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Abstract

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Keywords

GIS, Soil map, Land use/land cover, curve number, Rawnduz river basin.

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RESEARCH ARTICLE

Preparation of Curve Number Grid Map of Rawanduz River Basin in KRI Using GIS Techniques

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ABSTRACT

The study is being conducted with the goal of applying various models and techniques for catchment delineation and providing the opportunity to determine the Curve Numbers (CN) for the Rawanduz river basin (2956 Km^2), which is located in the northeastern section of Iraq, Kurdistan region, by utilizing Geographic Information System (GIS). Satellite data (Landsat 8 OLI) for 2020 was utilized to build land cover classes, with a classification accuracy of 90% and a Kappa index of 86.18%. The hydrologic soil map for the region is digitized from the Iraqi soil map. In specifically, Soil Conservation Service-Curve Number (SCS-CN) is technique that will be utilized to predict direct surface runoff. This technique incorporates a range of significant watershed features, such as Hydrological Soil Groups (HSG) and land use/land cover (LU/LC), to be utilized as input variables for numerous hydrologic processes. In terms of land use and hydrologic soil group combination, the lowest CN value was found to be 58 in forest areas, which corresponds to an increased ability of the soil to retain rainfall and will produce much less runoff, and the highest CN value was found to be 92 in medium-residential areas, which causes most of the rainfall to appear as runoff, with minimal losses.

Key Words: **GIS, Soil map, Land use/land cover, curve number, Rawnduz river basin.**

1-INTRODUCTION

The Curve Number is utilized in hydrology to calculate how much more rainfall is swelling through land or underground and also how much water generates surface water runoff. A CN is an index created by the Soil Conservation Service (SCS) and now known as the Natural Resource Conservation Service (NRCS), is utilized to measure the amount of rainfall which infiltrates the soil as well as the amount of surface runoff (Hawkins et al., 2008). Since of the easy, flexibility, and accessibility for ungauged basins, this strategy has been very well known inside the US (United States) and such other nations (Sartori et al., 2011). It was, to begin with, created for agricultural basins, and after that it was thus utilized in the region of urban areas. This approach should only be utilized with twenty - four - hour rainfall periods (Durrans et al., 2003, USDA, 1986). As it was not affected by time, it ignores variances produced by variable rainfall lengths and concentrations (USDA, 1986). Modeling is frequently utilized to decide CN. ESRI (Environmental Systems Research Institute) created ArcMap GIS for evaluating, constructing, modifying, retrieving, and displaying different data inputs (Wang and Cui, 2004). The CN approach has been incorporated into a few hydrological processes, like Storm Water Management Model (SWMM) (James et al., 2010), SWAT (Soil and Water Assessment Tool) (Arnold et al., 1996), WMS (Watershed Modeling System), Hydrological Modeling System (HEC-HMS) utilizes this approach to calculate surface runoff (Shadeed and Almasri, 2010). The CN is critical in either hydrologic models, like the rainfall-runoff modeling, for determining maximum discharges and runoff volume.

Manually calculating CN for large areas or multiple drainage watersheds can be tedious and time-consuming. Thus, GIS (Geographical Information System) is an excellent tool for such a project. HEC-GeoHMS is a geospatial hydrological modeling tool created with HEC of rapid creation for hydrologic processes instead of traditional approaches (Manual, 2003). The use of remote sensing (RS) and GIS is dependable way for preparing majority of the incoming data needed by the SCS-CN equation. It was created for the ArcMap system and uses the Spatial Analysis extension. The CN of a river basin is determined by utilizing a combination of land use, type of soil, and DEM (Digital Elevation Model) datasets. Hydrologic soils are divided into 4 types: A, B, C, and D (USDA, 1986). Group of A has a large capacity of infiltration, whereas Group of D has a lower capacity of infiltration.

