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Estimation of the Curve Number for the Lesser Zab Watershed Using GIS and HEC-GeoHMS

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Abstract. The soil conservative services–curve number (SCS-CN) method is one of the most fashionable methods among specialists and engineers for computing the direct runoff because of its simplicity, applicability, stability, and the capability to account for most of the hydrologist parameters that can affect the generation of runoff such as soil type, land use/land cover, hydrologic conditions of the soil, and antecedent moisture condition (AMC) in one parameter called curve number CN. Due to the huge development in the remote sensing (RS) and geographical information system (GIS) applications in the last years, this study aims to utilize this development to generate the curve number map for the Lesser Zab watershed in the north of Iraq. By providing Digital Elevation models (DEM) raster with 30 m and 12.5 m as spatial resolutions, soil data grid, and land use/land cover grid with 10 m resolution to be used in the geoprocessing, the goals of this study have been achieved using ArcMap 10.5, Arc Hydro, Geospatial Hydrologic Modeling Extension (HEC-GeoHMS), and HWSD Viewer software. The major soil types that have appeared in the study area are clayey soil and loamy soil which is the largest contributing type, the land use/land cover grid has six classes after reclassification, these are water surface, forest land, agricultural land, natural shrubs/scrub land, residential areas, and bare areas, but generally, the vegetation cover is the dominant land cover with about 90% of the watershed area. The resulted CN map revealed that the CN values ranging from 70 to 100 for the Lesser Zab watershed, the lower CN value refers to the lower potential of runoff while higher CN values refer to the higher potential of runoff. Finally, this study emphasizes that the CN values which have been extracted from both DEM rasters have not any significant difference, therefore the DEM with 30 m resolution is preferred due to the time-consuming geoprocessing of the DEM raster with 12.5 m resolution.

INTRODUCTION

The runoff is one of the most important parameters for any hydrological analysis, therefore any hydrological modelling application usually needs to deal with this parameter directly or indirectly. The runoff quantity and occurrence depend on climatic characteristics such as rainfall intensity, continuity, and dry spells over the years. On the other hand, it depends on many catchments' specific characteristics like the soil type, the topography of the catchment, vegetation cover, degree of imperviousness, and drainage sites [1]. Iraq is located within a semi-arid climatic region where fluctuation of rainfall per season among years is obvious especially for the last few years because of the global warming effects. In addition, the high population rate and an increase in water demand as well as the water resource strategies of neighboring countries, thereby huge stress has been applied to the water resources inside Iraq's boundaries leading to periods of droughts and consequently causing a scarcity and water shortage. Many countries in the world have the same problem, therefore to defeat this problem, the construction of dams for reserving the water is considered a vital serious matter [2], which leads the hydrologists to study this situation carefully to estimate and predict the runoff quantity, especially at ungagged locations [3], However, the north region of Iraq where the study area exists is considered as ungagged watersheds with almost unavailability of data or recorded in old and limited methods [4]. The curve number method SCS-CN which is the main topic of this research can be utilized effectively to estimate the runoff for these ungagged watersheds around the world, it can be described as a numerical index to estimate the potential runoff after a rainstorm event within a drainage area. Natural Resource Conservation Service (NRCS) within the United States Department of Agriculture (USDA) pioneered this empirical method mainly

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for small agricultural watersheds, also detailed it in the National Engineering Handbook, Sect.4, 1956, 1964,1969, 1971, 1985, and 1993. currently, the SCS-CN method becomes one of the most accepted techniques among specialists because of its ability to comprise many important parameters that have effects on runoff generation including soil type, land use/land cover, also the effect of antecedent moisture content as well as the surface hydrologic condition, taking all of them into one parameter called curve number (CN) [3][5]. because of this capability in reduction of direct parameters, the estimation of surface runoff by the SCS-CN method is considered a simple, predictable, and stable conceptual method [5][6]. In the last decade, many studies have demonstrated that by using remote sensing (RS) and geographical information systems (GIS) strong and very useful tools can be obtained to estimate the direct runoff volume, establish models for early warning systems of floods, establish models for simulating the sediments and pollutants transportation by flood waves or in waterways, and for working out in the urbanization growth field, the forest fire field, or in the direct soil erosion in catchments [7][8], all these applications could be achieved with saving concepts in time, effort, and cost-effectively [3]. Some studies made a progress in the evaluation of runoff which is dependent on the SCS-CN method directly inside the GIS environment [9], while others made this progress by exporting results to more specialist software like HEC-HMS or WMS [10][11]. Due to the above, the technique of evaluating the SCS-CN values for the watersheds is an important matter, because the CN is considered the key factor for direct runoff computation in the SCS-CN based hydrological modelling [9].

