

Chapter 9

Effects of Land Cover Change on Surface Runoff Using GIS and Remote Sensing: A Case Study Duhok Sub-basin



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Abstract A catchment area is an area from which runoff is resulting from precipitation flows. Land cover changes are the most significant factors that directly impact the runoff process. Much research on runoff response has focused on projected climate variation, while the endemic catchment area is directly affected by urban growth. Due to urbanization, the continuous growth in urban areas has led to a significant transformation of land cover pattern in built-up areas which has significantly affected the surface runoff behavior in the urban realm. This chapter aims to examine the impact of projected land cover changes on runoff in the Duhok sub-basin during the study period of 1990–2016. The study describes long-term hydrological responses within the quickly developing watershed of Duhok. Rainfall data from five meteorological rainfall stations in and around the study area were used. Historical data of land cover changes were mapped from 1990 to 2016, using a temporal satellite image (Landsat) to identify land cover and land use changes. Land use and land cover were integrated with a hydrological model SCS-CN to compute the runoff volume from the catchment area. Geographic Information Systems (GIS) was used to prepare different layers belonging to rainfall spatial distribution using Inverse Distance Weighting (IDW) tools, and various land covers were determined from remotely sensed data. Yearly average storm event rainfall data was used as a hydrological input to the SCS-CN model to estimate surface runoff over the years due to changes in the land cover of the Duhok watershed. The chapter indicates that the urban growth of the watershed increased from 10% in 1990 to 70% in 2016. Surface runoff volume increased from 12% in 1990 to 36% in 2016, while the vegetation land decreased from 47 to 14% in the same period. The chapter points out that an increment in built-up area or barren land cover and a decrease in vegetation cover have occurred, leading to larger surface runoff volumes in urban catchment areas.

Keywords Land cover change · Runoff · SCS-CN · GIS · Remote sensing

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9.1 Introduction

The need to provide shelter, water and food to people all over the world has led to changes in land cover, such as agricultural lands, urbanization, forests, etc. The great interest in land cover changes results from their direct relationship to many fundamental characteristics of the land and processes, such as geomorphological processes, land productivity and hydrological cycles (Endreny 2005; Githui et al. 2009). Evaluating the effect of land cover and land use changes on hydrologic conditions is vital for catchment area management and development (Woldesenbet et al. 2017). Many studies showed that the significant increase in global runoff in the 20th century was because of precipitation and land cover changes (Wang et al. 2017). A suitable understanding of land cover dynamics is fundamental for anticipating the future changes in urban runoff volume (Suribabu and Bhaskar 2015; Meierdiercks et al. 2010). The ramifications of anthropogenic activities on land cover and water resources have become clear. Generally, investigations demonstrated that transformations in catchment hydrology happen principally because of alterations in interception, infiltration, evapotranspiration and groundwater recharge which would join land cover transformations (Meierdiercks et al. 2010; Hameed et al. 2015). Evaluating the effect of land cover changes remains a significant step in catchment area management strategies as well as water resources planning and conservation measures. Conversion of land cover such as deforestation, pasturelands and grasslands for urbanization and agricultural intensification because of rapid population growth has become a critical environmental issue (Gyamfi et al. 2016). Unplanned urban growth is now a major problem in several countries. In developing countries, there is often a lack of consistent and reliable data including spatial data, and that situation is highly evident in Iraq where political conflicts and factional instability caused subsequent internal displacement and migration. However, improved economic opportunities and population growth are often the driving forces behind the high level of land cover and land use changes, particularly in the cities of Iraqi Kurdistan Region that enjoys a complete state of security and economic stability (Hameed 2017).

The change in land cover has a considerable impact on the nature of runoff. Land cover in some areas remains unchanged for long periods, while in other regions land cover sees drastic changes more frequently. Economic and social activities such as urban growth and agricultural development have a direct effect on land cover changes (Letha et al. 2011). Urban growth increases impervious covers (Guan et al. 2015) that lessen infiltration capacity and prompt downstream flooding (Karamage et al. 2016; Pan et al. 2017; Kulkarni et al. 2014). A catchment or basin is an area from which overflow or runoff resulting from rainfall flows past a signal point into lakes, streams, rivers or seas (Hamdi et al. 2011). Land cover describes the material such as rock cover, vegetation or water body which dominate the surface, whereas land use refers to how natural land is converted to a new use such as agriculture, settlements or industry etc. It composes key environmental information for many sciences, natural resources such as water resources, also for a range of human activities (Letha et al. 2011). Urban growth is one of the major environmental problems of a catchment area.