Several researches appear to agree that utilizing GIS to calculate CN is reliable and effective utilize of time such as .(Topno et al., 2015, Gajbhiye and Mishra, 2012) using the SCS-CN equation integrated with GIS for runoff prediction. This is a popular hydrological model for calculating runoff based on rainfall and CN. Remote sensing and GIS, combined with the SCS-CN model, are shown to be an effective tool for runoff prediction.(Zhan and Huang, 2004) utilized the tool of ArcCN Runoff, an application of the ESRI ArcGIS program, to compute runoff and generate CNs during a rainfall events inside a basin. The major purpose of this research is to create the CN grid map to find the runoff of the watershed. This study contains obtaining the spatial dataset, land use/land cover, type of soil, and CN grid using Hec-GeoHMS extension in the ArcMap

2-METHODS AND MATERIALS

2-1 Study Area

The watershed is situated in the northeastern section of Iraq, in the Kurdistan region, near Erbil, located between latitude (36°23´ and 36°80´ North) and longitude (44°16´ and 45°10´ East) and has an area of 2956 km^2. The Rawanduz river watershed goes through the villages of Rayat and Choman. Based on the tectonic map (Buday and Jassim, 1984), It is located inside the High Folded Zone, Imbricated Zone, Unstable Shelf, and Zagros Suture Zone. Figure 1 illustrates a map of study area

2-2 Processing of Data

ArcGIS ver. 10.8, Arc Hydro Tools and Hec-GeoHMS were utilized to pre-process the obtained data for the watershed.

1- Digital Elevation Model (DEM)

DEM utilized in this investigation was taken from Website of the US Geological Survey (USGS). The DEM is used to derive the slope, basins, gradient and drainage pattern. To begin geometric rectification, the DEM (30m) spatial resolution was projected to the Universal Transverse Mercator (UTM) data processing systems of Datum WGS 1984 (Zone-38). Rawanduz river basin DEM is illustrated in Figure 2.

2- Land Use

The Landsat image (Landsat 8 OLI) used in this investigation was obtained from the United States Geological Survey (USGS) Earth Explorer site (https://earthexplorer.usgs.gov/). LULC have a significant impact on infiltration and the amount of runoff. For the classification of images to be effective, several variables should be considered, counting the accessibility of high-quality images of Landsat, an accurate classification technique, and the users' competence and experience with processes. (Rwanga and Ndambuki, 2017). The analysis and classification method of different LULC classes were carried out using of two Landsat image 8 OLI (Operational Land Imager) images of satellite were obtained in 2020. The Supervised Classification Technique was done utilizing the Maximum Likelihood Algorithm in ArcGIS. Supervised classification concurring to (Eastman, 2003) occurs when "the user creates the spectral signatures of common classes, like urban and forest, and then the program assigns each pixel in the picture to the land cover to which its signature is most similar." Supervised classification was used after defining an area of study, which is referred to as training classes. To represent a certain class, more than one training area was employed. The training locations were chosen in accordance with the Landsat Image, Google Earth, and Google Maps. The main supervised classification operation sequence was as follows: defining training sites, extracting signatures, and classifying the Landsat image. The Maximum Likelihood Algorithm in ArcGIS is the most commonly used for image classification.

3-The Accuracy Assessment Estimator and the Kappa coefficient for Image classification

The Kappa index and accuracy assessment is the most critical and is the final step in the image classification process (Foody, 2002). The terms "accuracy evaluation" and "Kappa index" refer to the comparison of the classified image to another data source that is thought to be accurate or ground truth data. Accuracy makes the value of information of the resulted data to the user. This procedure employs three geospatial tools in ArcMap:

Construct Accuracy Assessment Points, Modify Accuracy Assessment Points, and Calculate Confusion Matrix (Arumugam et al., 2021).