Several researchers have studied and made their experiments and results depending on the SCS-CN method. In this regard, a study conducted by Hong et al. in the USA to produce a global curve number map used for an early warning and assessment of global flood potential in real-time by incorporating real-time precipitation from (http://trmm.gsfc.nasa.gov)[12]. Martin et al. developed a flood hazard map for the Sironko watershed in Uganda by depending on the SCS-CN loss method, they achieved less than 5% as a percentage of peak error between simulated and observed data in their model [13]. Ahmad et al. made their study on the upper Sheonath sub-basin to compute direct runoff using the SCS-CN method by using RS and GIS directly and concluded that their technique is a powerful tool for the runoff estimation over the catchment [6]. According to Shukur's study of creating the SCS-CN map for the Salt Creek watershed in Northern Oklahoma, the values of the SCS-CN were varying from 58 to 100, where 100 refers to water or impervious land and 58 refers to land with the highest infiltration like forest or agricultural land. Shukur assured that the (SCS-CN) method can produce fast, predictive, oriented, and high accurate results [14]. In the study conducted by Sumarauw et al. on the Jobaru River Basin in Japan from 1948 to 2005 to monitor land-use change, they concluded that changes in the land use/land cover classes led to changes in the CN values and therefore remarkably changes in the peak flow of the river basin [15]. Soulis studied the effect of wildfire on the curve number of the Lykorrema watershed in Greece and concluded that the CN values have increased after forest fires by 25 units causing an increase in the runoff depth and peak flow by a factor of more than 7.7 and 11.8 respectively [16]. Tassew et al. concluded in their rainfall-runoff model on Gilgel Abay Catchment in Ethiopia that the CN is the most sensitive parameter followed by lag time in the hydrological modelling of the catchment [17]. Caletka et al. made their study on five catchments in the Czech Republic to estimate the runoff, but they found that the traditional SCS-CN method is hardly applicable and therefore they needed to modify the values of the initial abstraction and the curve number to obtain good and reasonable direct runoff in all catchments understudy, they concluded that the CN values need to be more flexible and being as a catchment-dependent parameter, also the initial abstraction needs to be lower than 0.2 to get more accurate results [18]. Ling et al. developed a new SCS-CN calibration method using non-parametric inferential statistics on Wangjiaqiao Watershed in China and concluded that by reducing the initial abstraction to 0.043 an excellent accuracy can be obtained in the runoff estimation of the watershed than using conventional SCS-CN model with 96% reduction in model prediction errors [19]. Hamdan et al. have used SCS-CN based HEC-HMS for modelling Al-Adhaim River Catchment parameter. They evaluated their results with an excellent coefficient of determination equal to 90% in calibration and validation, and they concluded that the curve number CN is a very sensitive parameter in the SCS-CN based hydrological modelling [10]. Khzr et al. studied the effect of changes in the land use/land cover classes of Al-Sulaymaniyah watershed within the Kurdistan region of Iraq in 1999, 2009, 2019, and they found that the direct runoff increased from 25.78 million m^3 in 1999 to 107.83 million m^3 in 2019 due to the urbanization of the watershed which led to an increase in the CN values in those periods consequently [4]. Hernández-Guzmán et al. developed an open-source graphical user interface GUI called "Sara4r" based on R software to estimate the direct runoff easily, and they get the same results of runoff that were already obtained using a GIS-based hydrological model for two watersheds in Mexico [20]. It is important to be noticed that there are many modifications suggested to the original SCS-CN method over years to improve the accuracy of the results. Sahu et al. applied four of these modified models to Amba and Kalu watersheds in India, these models utilize the antecedent 5 days of rainfall in the standard SCS-CN equation, and they indicated that the Sahu et al. and SME models were equally well and better than others models including the original SCS-CN method [21]. In the same way, Shi et al. used the SCS-CN concepts to improve the soil moisture accounting (SMA) loss method, they applied this improved method in three watersheds on the Loess Plateau in China, and get very well results in comparison with conventional SCS-CN or SMA methods [22].

Due to the vagueness of the right procedure that should be followed to produce such important hydrologically parameters as the curve number (CN) map, especially for ungagged watersheds, this research aims to define the curve number map for the Lesser Zab catchment in the north of Iraq, which is considered one of the most important watersheds of the Tigris River in Iraq, this map, in turn, will help other researchers in the future to evaluate the direct runoff of the watershed by rainfall-runoff models or may be used in other hydrological studies or applications. This research also aims to assess the use of RS, GIS, and HEC-GeoHMS performance for the curve number (CN) map generation.

METHODOLOGY

Study Area

The Lesser Zab or Lower Zab is one of the main five tributaries of Tigris in the north region of Iraq, other tributaries are the Upper Zab river, Al- Khabour river, Al-Adhaim (Al-Ozem) River, and Sirwan (Diyala) river. The Lesser Zab and the Upper Zab contribute the largest flow discharge to the Tigris River. Administratively, this watershed is located within the boundaries of the following Iraqi governorates, which are Erbil, Sulaymaniyah, and Kirkuk, representing 80% of the gross watershed area, while the remaining 20% of the area and the origin of the river are being inside Iranian boundaries extending from Zagros mountains. The Tigris River runs south from Al-Sharkat city and meets the Lesser Zab river about 30 km north of Al-Fatha city and 220 km north of Baghdad. The Lesser Zab watershed is approximately located from WE longitude 43.39° to 46.26° and from SN latitude 35.16° to 36.79° [23]. The Lesser Zab watershed covers an area of around 19780 km^2 with a river length equal to 302 km and has two main dams inside Iraq, Dokan dam and Al-Dibis dam, both of which are used for flood control, and irrigation purposes. The peak flow of the Lesser Zab river usually occurred in the spring season specifically in April month because of heavy rain and snow melting in this month [24]. The elevations of the watershed range from 100 masl to 3590 masl, the major land use/land cover classes of the watershed are shrubs/scrub lands with sparse small trees, this category covers 60% of the whole watershed area and agricultural lands with around 31% of the watershed area. According to the USDA classification of soil, about 23% of the watershed topsoil is clay soil, while 77 % of the topsoil is loam soil. The area under study is illustrated in Fig.1 below.