The urban growth process includes an unsustainable use of natural land cover and causes numerous problems both within and outside the city (Zare et al. 2016). The urban hydrological system of a catchment area increases the fluctuation amount of surface water which may become extremely high during periods of rainfall (Kulkarni et al. 2014). Hydrological impacts of the increased impervious surface area typically result in higher flow peak and increasing runoff or streamflow volume (Perrin and Bouvier 2004), which lead to shifts in subsurface flow to surface flow and increases in flood frequency (Li and Wang 2009).

The objectives of this chapter are to assess the impact of land cover and land use changes on the runoff surface in sub-basin of Duhok city and to determine the contribution of changes in individual land cover and land use to changes in the major runoff component.

9.1.1 Land Cover and Land Use

Land use/cover throughout the world is mounting rapidly and puts the high risk on environmental components (such as water, soil, rainfall, and temperature and runoff rate) particularly in metropolitan areas. Therefore, the issues of land use/cover change demands wide interests (Guo et al. 2012). Changes in land cover are mainly man-made as the consequences of population growth, and they have an impact on the environment. The physical characteristics of earth's surface are called land cover, and they include physical features of land created solely by human activities such as settlements, based on the distribution of vegetation, water, soil and other features. However, the way land is used by humans is called land use, and includes land utilized for economic activities (Rawat and Kumar 2015).

Urbanization plays a major role in changes of land use/cover by replacing the natural land cover with inhabited sites, vegetation for economic purposes and infrastructure. Urbanization refers to changing the land cover by civil engineering constructions such as roads, housing etc. Urban expansion can be harmful to a region and ultimately to a large extent if it moves too far and is unbound, and it emphasizes the need for a cautious method to urban expansion planning (Du et al. 2014). The process of urbanization has a significant hydrological effect regarding manipulating the run-off nature (Goudie 1990). Human activities are the main geomorphic cause that impacts the earth surfaces; another effect of urban growth is that farming is the key procedure currently affecting the earth (Sharp 2010; Rasul et al. 2018). Nowadays, over 50% of the population in the world live outside of cities, and it is predicted that by 2025, this will decrease to less than 33% (Zhang et al 2013).

Remote Sensing and GIS techniques have been extensively applied to observe land use/cover changes through gathering, storing, evaluating, and awarding of geospatial data for diverse aims (Belaid 2003; Fadhil 2011). To acquire differences and update the data on the state, feature, pattern and growth of urban situations, advanced techniques are required (Esch et al. 2010). Remote sensing (RS) and Geographic Information systems (GIS) are effective techniques for conducting studies

such as detection of land cover change and forecasting future situations (Ahmed and Ahmed 2012; Fadhil 2013). Remote sensing data broadly adapt in different fields such as urbanization monitoring, land use/land cover mapping, analysis of urban heat island, estimation of impervious area and evaluation of urban ecological security (Yang 2011; Al-Quraishi 2004; Fadhil 2006). Image satellite is now very useful for analyzing urban areas that are integrally appropriate to analysis urban land use land cover changes at different spatial and temporal scales (Phinn et al. 2002; Wilson et al. 2003). In current years, a geographic information approach has been well-recognized for urban land use. Geographical planning has been used as a tool for geospatial simulation and land use change modeling, and its forecast has been confirmed in earlier studies of Land use change as efficient. There are several studies pointed to geospatial simulation and land use change modeling (Wang and Zhang 2001; Araya et al. 2010; Suribabu et al. 2012; Wu et al 2006; Bharath et al. 2013; Griffiths et al. 2010; Dewan and Yamaguchi 2009; Xiao and Weng 2007; Buyadi et al 2013; Jiang and Tian 2010; López et al. 2001; Lu et al. 2004; Mitsova et al 2011).

Geometrics technology with urban land use was applied in several studies in Duhok city to evaluate LULC changes and their effects on different fields, such as (Mohammed and Ali 2014) who attempted to assess urban expansion and changes in land use/cover in Duhok city between 2003–2012 utilizing multi-dates. The study documented that residential areas have expanded remarkably while other classes have decreased. Also, (Mustafa et al. 2012) implemented supervised classification with maximum likelihood to detect urban land use cover changes between (1989–2012). The study area was divided into five classes: forest, soil areas, grassland, water, and urban/built-up areas. The result showed that the urban land increased whereas all the other classes decreased.