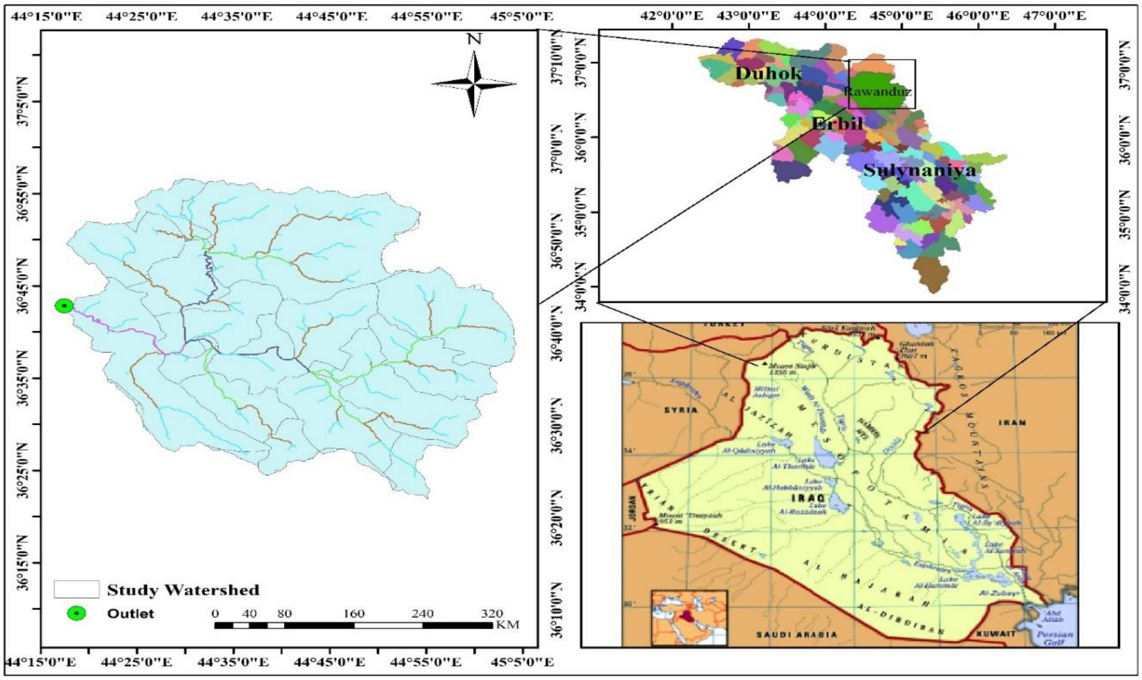

Figure 1: Location map of Rawanduz river ungauged basin map

4- Soil map preparation

The map of soil of the Kurdistan area of Iraq was received from the Agriculture Department and Water Resources of the Kurdistan Region Administration, Iraq. The Iraq soil map was downloaded from The Global Hydrologic Soil Groups (HYSOGs250m) for the Curve Number-Based Runoff soil map. Internet sites in 2018 and updates in 2020 (Ross et al., 2018). The soil map was geo-referenced using ArcGIS, and then the soil data for the watershed was extracted by using ArcGIS tools. Figure 3. illustrates the soil map of the Rawanduz river basin, which includes four distinct types of soil: clay loam, loam, sandy clay, and sandy clay loam. Therefore, the hydrologic soil group (HSG) is the information needed to compute a CN. There are four groups (A, B, C, and D) and three dual groups (A/D, B/D, and C/D). Table 1 defines each of these terms.

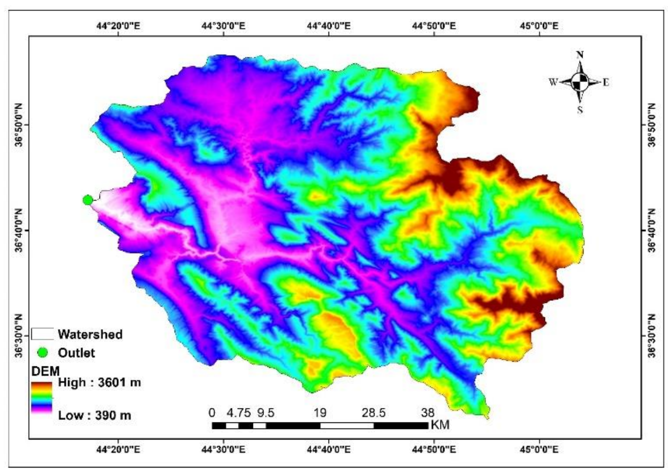

Figure 2: Digital elevation model map of Rawanduz river basin (https://earthexplorer.usgs.gov/).

Table 1: Illustrates the HSG and the associated soil texture (Maidment, 2011)

HSG	*Soil Type Texture*	*Runoff Potential*	*Rates of Infiltration*
A	Sand, loamy sand and sandy loam	Low	High
B	Silty loam and loam	Moderate	Medium

C	Sandy clay loam	High/moderate	Low
D	Silty clay loam, sandy clay, silty clay, and clay	High	Very Low