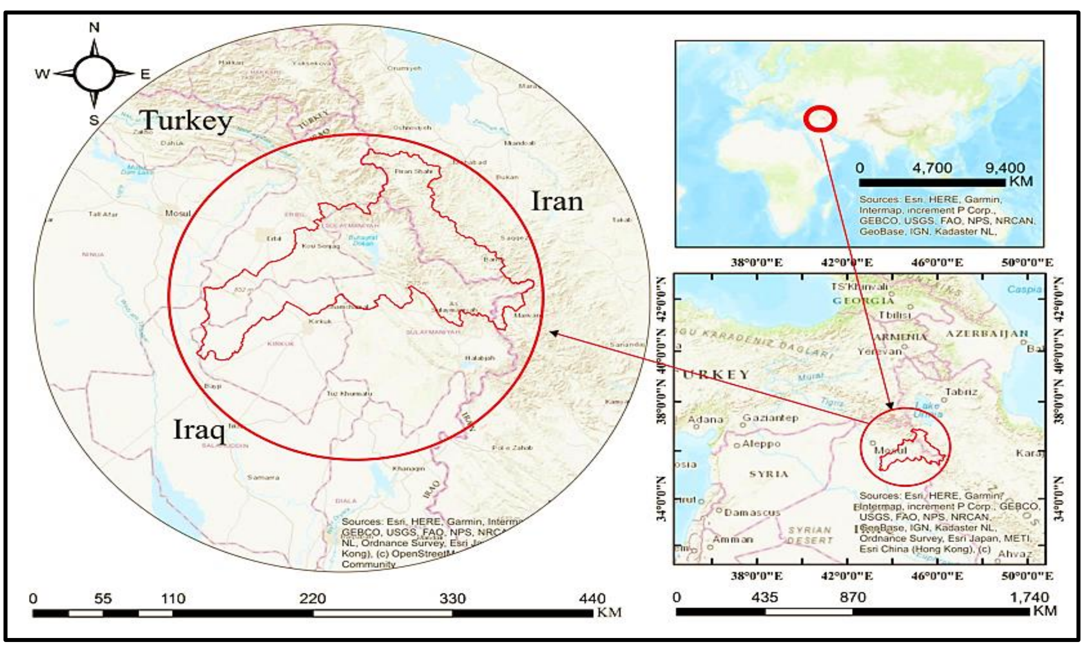


FIGURE 1. Location of The Lesser Zab Watershed on the globe, (Arc GIS by Author).

SCS-CN Method

The SCS-CN method is a result of many experiments on watersheds, the original version of the SCS-CN is firstly developed by the soil conservative services (SCS) in the USA, Mockus 1949 [25]. This method was developed to estimate the total runoff of watersheds based on total storm rainfall excluding the time as a variable in any way. This method depends on water balance and has been derived to satisfy the conservation of mass. For a better understanding of this method, there are two basic assumptions to get the SCS-CN standard equation [5].

The first assumption is that the ratio of actual cumulative infiltration to the maximum potential infiltration is equal to the ratio of direct runoff to the maximum potential runoff, while the second assumption is that the initial abstraction is a fraction of maximum potential retention. By setting the value of the initial abstraction Ia = 0.2S, the well-known standard SCS-CN equation is:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{1}$$

Where:

- Q: daily runoff depth (mm)
- P: daily rainfall depth (mm)
- S: maximum potential retention (mm)

The maximum potential retention of land (S) depends on the same factors that the CN value usually depends on. For convenience usage in the soil applications, the NRCS of the USA has directly expressed these parameters with each other as the following formulae in the unit of (mm).

$$S = \frac{25400}{CN} - 254 \tag{2}$$

$$CN_{II} = \frac{25400}{S+254} \tag{3}$$

Where:

- S: maximum potential retention (mm)
- CN or CN-II refers to the standard curve number alternatively. The CN is a dimensionless parameter.

Generally, the range of CN values is (100 ≥ CN ≥ 0). The CN value of (100) represents 100% of direct runoff occurrence while the CN value of (0) represents 0% of direct runoff occurrence. The curve number CN depends on soil type, land cover, and antecedent moisture content [5], some of these factors are briefed in the sections below.

Soil Type

The soil is classified into four hydrological groups, which are A, B, C, and D. This classification is based on the final infiltration limit, percentage of the main soil ingredients, effective soil layers depth, and permeability. These hydrological groups are briefed below:

- Group A: soil with low runoff potential and high infiltration rate with (8-12) mm/hr, therefore these soils usually be well to excessive drained such as deep loess, deep sand, and aggregated silt.
- Group B: soil with moderately low runoff potential and moderately high rates of water infiltration with (4-8) mm/hr, such as sandy loam, red sandy loam, and shallow loess.
- Group C: soil with moderately high runoff potential and moderately low rates of water infiltration with (1-4) mm/hr, such as shallow sandy loam, clayey loam, and soil low in organic content but high in clay texture.
- Group D: soil with high runoff potential and very low infiltration rate with (0-1) mm/hr, such as heavy plastic clay, certain saline soils, and deep black soils.

Antecedent Moisture Condition (AMC)

Antecedent moisture condition (AMC), refers to the quantity of water that is stored in the soil for five days before the rainstorm event occurred. Depending on the type of season, the curve number CN may be converted to CN-I or CN-III. The classification of AMC by SCS is as follows:

- AMC-I: dry soil but not to a welting point, this group produce low-runoff potential.
- AMC-II: Average wetness condition of the soil, this group produce moderate-runoff potential.
- AMC-III: saturated soil within the past 5 days, this group produce high-runoff potential.