9.1.2 Soil Conservation Service Curve Number (SCS-CN) Method

Easy methods for estimating runoff from catchment areas are particularly important in hydrologic engineering that is applied in many hydrologic uses, such as water balance estimation and flood design. The SCS-CN method is widely used for estimating runoff of depth and volume for a given rainfall event (Zhan et al 2005). The CN factor value depends on the various soil, land use, land cover and climate conditions. The method was originally developed by the Soil Conservation Services (United State Department of Agriculture) to estimate water surface volumes for a given precipitation event. It is the most popular technique among engineers. It is also simple to obtain and well documented environmental input, and it computes for many of the factors impacting runoff generation, incorporating them in an individual CN parameter (Soulis and Valiantzas 2012; Mockus 2007).

The procedure estimates the runoff depth from the pixels of the watershed as a function of existing soil type, land cover, land use and climate condition. Land cover

and land use characteristics in the Soil Conservation Service approach is explained by Curve Number (Li and Wang 2009). It is possible to estimate a composite CN for an entire catchment by area weighted average of CN for sub-basin units. Runoff volume from entire sub-basin can easily be estimated by composite CN for a variety of rainfall inputs. The SCS-CN model is simple, predictable, stable and accurate to reflect the catchment area characteristic for depth of runoff estimation. Also, the SCS-CN approach is more suitable for heavy precipitation of longer duration rather than light rainfall, and it is suitable for small watersheds. On the other hand, the application of the SCS-CN model illustrates the possibility of using this model for continuous time series precipitation-based estimation of runoff depth and to assess the impact of land cover and land use changes on runoff volume in a catchment area (Kowalik and Walega 2015).

9.2 Methodology and Data

9.2.1 Study Area

Duhok city covers the center of Duhok province which is located on latitudes $37^{\circ} 6' 15''\text{N}$; $43^{\circ} 49' 51''\text{E}$ in the north of Iraq and is about 585 m above the sea level Fig. 9.1 (Abas 2012). The Study area has a strategic site, being close to the tri-junction of the borders of Iraq, Turkey and Syria in the north-west of Kurdistan region. The topography has caused a linear shape due to being comprised by two mountain chains, the Bekher and Zawa Mountains from the north to the south respectively. The study area is surrounded by Edit Township of Mamseen Mountain from the east and Semel agricultural plain in the west. The city of Duhok also has two rivers passing through it, they are named the Duhok and Heshkarow Rivers, and they meet in the south-west of the study area. These stream waters are utilized for irrigating the agricultural area; also, Duhok dam was constructed in the northern part of the city in the period 1980–1988 for irrigating considerable rain fed agrarian lands, which are situated in the west of the city and lengthen to neighboring Semel area (Brendan et al 2005; Dawn 2010).

9.2.2 Climate Conditions

The climate of Duhok city is comparable to the Mediterranean climate, with the effect of comparatively high altitude of the surrounding mountains. The main characteristics of the Mediterranean climate are dry, extremely hot summers with bright sunlight and low comparative moisture (Koeppel and De 1959). Whereas, stated that higher comparative humidity and similarly lower quantity of sunshine mark the winter season as compared with the summer season. The study area in the winter