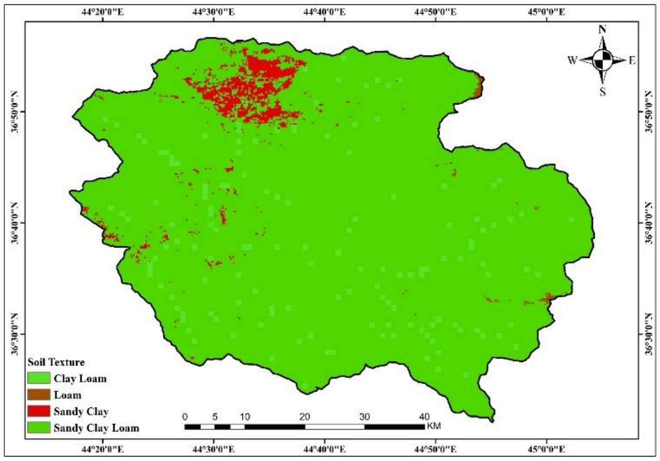

Figure 3: Soil Map of the Rawanduz Basin with soil texture (HYSOGs250m)

5-Curve Number (CN) Grid map

The data for land use map, map of soil, and map of DEM were used in GIS ArcMap. The CN grid map was created utilizing ArcGIS's HEC-GeoHMS extension tool. The maps of soil and land use of the study region were integrated utilizing Union tool inside the Arc Toolbox, and a CN Look-Up tables was created utilizing create table inside Arc Toolbox with each soil land map was provided. A CN grid map was produced by HEC-GeoHMS after merging the LULC and HSG maps utilizing ArcMap. HEC-GeoHMS utilizes the combined feature class (union) and the lookup table (CN_LookUp) as an input to create a CN grid map. The conceptual structure for CN grid mapping is depicted in Figure 4.

3-RESULT AND DISCUSION

The map of LU/LC and HSG map have been generated for development of CN grid map, and the findings are given below.

3-1 Hydrological Soil Group (HSG) Map

In ArcGIS, the hydrologic soil group was computed and used as an input data for the CN grid map. The soil code has been allocated to each soil group in the basin. The HSG of B, C, C/D, and D groups are shaped in ArcMap software as illustrates in Figure 5.

PctA, PctB, PctC, and PctD are the names of four new fields. For Rawanduz river basins, only one soil group is assigned to each polygon, so a polygon with soil group "A" will have PctA = 100, PctB = 0, PctC = 0, and PctD = 0. Likewise, for a polygon with soil group D, only PctD = 100, while the other three Pcts are zero. For a polygon with soil group C/D, it will have PctC = 50 and PctD = 50, and the other two Pcts are zero. The attribute table shown below was produced. The Soil Code will be populated with the letters A, B, C, and D, as illustrated in Figure 6.

3-2 Classes of Land Use/Land Cover

The supervised classification and maximum likelihood methods are used to classify the images in ArcGIS. The region from each class was computed by dividing the count of pixel and whole region into consideration