The right (AMC) class can be identified by knowing the total amount of rainfall in the previous 5 days. In this study, the class AMC-II with average wetness has been adopted to get the standard curve number values (CN-II) for the watershed under study. Table 1 below have shown the limits of these AMC groups.

TABLE 1. Antecedent Moisture Conditions (AMC) groups by SCS [26]

AMC Group	Total Rainfall Depth in the Previous 5 Days (mm)	
	Dormant Season	**Growing Season**
I	Less than 12.7	Less than 35.6
II	12.7-28	35.6-53.4
III	More than 28	More than 53.4

Land Use/Land Cover

This parameter describes the nature of the soil surface layer or the type of land utilization. All tables that are dedicated to providing the curve number values need the land use/land cover parameter, also the type of treatment and hydrological condition of the surface soil layer is needed. By knowing land use and land cover condition, these tables provide the curve number values under AMC-II which is called CN-II, therefore if the specification of the AMC group was under the first group I or the third group III, then the curve number extracted from tables should be converted from CN-II to CN-I or CN-III using eq. (4) or eq. (5) respectively, where the CN is a dimensionless parameter [5].

$$CN_I = \frac{CN_{II}}{2.281-(0.01281*CN_{II})} \tag{4}$$

$$CN_{III} = \frac{CN_{II}}{0.427+(0.00573*CN_{II})} \tag{5}$$

Data Preparing

Many spatial dataset layers have been downloaded and prepared for processing; they are briefed below:

1. DEM raster for the study area has been downloaded from U.S Geological Survey USGS with a spatial resolution of 30 x 30 m https://earthexplorer.usgs.gov/, and 12.5 x 12.5 m resolution from NASA Earth Data https://search.asf.alaska.edu/.
2. The land use/Land cover grid for the study area has been downloaded from Environmental Systems Research Institute (ESRI) https://livingatlas.arcgis.com/landcover/ with very special characteristics such as a 10 m spatial resolution map of the earth that was gathered by high-resolution Sentinel-2 satellite for each year from 2017-2021, with more 2000000 of earth observations from 6 spectral bands to produce the final map.
3. The soil data grid and its special viewer have been downloaded from the Harmonized World Soil Database (HWSD) which is published by the Food and Agricultural Organization of the United States (FAO) with a 30 arc-second raster database resolution, https://www.fao.org/soils-portal/data-hub/.

Research Method

As mentioned before, a specific number of input data have been provided such as Digital Elevation Model DEM, Land use/land cover grid, and Soil Data grid for the watershed to obtain the final CN grid by working out and manipulating these data grids inside ArcGIS 10.5, Arch Hydro, HEC-GeoHMS, HWSD viewer from the Food and Agricultural Organization FAO, also the online soil type calculator from USDA-NRCS. The Step-by-step procedure for the CN grid generation has been followed as prepared by Merwade [27][28]. The method steps which are followed in this study are briefed and illustrated in Fig.2 below:

1. Geoprocessing of the DEM raster was been done by Arc Hydro after clipping out the study area to the appropriate coordinate system which is WGS-UTM-Zone 38, the geoprocessing included the DEM reconditioning and the DEM sinks filling to be used later in the generation of CN grid.
2. Reclassification of the land use/land cover grid legend after clipping out the study area boundaries.
3. Clipping out the original soil grid to the required boundaries of the study area.
4. Generating new fields in the attribute table of the soil grid, and filling these fields with information extracted from HWSD Viewer.
5. Merging the land use/land cover grid with the soil data grid to produce a merged attributes grid.
6. Generating the CN-Lookup table that should contain the appropriate corresponding curve numbers CN.
7. Generating the CN grid by using HEC-GeoHMS and making an appropriate symbology of the resulted grid.