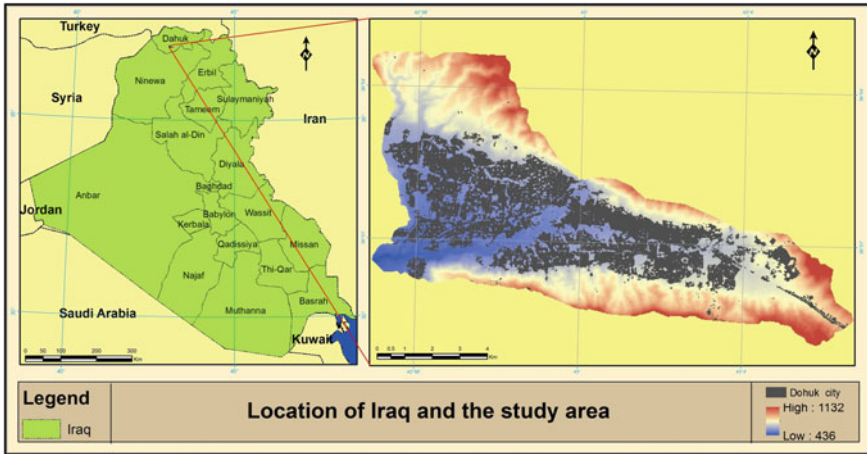


Fig. 9.1 Location of the study area

season is considered cold with snowfalls on the highlands. The temperature and evapotranspiration in the winter season are least (1.56 °C and 1.20 °C mm), and the precipitation is maximum (358.41 mm). The hot season starts in June until the beginning of September when the heat and evapotranspiration are maximum (43.30 °C and 13.70 mm), whereas the precipitation is least (0.00 mm). The mean annual precipitation was around 514.00 mm for the period (2000–2015). However, the average yearly temperature for the same period was around 20.44 °C.

9.2.3 *Satellite and Rainfall Data*

Five stations in and around the study area were employed to estimate surface runoff from rainfall data (Duhok, Malta, Duhok dam, Zawita and Sumel stations). The stations of the study area recorded continuous data from 2001 to 2016. Daily and monthly rainfall data are available for every year. The minimum average rainfall, which was recorded in Sumel, is 430 mm/year, and the maximum average rainfall in Zawita station is 747.8 mm/year. GIS tools were applied to estimate the spatial distribution of rainfall. Grids of rainfall were calculated and mapped for a selected rainfall depth per pixel. Inverse distance weighting (IDW) was used to determine the spatial distribution of rainfall and transfer the data to a raster layer in 30 m resolution.

This study adapted both primary and secondary data. Multi-temporal remote sensing data was required to research changes in land use/land cover over the study area. The primary data was collected from the United States geological survey (USGS). In the study, two Landsat images were comprised: TM-5 (02 August 2000) and (21 August 2015) with 30 m resolution. Secondary data were obtained from the Gover-

norate and Municipality of Duhok city which provided maps such as the municipal boundaries, geographical, wards, and master plan maps.

Data preprocessing: Before conducting the study, Landsat data was examined and processed to generate land use maps and their effect on runoff. Images were geometrically corrected and projected to the Universal Transverse Mercator (UTM) coordinates zone 38 N, WGS 1984. Furthermore, to improve the visual interpretability, image enhancement was used to aggregate the difference among features.

9.2.4 Images Classification

Examining the effects of anthropological actions on land cover/use classification is essential for revealing land use/cover changes in the period of the study. Earlier training samples were developed based on additional information from different sources such as higher resolution Google map and aerial photographs. Several samples were selected from the image for each category; each class had 50 training samples of 50 pixels. Then, the supervised classification was utilized for each satellite to extract the detailed changes. A maximum likelihood classifier was adapted for initial classification as it shows higher accuracy classification (Lillesand et al. 2008; Faqe 2015). Six land use/cover categories were designated in this chapter, namely vegetation area, barren land, forest; ruck, water, and built-up area. Finally, both classified images were evaluated again for accuracy. For measuring remotely sensed data, the procedure of supervised classification is commonly used (Richards 1999). Supervised classification is a method of categorizing pixels through a well-known computer algorithm and the current statistical descriptors of land cover (Lillesand et al. 2008). It depends on the prior information on the study site (Ahmed and Ahmed 2012). For digitizing polygons around each training site, a chosen color composite ($RGB = 432$) was used for similar land cover. Then each known land cover type was assigned to a unique identifier. To achieve precise classification results, maximum likelihood supervised classification is a suitable approach (Gómez et al. 2008) and it provides the best consistent Landsat band mixture. The maximum likelihood method offers a more accurate result of classification than other methods such as (Parallelepiped) thus the current study selected maximum likelihood classifier.