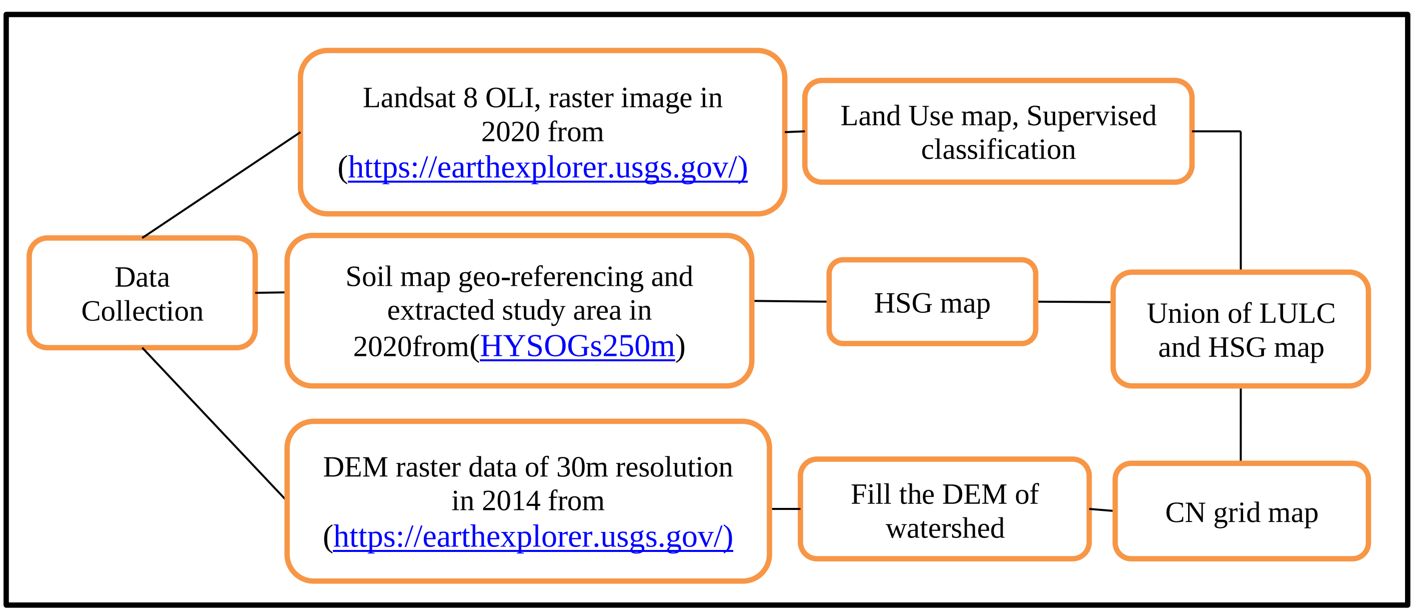

Figure 4: Curve Number (CN) Mapping Conceptual Framework.

(watershed). As a result, the percentage distributions of each classed region is recorded within Table 2. Rate of ranges as classified are: Forest (88.4%), Agriculture (8%), Medium residential (3.5%), and Water body (0.1%). The total classification accuracy was 90%, while the Kappa coefficient was 86.18%. Figure 7. depicts the several kinds of LU/LC in watershed.

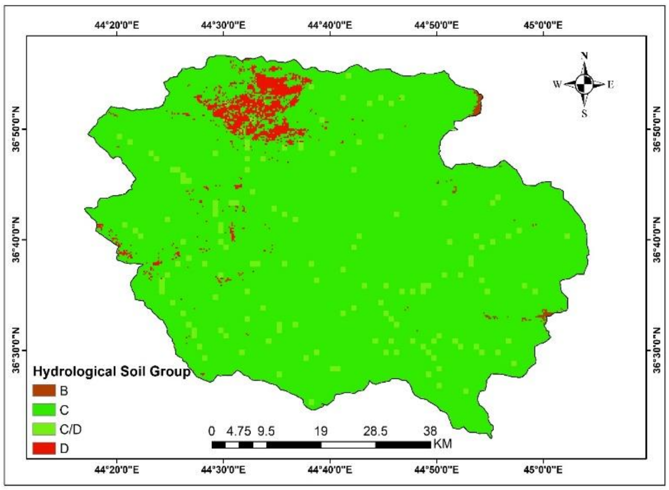

Figure 5: The map of HSG of Rawanduz river basin (HYSOGs250m)

Table 2: The area of LULC in the Rawanduz river basin

Number	*Land Use Type*	*Area in Percent*
1	Water Body	0.1
2	Forest	88.4
3	Agriculture	8
4	Medium Residential	3.5

3-3 Curve Number (CN) Grid Map

Figure 8 shows a union attribute table for soil and LU/LC. Figure 9 shows a lookup CN attribute table. The right CN were allocated to all combinations using usual SCS-CN database. The CN parameter is unit less and ranges 0 (highest range of infiltration) to 100 (zero rate of infiltration). The determined CN with each polygon would be for average conditions. The CN map was created by intersecting the Land Use and soil

