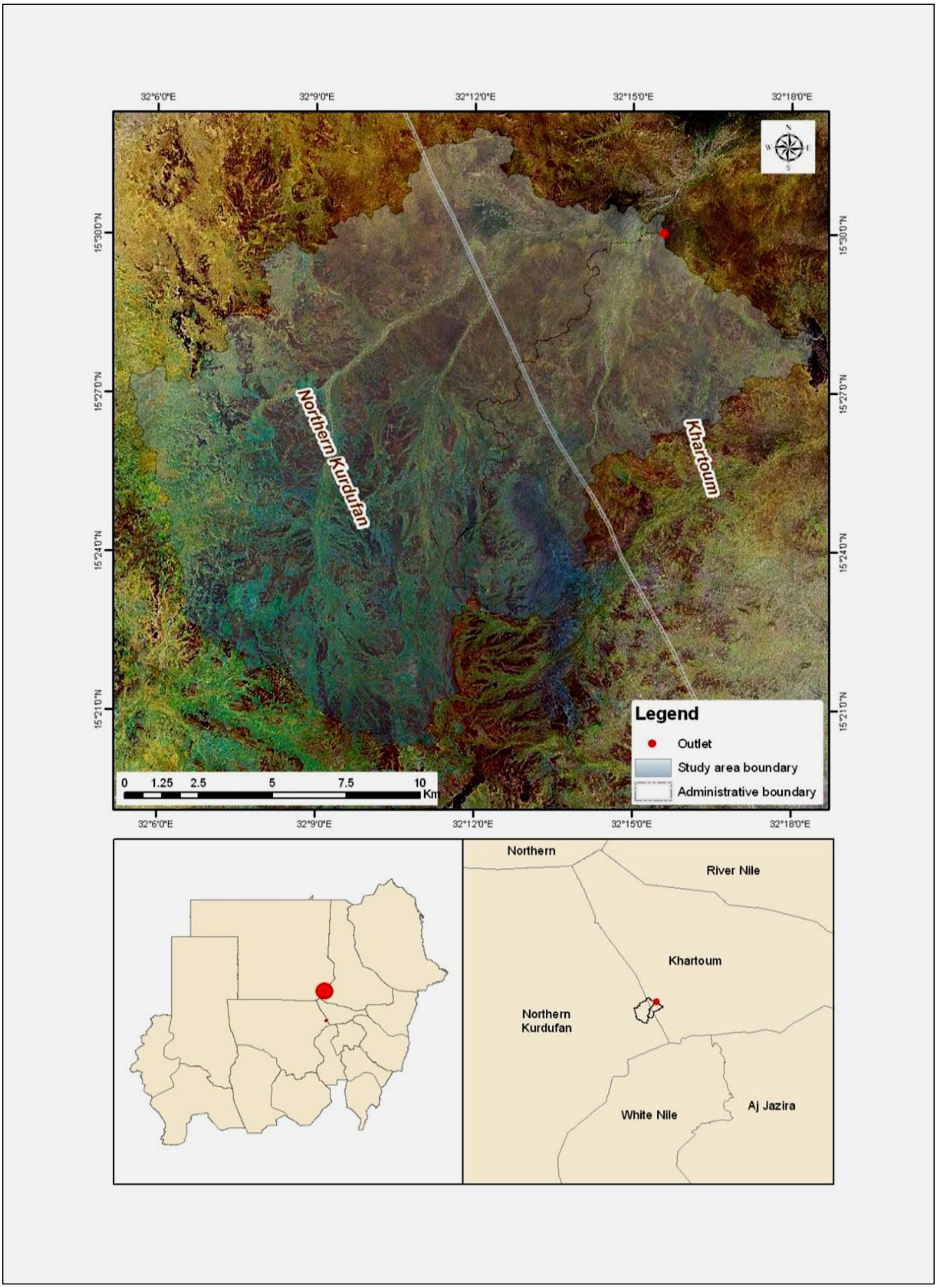

Fig.1: Location of study area decertified watershed

II. MATERIAL AND METHODS

2.1 Development of a semi-distributed model for study area watershed

In order to develop a hydrological model, ArcGIS [9.3], Archydro [1.3], HEC-GeoHMS [5], DNR Garmin [2.02] and HEC-HMS [3.1.0] were used integrally to develop hydrologic inputs for Hydrological Engineering Center-Hydrological Modeling System (HEC-HMS) semi-distributed model for the study area. The constructed model divided the studied watershed into 35 subbasins, and then two simulation runs were carried out to cover the first period from 22nd July to 4th August 2011, which contains 3 rainstorms, and the second period from 20th August to 2nd September 2011, which contains two rainstorms. The constructed model was calibrated for both simulation runs (1) & (2) Ahmed (2020[6]).