9.2.5 SCS-CN Model and the Proposed Method

The SCS-CN is an event-based rainfall-runoff model that is widely used in the design of major hydraulic structures. The SCS model uses the CN values as input parameters to estimate runoff depth (DeFries and Eshleman 2004). The CN is estimated per pixel for a watershed using land cover, land use and soil types that are reclassified into Hydrologic Soil Groups (HSG) (see Table 9.1) (Hameed 2013). The SCS approach divides soils in any watershed area into four HSG according to the United States

Table 9.1 Soil groups and corresponding soil texture

Soil group	Runoff description	Soil texture
A	Low runoff potential because of high infiltration rates	Sand, loamy sand and sandy
B	Moderately infiltration rates are leading to a moderate runoff potential	Silty loam and loam
C	High/moderate runoff potential because of slow infiltration rates	Sandy clay loam
D	High runoff potential with very low infiltration rates	Clay loam, silty clay loam, sandy clay, silty clay and clay

Geology Survey land use and land cover classification system (A, B, C, and D). Soil classification to HSG relies on infiltration rates and the soil texture composition (Day 2010). Table 9.1 illustrates the HSG depends on the United States Geology Survey classification System.

Depending on Table 9.1 that explains soil texture and its soil group to find the HSG of the study area, Fig. 9.2 shows the spatial distribution of hydrologic soil groups in the study area. The hydrologic soil group of the study area is distributed into three main types; A, B and C. Depending on Table 9.1, the study area could be divided into low and high-moderate runoff potential. The soil texture consists of three main zones; Deep, Lime-rich and gravelly silty clay to clay with surface cracks, shallow to moderately deep, well-drained loamy to clayey soils, and deep, well-drained lime-rich soils with a variable texture and gravel content. The soil types were generated from reconnaissance soil maps of the three northern governorates, Iraq 2001. As shown in table 1, runoff potential of the study area is distributed between low, moderate and high or moderate runoff potential.

9.2.6 Estimate Runoff Depth

Evaluation of runoff depth is most important for assessing the potential water supply during rainfall events. The Soil Conservation Service and Curve Number model assumes that the ratio of actual soil retention after water surface begins to reach potential maximum retention is equal to the ratio of water surface to available rainfall,

$$\frac{F}{S} = \frac{Q}{P - I_a} \quad (9.1)$$

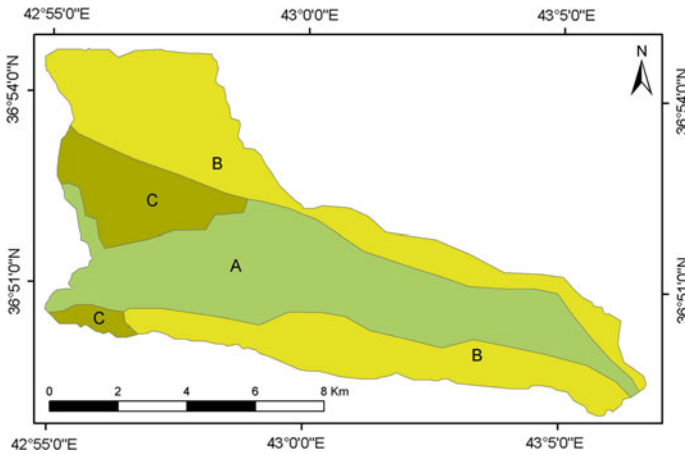


Fig. 9.2 Classified soil map into hydrologic soil groups (A, B and C)

where F is cumulative infiltration, S is the potential maximum retention (mm), Q is a runoff (mm), P is storm rainfall (mm), and I_a is an initial abstraction. The value of I_a is set equal to $0.2S$ in Eq. (9.1). Therefore, the SCS-CN model can be expressed as follows:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad P \geq 0.2S \tag{9.2}$$

For the application of Eq. (9.2), S is expressed in the form of a dimensionless runoff curve number that represents the runoff potential of the land cover soil characteristics governed by soil antecedent moisture condition, soil texture and land cover and land use.

$$S = \frac{25,400}{CN - 254} \tag{9.3}$$

where S is expressed in mm. The values of CN can be taken from tables, and they are dependent on the hydrologic soil group, land cover and land use, hydrologic condition and land treatment. The CN high values point to higher surface runoff, while the CN lower values refer to lower runoff (Zare et al. 2016). The hydrologic condition indicates the impact of land cover and represents the surface conditions in the catchment area in relation to infiltration and runoff (Weng 2001). The land cover and land use that are extracted from satellite images in remote sensing can be used together with a map of hydrologic soil group in GIS to match the hydrologic soil group with land cover and land use. Table 9.2 generated the curve number dependent on the USGS classification system (A, B, C and D).