Table

S_G_P

OBJECTID *	Shape *	Id	gridcode	Shape_Length	Shape_Area	SOIL_GROUP	PctA	PctB	PctC	PctD
160	Polygon	160	1	0.011319	0.000006	B	0	100	0	0
161	Polygon	161	1	0.108431	0.000283	B	0	100	0	0
274	Polygon	274	1	0.007812	0.000003	B	0	100	0	0
275	Polygon	275	1	0.01182	0.000006	B	0	100	0	0
276	Polygon	276	1	0.00786	0.000003	B	0	100	0	0
282	Polygon	282	1	0.01182	0.000006	B	0	100	0	0
283	Polygon	283	1	0.00786	0.000003	B	0	100	0	0
285	Polygon	285	1	0.014735	0.00001	B	0	100	0	0
293	Polygon	293	1	0.031127	0.000036	B	0	100	0	0
451	Polygon	451	1	0.00786	0.000003	B	0	100	0	0
455	Polygon	455	1	0.008333	0.000004	B	0	100	0	0
457	Polygon	457	1	0.007812	0.000003	B	0	100	0	0
458	Polygon	458	1	0.00786	0.000003	B	0	100	0	0
462	Polygon	462	1	0.00786	0.000003	B	0	100	0	0
463	Polygon	463	1	0.027109	0.000033	B	0	100	0	0
464	Polygon	464	1	0.017035	0.000016	B	0	100	0	0
465	Polygon	465	1	0.00786	0.000003	B	0	100	0	0
467	Polygon	467	1	0.01182	0.000006	B	0	100	0	0
468	Polygon	468	1	0.093495	0.000184	B	0	100	0	0
471	Polygon	471	1	0.027345	0.000026	B	0	100	0	0
472	Polygon	472	1	0.00786	0.000003	B	0	100	0	0
473	Polygon	473	1	0.008333	0.000004	B	0	100	0	0
474	Polygon	474	1	0.007812	0.000003	B	0	100	0	0
480	Polygon	480	1	0.007812	0.000003	B	0	100	0	0
21	Polygon	21	2	0.00786	0.000003	C	0	0	100	0
24	Polygon	24	2	0.007812	0.000003	C	0	0	100	0
29	Polygon	29	2	0.007812	0.000003	C	0	0	100	0

1 (0 out of 522 Selected)

S_G_P

Polyte

Figure 6: Attribute table of soil, soil_group filled populated with letters A, B, C, and D

hydrological group maps. The values of CN in the Rawnduz Basin range between 100 and 58. The weighted CN from the basin is equal to 74. The CN grid map is illustrated in Figure 10.

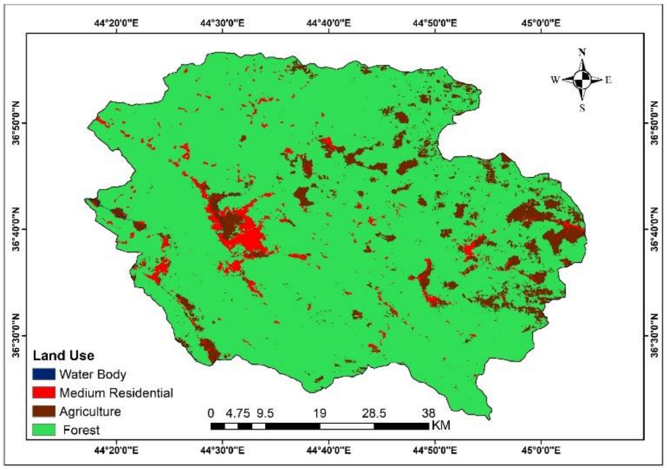

Figure 7: LULC of Rawanduz River Basin

Table

union

FID	Shape *	FID_soil_gro	Id	gridcode	Shape_Leng	Shape_Area	SOIL_GROUP	PctA	PctB	PctC	PctD	FID_lu_po	Id_1	gridcode_1
0	Polygon	1	1	3	0.020063	0.000013	D	0	0	0	100	0	1	4
1	Polygon	1	1	3	0.020063	0.000013	D	0	0	0	100	8567	8568	3
2	Polygon	2	2	3	0.00786	0.000003	D	0	0	0	100	8567	8568	3
3	Polygon	3	3	3	0.011789	0.000006	D	0	0	0	100	8567	8568	3
4	Polygon	4	4	3	0.01199	0.000005	D	0	0	0	100	8567	8568	3
5	Polygon	5	5	3	0.00786	0.000003	D	0	0	0	100	8567	8568	3
6	Polygon	6	6	3	0.00786	0.000003	D	0	0	0	100	8567	8568	3
7	Polygon	7	7	3	0.00786	0.000003	D	0	0	0	100	8567	8568	3
8	Polygon	8	8	3	0.01182	0.000006	D	0	0	0	100	8567	8568	3
9	Polygon	9	9	3	0.00786	0.000003	D	0	0	0	100	8567	8568	3
10	Polygon	10	10	3	0.011789	0.000006	D	0	0	0	100	82	83	2
11	Polygon	10	10	3	0.011789	0.000006	D	0	0	0	100	8567	8568	3
12	Polygon	11	11	3	0.00786	0.000003	D	0	0	0	100	85	86	4
13	Polygon	11	11	3	0.00786	0.000003	D	0	0	0	100	8567	8568	3
14	Polygon	12	12	3	0.019188	0.000017	D	0	0	0	100	8567	8568	3
15	Polygon	13	13	3	0.011789	0.000006	D	0	0	0	100	8567	8568	3
16	Polygon	14	14	3	0.014816	0.00001	D	0	0	0	100	8567	8568	3
17	Polygon	15	15	3	0.053194	0.000106	D	0	0	0	100	8567	8568	3
18	Polygon	16	16	3	0.007812	0.000003	D	0	0	0	100	8567	8568	3
19	Polygon	17	17	3	0.00786	0.000003	D	0	0	0	100	102	103	2
20	Polygon	17	17	3	0.00786	0.000003	D	0	0	0	100	103	104	4
21	Polygon	18	18	3	0.00786	0.000003	D	0	0	0	100	8567	8568	3
22	Polygon	19	19	3	0.038815	0.000075	D	0	0	0	100	34	35	4
23	Polygon	19	19	3	0.038815	0.000075	D	0	0	0	100	8567	8568	3
24	Polygon	20	20	3	0.01182	0.000006	D	0	0	0	100	183	184	4
25	Polygon	20	20	3	0.01182	0.000006	D	0	0	0	100	8567	8568	3
26	Polygon	21	21	2	0.00786	0.000003	C	0	0	100	0	183	184	4