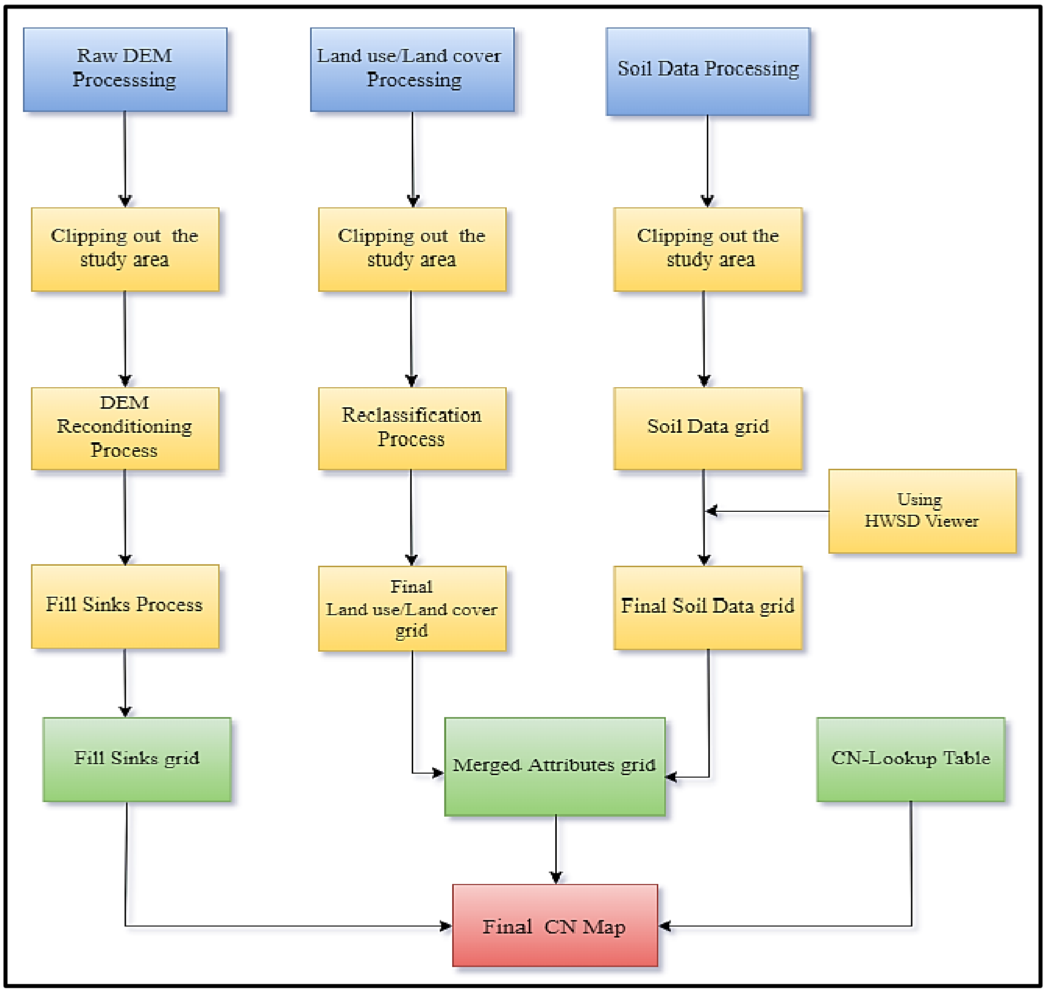


FIGURE 2. Overview flowchart for a generation of the curve number (CN) map.

Data Processing

DEM Processing

DEM layers with a resolution of 30x30 m per cell have been prepared to Arc Map10.5 and mosaicked to a new raster, then the clipping out of the study area from the DEM raster has been done. By using Arc Toolbox or Arc Hydro, the DEM reconditioning and Fill sinks orders have been done, so that a new resulted raster could be used later in HEC-GeoHMS. The DEM raster processing is illustrated in Fig.3 below.

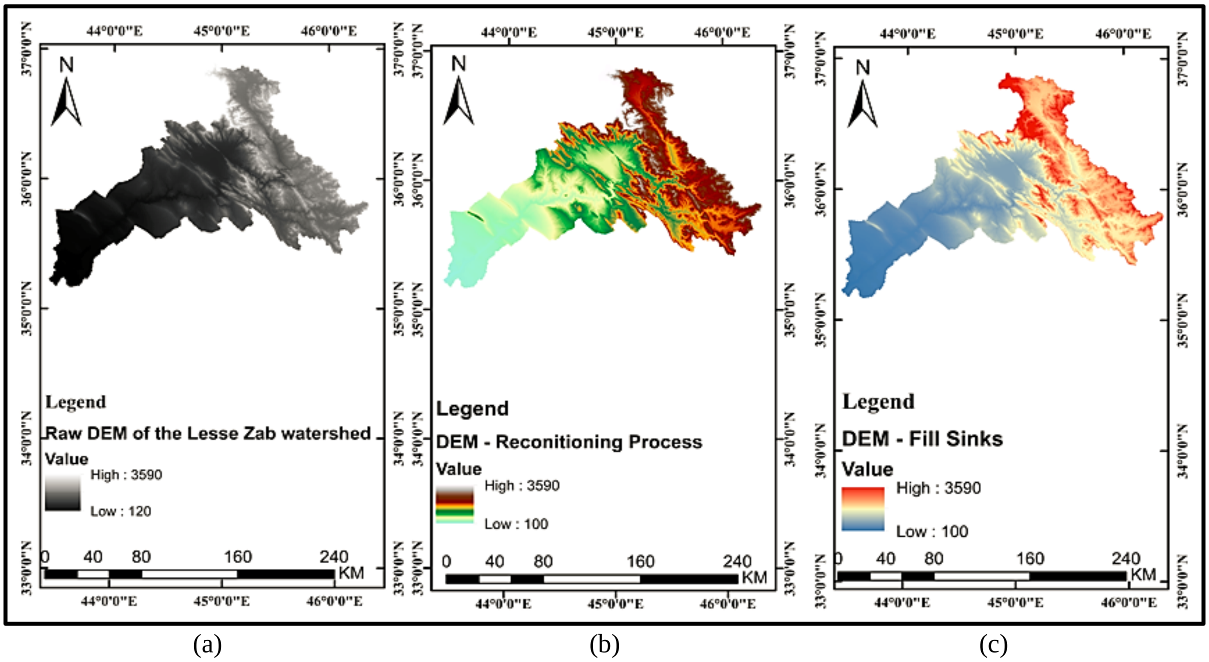


FIGURE 3. DEM raster processing**,** part (a) represents the Raw/original DEM raster, part (b) represents the DEM raster after Raw DEM reconditioning, and part (c) represents the DEM raster after the Fill Sinks order is applied.

Land Use/Land Cover Processing

In this study, the Land use/land cover grid has been downloaded from ESRI for the area that covers the whole of the watershed and the surrounding area, then the clipping out of the watershed area and the reclassification have been done. The reclassification of the grid legend to a common category legend was done using the “Reclassify tool” from spatial analyst tools of Arc Toolbox. The land use/land cover grid processing is illustrated in Fig.4 below.