Table 9.2 Runoff curve number for combinations of different land cover and hydrological soil groups

Land cover	A	B	C	D
Bare soil	74	83	88	90
Built up	98	98	98	98
Forest	36	60	73	79
Grass and open wood	49	69	79	84

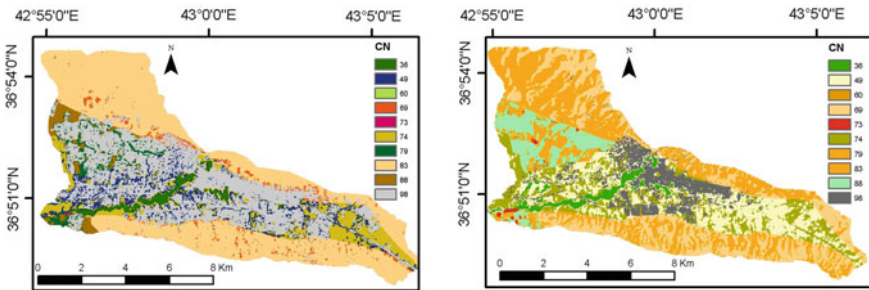


Fig. 9.3 Curve number map for the study area

Estimating the spatial and temporal variations runoff depth each pixel of the study area uses the SCS-CN model. The rainfall distribution layer was used as the main parameter to estimate runoff depth. Inverse Distance Weighting was applied to interpolate determined pixel values of rainfall in a linearly weighted combination of a set of station points. Runoff for each pixel and each studied year was estimated by applying the SCS-CN model using as inputs rainfall depth and the corresponding CN values raster layers. The resultant runoff rater layers were then intersected with land cover and land use to estimate the runoff volumes corresponding to each land cover category for each year as shown in Fig. 9.3. Distribution of CN in the study area shows that there are different values of CN. The minimum value of CN is 36, while the maximum value of CN is 98. This difference completely depends on the soil types and land cover to display the capability of the study area in runoff and infiltration as shown in Fig. 9.3 and also Fig. 9.4 illustrates the methodology of the study to detect the affect of land use / land cover changes on the runoff volume.

9.3 Results and Discussion

9.3.1 Changes in Land Cover

The watershed of Duhok city experienced several significant land cover changes between 1990 and 2016. Table 9.4 and Fig. 9.5 illustrate the spatial distribution