0 (0 out of 9484 Selected)

union

Figure 8: Attribute tables of the soil and land use/land cover union map

Table

CNLOOKUP

OBJECTID *	LIValue	Description	A	B	C	D
1	1	Water Body	100	100	100	100
2	2	Medium Residential	77	85	90	92
3	3	Forest	32	58	72	79
4	4	Agriculture	72	81	88	91

0 (0 out of 4 Selected)

CNLOOKUP

Figure 9: CN-LOOKUP attribute table

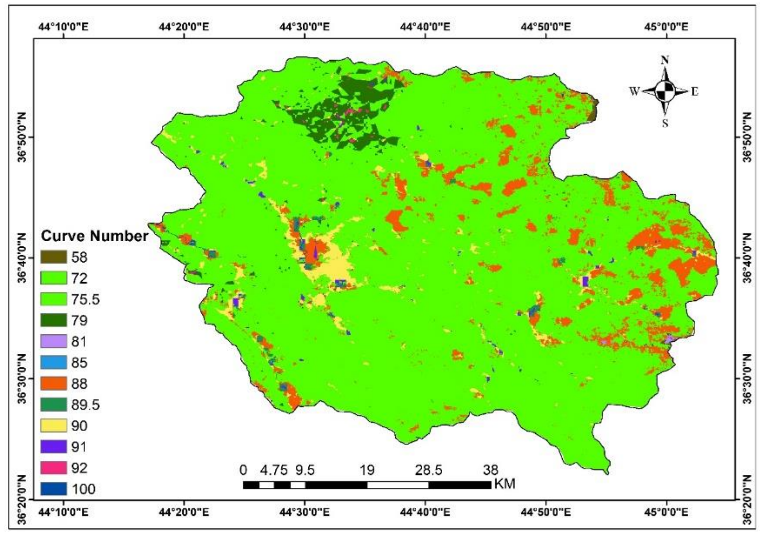

Figure 10: Curve Number grid map of Rawanduz River Basin

CONCULSION

The following findings are described in the current study:

1- The ArcGIS ver. 10.8 software and the Hec-GeoHMS extension are appropriate techniques for computing CN. ArcMap is used to create a watershed delineation, image classification, merge the LULC and HSG maps, and a CN lookup table. The CN grid map was produced by the Hec-geoHMS extension tool using the combined feature class (union) and the lookup table (CNLookup). The CN is accurately and simply obtained using the capability of the CN technique to integrate layers of soil and layers of land use, which simplifies computations and produces an accurate CN. The calculated CN without the use of ArcGIS could be time-consuming.

2- In this research, four HSG were recognized: soil types B, C, C/D, and D. Four different types of LU/LC have been recognized: these include water, medium-residential, forest and agriculture. This data is extremely valuable to modeling of rainfall-runoff in order to predict runoff parameters and maximum discharge utilizing the SCS-CN approach.

3- According to the findings, a CN of 100 denotes the water surface. The maximum CN of 92 indicates high runoff and low rates of infiltration in medium residential, whereas the minimum CN of 58 indicates low runoff and high rates of infiltration in forested area. The CN of 75.5

refers to forest areas for the HSG as C/D, and the CN of 89.5 indicates the agriculture areas.

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