Soil Data Processing

In this study, the global soil grid has been downloaded from FAO and the appropriate shapefile representing the study area has been used to extract soil data raster. This raster has been converted to the appropriate coordinate system of UTM-zone 38, the resulted raster then has been converted to polygons by an appropriate tool in Arc Toolbox. Many features of the soils can be obtained from HWSD Viewer for depths reaching one meter. Therefore, many specified fields that appear in the viewer and carried important information about the soils can be generated in the attribute table of the soil grid. These fields were containing the values of soil PH, and the percentage of gravel, sand, silt, and clay. In addition, the dominant soil group, soil unit name, soil texture, type of soil, and so others. Also, the online soil calculator provided by NRCS (https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils) can be used to identify the type of soil, this calculator is based on the soil triangle of the silt, sand, and clay percentages. By knowing all the information about the soil from HWSD Viewer and/or the soil calculator, the hydrological soil group can be identified easily [29]. Figure 5 has shown the details of the soil grid processing for the Lesser Zab watershed.

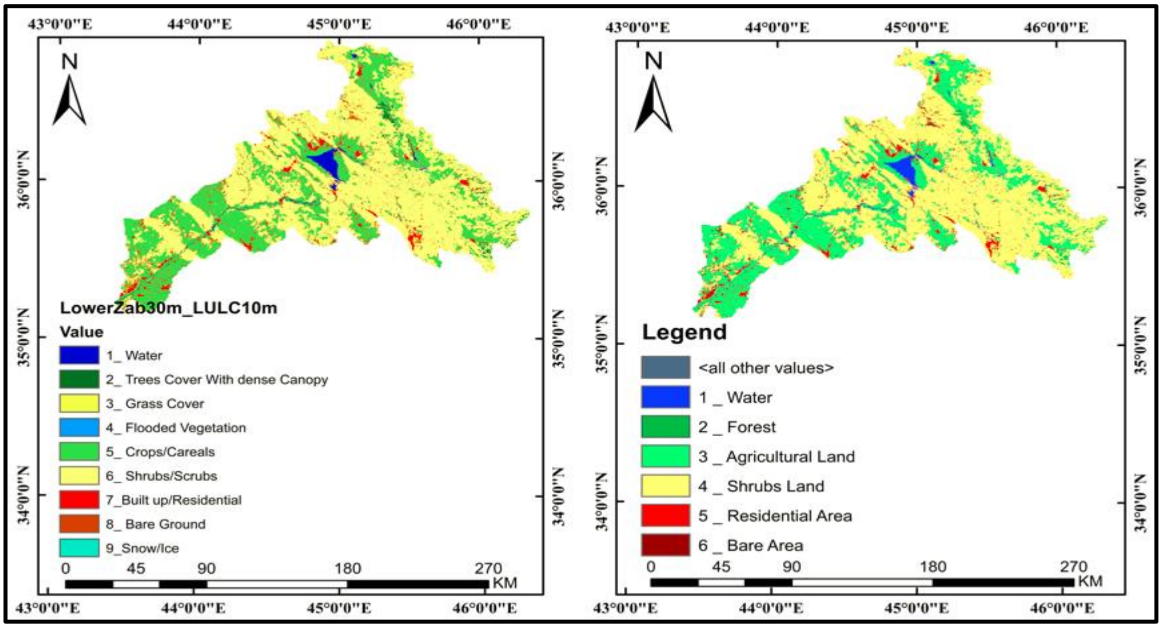


FIGURE 4. Land use/Land cover processing, part (a) represents the original land use/land cover grid from ESRI, while part (b) represents the land use/land cover grid after reclassification.