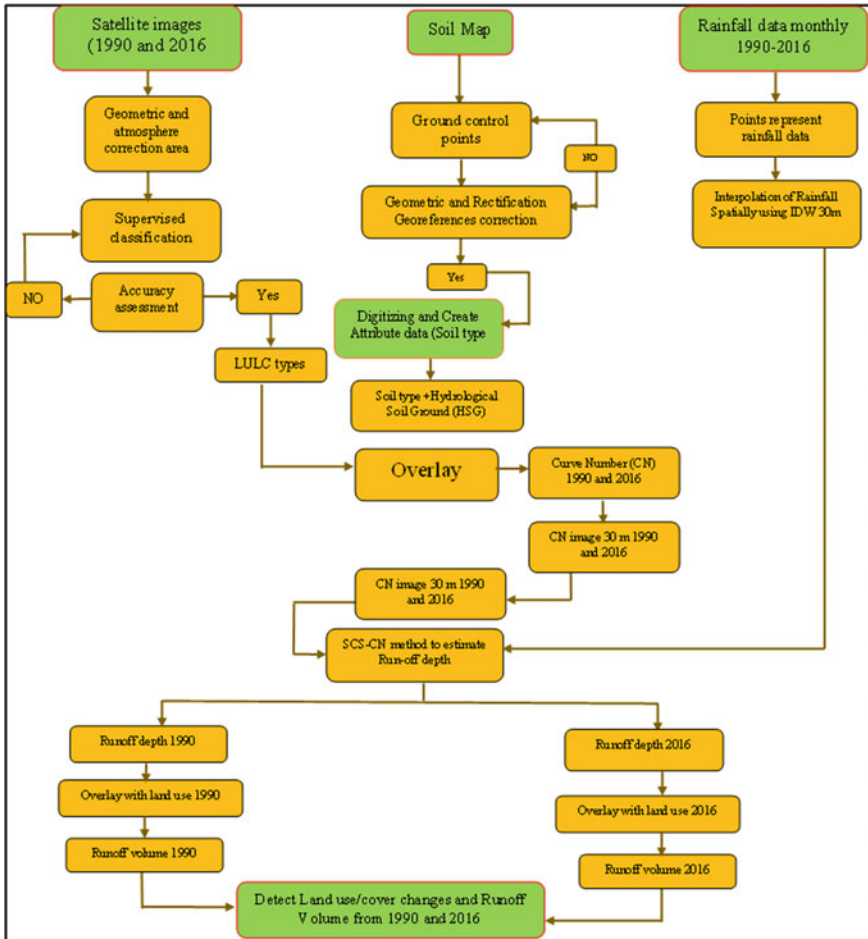


Fig. 9.4 The flowchart illustrates the methodology

of land cover changes in the study area. The supervised classification was used to produce the land use land cover map in 1990 and 2016 with high accuracy as seen in Table 9.3. The overall area of interest is about 8737.8 ha; as seen in Table 9.3. Figure 9.5 displays the land cover changes that occurred in Duhok watershed through the study period. As illustrated, the spatial spread of the land cover types and the urban land growth amounts varied considerably in the period of the study. The detailed hectares of land cover change in Duhok watershed is documented in Table and chart 1. The study selected four classes (Built-up, grassland, forest and bare land).

Table 9.4 proved that the dominant area in 1990 was grassland that made up around 3,814.6 ha in 1990, and it dropped to 1,048.34 ha in 2016. Thus, forest area decreased from 290.16 ha to 211.209 ha in 2016. Noticeable alteration occurred in

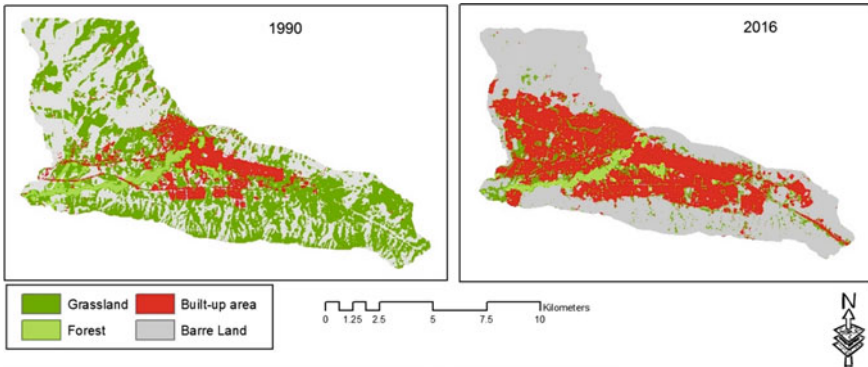


Fig. 9.5 Supervised classification of land use/cover map

Table 9.3 Accuracy assessment of land use/cover between 1990 and 2016

Year	1990	2016
Overall accuracy	93	90
Kappa index	0.91	0.89

Table 9.4 Shows the quantity of land use change

Class	The area in hectare 1990	The area in hectare 2016
Built-up	822.87	2804.44
Grassland	3814.6	1048.34
Forest	290.16	211.209
Bare land	3775.68	4673.79
Total	8737.779	8737.779

total vegetation area, these types of land covers decreased by 23.6% from 4,139.229 to 1,259.549 ha between the years 1990 and 2016. In contrast, the finding indicated that bare land significantly increased from 3,737.68 ha to 4,673.79 ha from 1990 to 2016. The study revealed that exceptional changes took place in the quantity of the vegetation class between 1990 and 2016. The modifications might be the outcome of many factors such as urban growth and climate change. The study area experienced drought seasons in 1999 and 2002. Due to most of the vegetation types in the study site being reliant on precipitation, the increase and decline of precipitation results in alterations in vegetation area. Also, urban classes (inhabited, profitable, road, education and other administrative building) remarkably increased by (822.87 ha) (2,804.44 ha) and between 1990 and 2016. This excessive change in urban areas is an outcome of the political and economic modifications that have occurred in the region. The finding of the study agrees with the results of (Al Rawashdeh and Saleh 2006; Shupeng et al. 2000; Weng 2014) who posited that economic and political factors contribute to urban land use change.