2.2 Development of raster datasets for spatial suitability analysis

Figure (2) shows the major steps taken to process the collected datasets to generate useful output in the form of runoff potential and suitable runoff harvesting sites using GIS tools. Three major factors were selected to perform spatial suitability modeling as suggested by Sharma and Singh (2012[7]) which were potential runoff, populated sites and cropped sites. With reference to Ramakrishnan *et al* (2009[8]), Ahmed (2020[6]) suggested two additional factors as shown in Fig (2); the first factor is sub-basins average runoff which was obtained from calibrated semi-distributed model, and the second factor is the sub-basins outlet locations. The raster datasets needed for analysis were produced as follows:

(1) **Potential runoff layer:** Both the SCS-CN and Slope raster layers were combined to produce it; with reference to Hassan *et al* (2020[9]), the produced layer was then reclassified into 5 classes so that

all the produced layers will be on one scale, which in this case is from 1 to 5, considering that number 5 is the highest suitable location for water harvesting.

(2) **Inhabited sites, sites planted with field crops layers**: These sites were tracked using a GPS, and then by using the straight line distance function, the produced layer was buffered by 100 meter distance as a distance suitable for water harvesting from inhabited and cropped sites as suggested by Sharma and Singh (2012[7]). With reference to Hassan *et al* (2020[9]), the two produced layers were also reclassified into 5 classes.

(3) **Sub-basins runoff layer**: Values of mean runoff volumes for the sub-basins were extracted from the calibrated semi-distributed model (simulation runs 1&2) then attached to each subbasin. The layer was converted to a raster layer, and then the produced layer was buffered by 1 Km distance as a distance appropriate to construct barriers for water harvesting cross Wadi section as suggested by Ahmed (2020[6]); With reference to Hassan *et al* (2020[9]), the produced layer was also reclassified into 5 classes.

(4) **Sub-basin outlet locations layer**: Outlet locations for each sub-basin were also extracted from the calibrated semi-distributed model (simulation runs 1&2) and then attached to each sub-basin, the produced layer was also buffered by 1 Km distance as a distance appropriate to construct barriers for water harvesting far from each subbasin-outlet as suggested by Ahmed (2020[6]). With reference to Hassan *et al* (2020[9]), the produced layer was also reclassified into 5 classes.

2.3 Factors evaluation using a raster calculator

With reference to DWSRM/ENRDRI (2020[10]) of NCR, produced raster datasets of runoff potential, settlements, croplands, sub-basin runoff, and subbasin outlets were given appropriate weights, then by using raster calculator, all layers were evaluated. The number of coding categories of the produced raster layer was changed to 3 new categories which are high, medium and low suitability to facilitate display of results.

III. RESULTS AND DISSCUSIONS

Obtained results showed that the most, medium and least suitable areas for runoff harvesting at the studied watershed are located around the sub-basins outlets at end of the longest flowpaths of each two Wadis as shown in Figure (3).

Obtained results were found to be compatible with findings of Sharma and Singh (2012[7]) who stated that providing an accurate spatial representation of potential runoff estimation in any water basin is an important factor for establishing any water harvesting strategy in the relevant basin. Measurement of runoff volume at the end of the longest flowpaths within the study area watershed is rather difficult due to the nature of watershed surface which contains a number of sandy hills and stone heights so Ahmed (2020[6]) suggested using sub-basins average volume generated by the SCS_CN method and using the sub-basins outlet locations as additional factors for analysis as suitable sites to construct earthen or rocky barriers for water harvesting. The buffered distance suggested by Ahmed (2020[6]), which is 1 km was found to be plausible since it considered diversity of the spatial variance and generated runoff of studied watershed. Although Ramakrishnan *et al* (2009[8]) carried out field investigations for their derived suitability maps and obtained an accuracy of 80-100%, field investigations of the derived sites were obstructed by the hard surface nature of the examined watershed. Finally, obtained results showed that, the suggested GIS approach which considers additional factors, is well realizes hydrological modeling inputs by identifying specific areas (sub-basins) in the studied watershed, which are the potential sites for water harvesting.