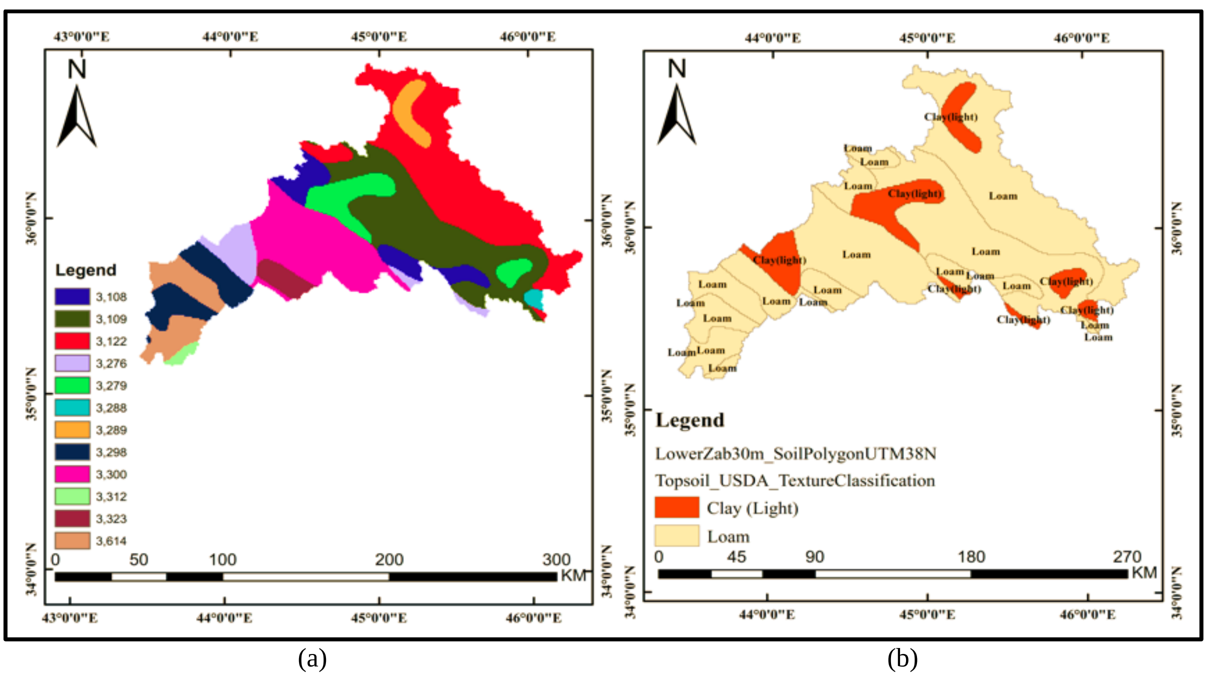


FIGURE 5. Soil data processing, part (a) represents the clipped raster of the area under study from the original FAO soil map with the soil code that appeared in the legend of the map. Part (b) represents the topsoil types layer of the Lesser Zab watershed.

Merging Process and Creating the CN-Look up Table

By using the "Union" tool from the "overlay" menu of analysis tools in Arc Toolbox, the preceded grids after conversion of each one to a polygons grid have been combined into one new grid containing all attributes of the soil data grid and land use/land cover grid. The resulted grid after the merging process is illustrated in Fig.6 below.

By using the Arc catalog, a new table contain categories of land use/land cover that have been generated after the reclassification of the legend and the corresponding curve numbers (CN-II). The values of the curve numbers for the CN-Lookup table can be obtained from Technical Release-55 of USDA [30], or SCS-CN Methodology [31].

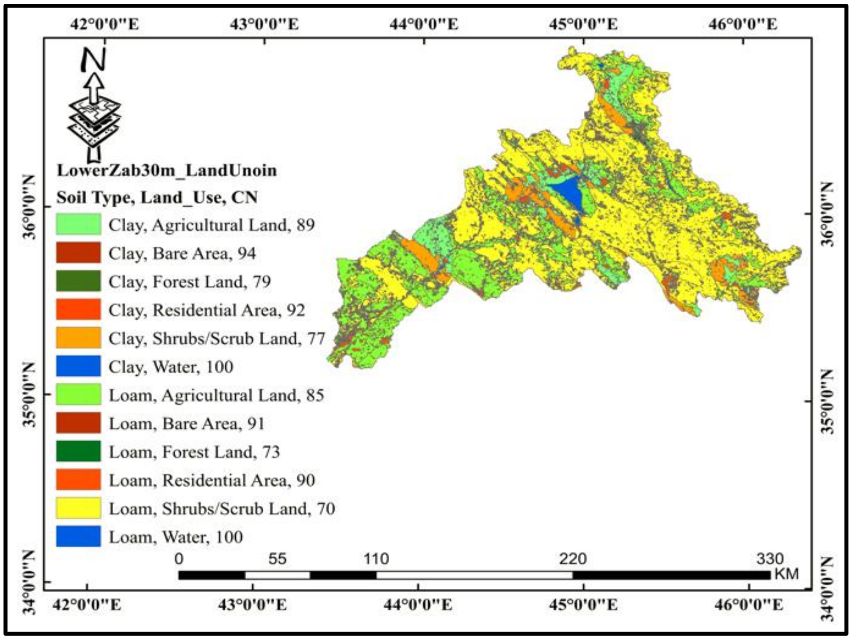
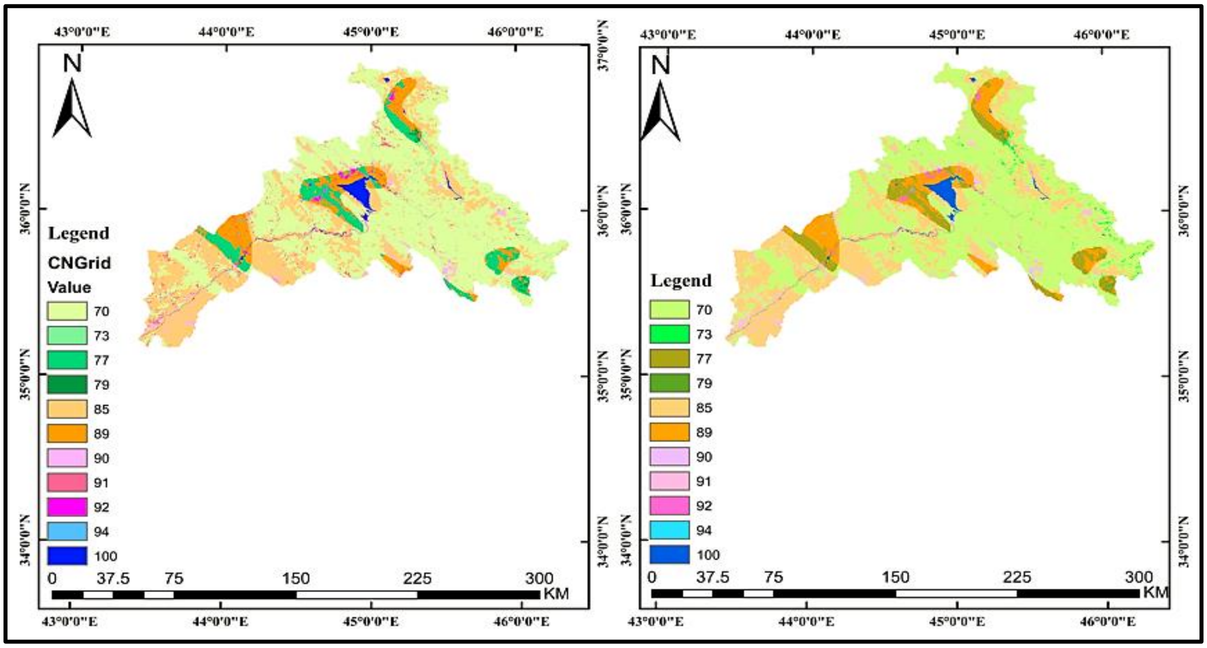


FIGURE 6. Represents the merged attributes grid of the watershed soil, the legend shows the soil type, land use/land cover classes, and the corresponding curve number (CN).

Generating the CN-II Map

HEC-GeoHMS software has been used to calculate the final CN grid by using the "Generate CN Grid" order from the "utility" menu. The final CN map has been obtained by utilizing the Fill sinks grid, merged attributes grid, and the CN-Lookup table as inputs data. All the preceded steps to generate the CN map have been done for the DEM raster with 30 m and 12.5 m spatial resolutions. The resulted maps are illustrated in Fig.7 below.



(a) (b)

FIGURE 7. The resulted CN maps, part (a) the CN map with 30 m resolution, and part (b) the CN map with 12.5 m resolution.

RESULTS AND DISCUSSION

This study reveals that the curve number (CN) values of the Lesser Zab watershed are varying from 70 to 100, this range has moderately high to very high values of the curve number. The lower values of the CN in this range refer to shrubs/scrub lands where there is a moderately low dense vegetation cover, while, the higher values of the CN in this range refer to the areas with shallow vegetation cover until reaching the bare area, residential area, and submerged lands with water.

To interpret these high values of the curve number range, two factors that play an important role in the values of the curve number CN should be introduced, these factors are the land use/land cover classes in the watershed and the soil types. There are six classes of land use/land cover in this watershed, they are forest land, agricultural land, shrubs/scrub land, residential area, bare area, and the water class. The major class of the land use/land cover in the watershed are the shrubs/scrub lands with sparse small trees, this class covers 60% of the watershed area, while the second major class is the agricultural land which covers 31% of the watershed area, the last 9% of the watershed area is contributing to the remaining land use/land cover classes.

The other important factor is the soil type. The clayey soil texture with about 23 % of the watershed area and the loamy soil texture with about 77 % of the watershed area represent the dominant types of the topsoil layer for about 30 cm depth from the ground surface, while the dominant soil types in the next 70 cm depth below the first layer are the clay texture and clayey loam texture as largest part also. The associated minor soils in the first and second layers are varying from clayey loam to clayey soil in texture, therefore the clayey loam texture is contributing to the largest part of the loamy soil group in the watershed, thus the corresponding hydrological soil groups according to the USDA classification are group "C" and group "D". The soil type with the hydrological group of "C" has an infiltration with (1-4) mm/ hr, while for the hydrological group of "D" the final infiltration limit is (0-1) mm/ hr. These low to very low limits of infiltration can explain the reason for the moderately high to very high potential runoff in the watershed. Together with the previous reason, it should be noticed that about 60% of the watershed area is covered with shrubs, scrub bushes, and savannas with very sparse grasses, which means low absorption of water from the soil for plant growth needs, which means an increase in the limits of the potential runoff of the watershed.

Due to the above, the generated curve number map has shown two main values, the first major value of the curve number is equal to 70, which is resulted from the shrubs/scrub lands class that is located on loamy soil texture with about 54% of the whole watershed area. The second major value of the curve number is equal to 85, which is resulted from the agricultural land class located on the loamy soil texture with about 25 % of the whole watershed area, Fig.6 and Fig.7 can give some help to understand that.

Due to the direct relationship between the land use/land cover and the CN values, this study can be extended in the future to cover the effects of changing land use/land cover on the values of the curve number for the Lesser Zab watershed, for example after forest fires or after urbanizing large areas in the watershed.

It is very obvious in this study that using RS data, GIS, and HEC-GeoHMS create a very strong, simple, oriented, and predictable system for the curve number grid evaluation, otherwise, it seems so difficult to achieve progress without following this systematic procedure due to the lack of the needed data experimentally.

CONCLUSION

The technique of using the RS data, Arc GIS, and HEC-GeoHMS for the generation of the curve number (CN) map for any watershed is a very effective technique, it is so simple, and too accurate in the obtained results, this technique can be applied with time, effort, and cost-saving concepts.

The Lesser Zab watershed has moderately high to high curve numbers (CN) ranging from 70 to 100 because of the effects of the dominant soil type and land use/land cover classes in the watershed. The dominant topsoil types are loamy soil and clayey soil, with 77 % as loam soil and 23% as clay soil respectively. The major land use/land cover class that occupies around 60% of the watershed area is the Shrubs/scrub land with small trees and sparse grasses, while the second major class is agricultural land with only 31% of the watershed area.

This study reveals that the curve number grids for both spatial resolutions of 30 m per cell from USGS and 12.5 m per cell from NASA have the same values and distribution, for both of them about 54% of the watershed area has a curve number value equal to 70, while 25% of the watershed area has curve number equal to 85, thereby the researchers in the future could get enough with 30 m per cell as the spatial resolution of the DEM raster to evaluate the CN map.

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