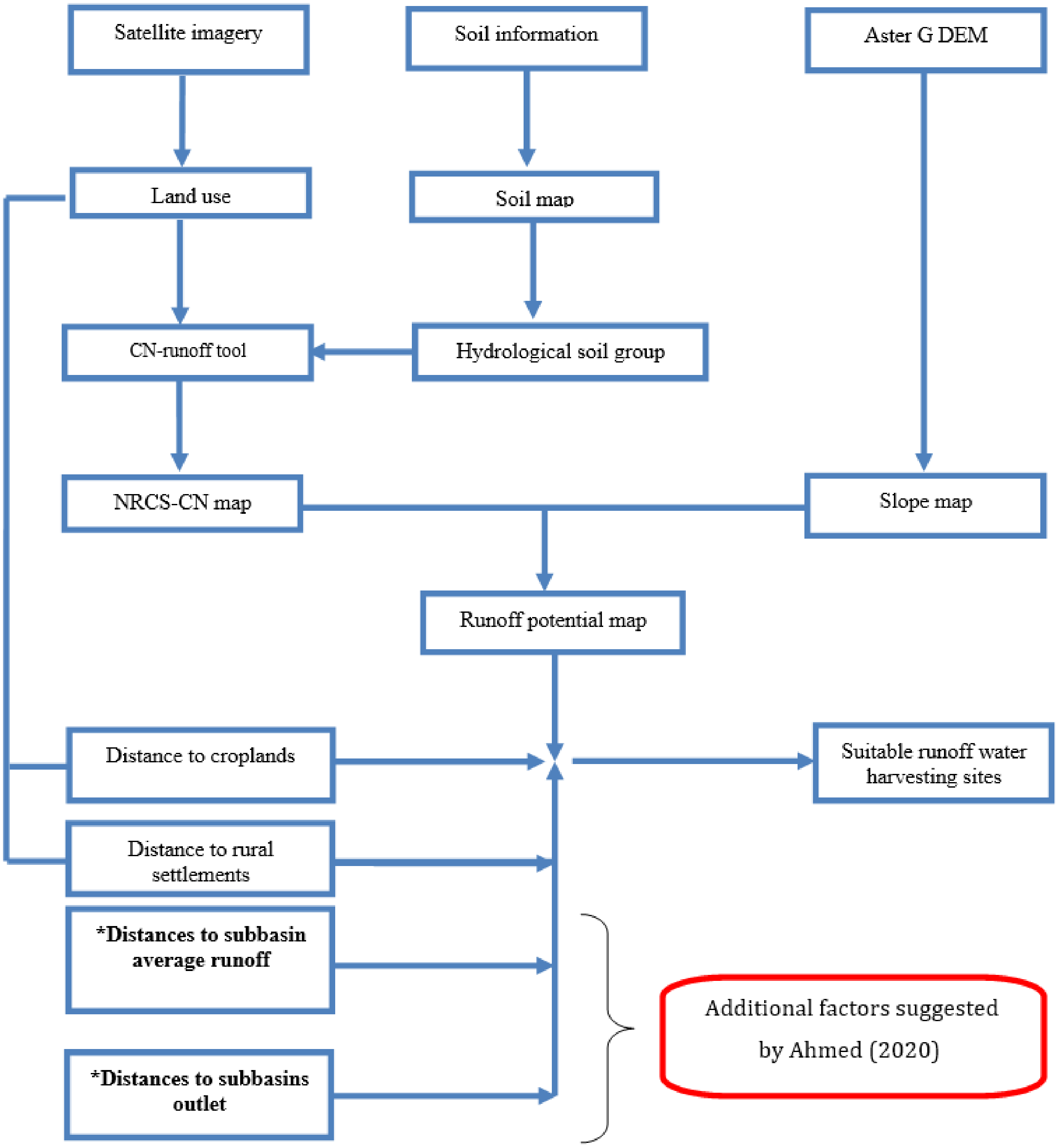

Fig.2: Flow chart for deriving suitable runoff harvesting sites

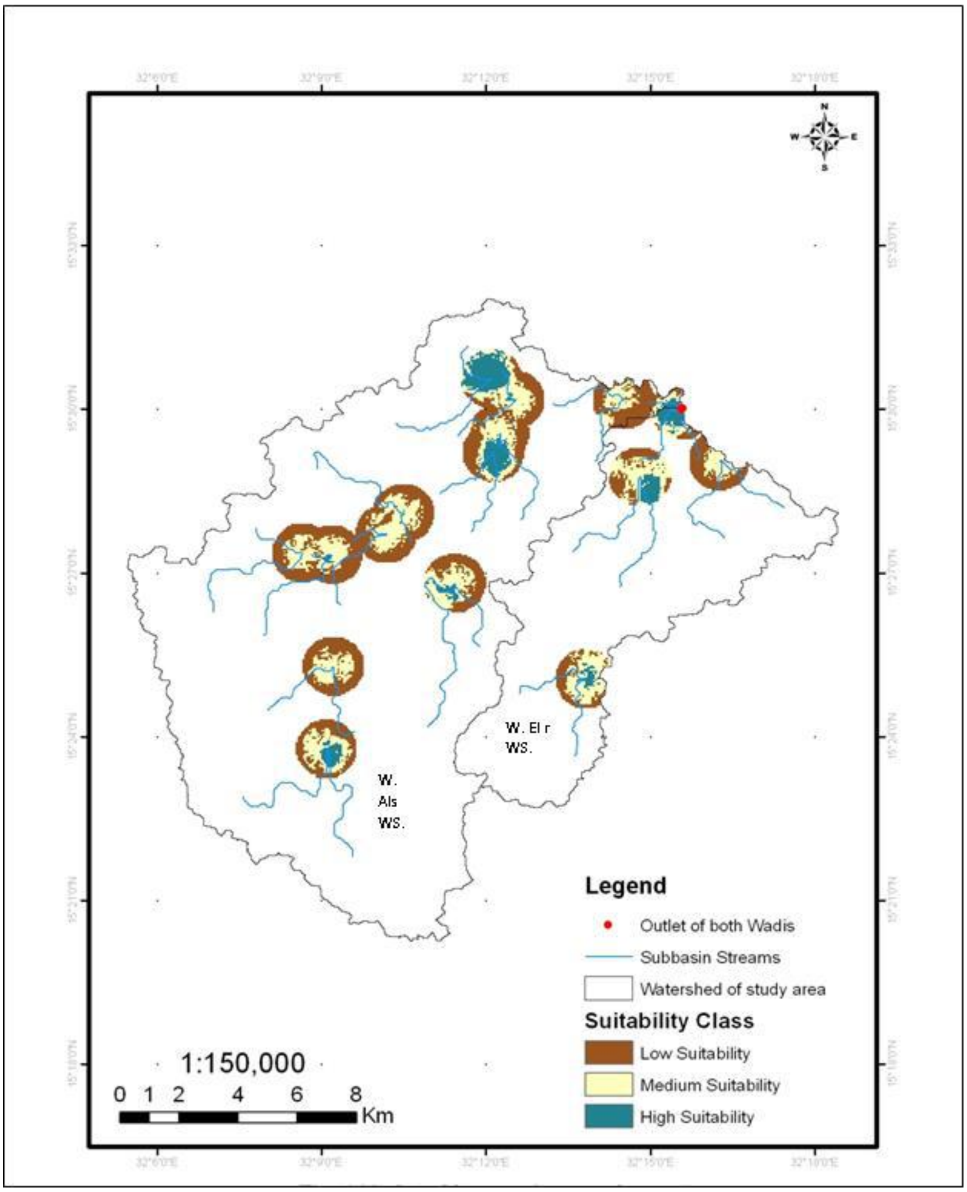

Fig.3: Suitable areas for runoff harvesting at Wadi Elrawakeeb & Wadi Alsayal watershed

W. Als WS= Wadi Alsayal Watershed.

W. El r Ws= Wadi Elrawakeeb Watershed.

IV. CONCLUSION AND RECOMMONDATIONS

In conclusion, the conventional hydrological data are inadequate for the purpose of modeling rainfall-runoff relationship of ungaged Wadi systems. Remote sensing data such as ASTER GDEM 30 m resolution is of great use for the estimation of relevant hydrological data and can serve as model inputs to construct semi-distributed model linking rainfall-runoff. GIS offers the potential to increase the degree of definition of spatial sub-units, in number and in descriptive details. In this study a GIS approach has been utilized for the identification of suitable sites for potential runoff harvesting at Wadi Elrawakeeb and Wadi Alsayal desertified watershed, the adopted GIS approach can be utilized considering additional factors that take the spatial variation in the examined watershed into account to obtain more adequate results. The study recommends using of high resolution ASTER G-DEM, as well as adding more factors to the analysis, especially those related to generated runoff volume, the study also recommends conducting of field investigations into the selected locations of runoff harvesting that had been identified to obtain fairer and accurate results.

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