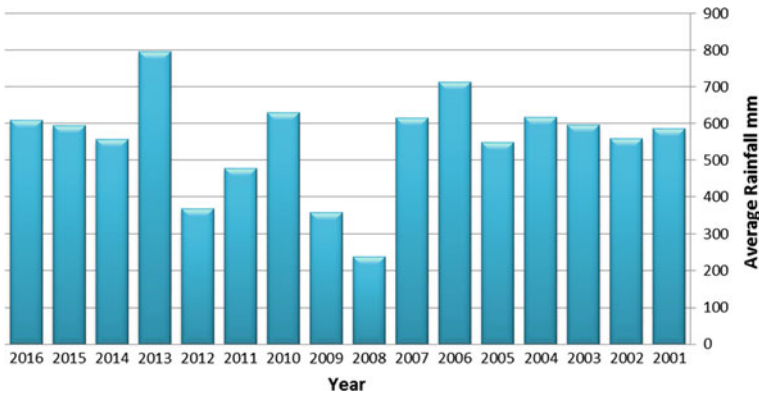


Fig. 9.6 Comparison of rainfall between 2001–2016 and 2016

9.3.2 Rainfall Variable in Time

The total rainfall received in the study area from 2001 to 2016 was highly variable from one year to another. The variable depends on the type of climate and the length of the considered period. The climate of the study area changes between the warm climate region and Mediterranean climate of the steps. The characteristic of this type of climate is dry and wet periods (Faqe et al. 2016). Comparisons of the average monthly rainfall by 5 stations in and around the study area were made on a yearly basis. Figure 9.6 illustrates the variation of the average rainfall between different years. The average annual rainfall was around 554.5 mm/year. The depth of rainfall fluctuated from 2001 to 2016. The minimum mean annual rainfall in the same period was 239 mm in 2008, while the maximum mean annual rainfall was 797 and 713 mm in 2013 and 2006 respectively. These differences in the amount of rainfall caused changes in runoff potential. Therefore the volume of runoff potential could be changed from year to year. Spatial distribution values of rainfall in the study area increased from south-west to north-east. This difference in the spatial distribution values of rainfall is linked with the climate condition and topography (Rijabo and Bleej 2010).

9.3.3 Changes in Potential Runoff

The results showed in Fig. 9.5, and Table 9.4 demonstrate the feasibility of converting land cover parameters so that all parameter divisions could be simulated. A set of rainfall data was used for a different land cover and land use condition to analyze the effect of land cover changes on runoff generation. Many studies have shown that vegetation land cover can play a positive role in decreasing runoff potential.

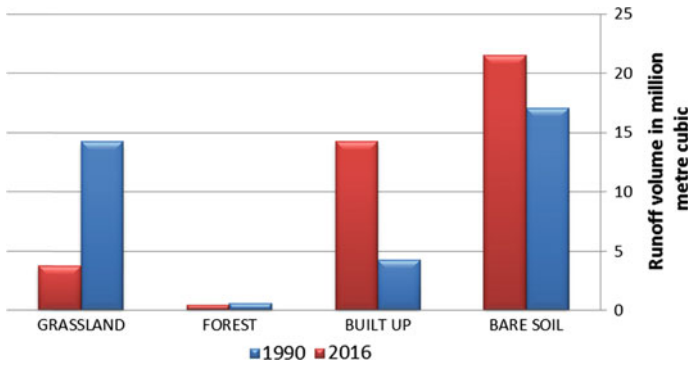


Fig. 9.7 Runoff volume change from 1990 to 2016 according to land cover changes

The spatial distribution of impervious areas and bare soil in the sub-basin watershed of Duhok had a significant impact on the generation of surface water. Figure 9.7 illustrates the impact of land cover changes on the volume of water surface from 1990 to 2016. The main change in the volume of runoff in the same period was clearly shown in built-up, bare soil and grassland cover. Runoff volume increased from 4.2 to 14.3 million cubic meter from 1990 to 2016 respectively, and runoff volume of bare soil also increased from 17 to 21 million cubic meter in the same period. The impervious area provided most of the runoff. The increased urbanization in the study area led to a decrease in grassland and forest area; therefore, the decline of vegetation area resulted in the increased water surface. The grassland land and forest area decreased from 3,814.6 to 1,016.5 ha and 288.1 to 211.2 ha respectively as shown in Fig. 9.5.

The transformation in land cover from vegetation area to built-up and bare land from 1990 to 2016, that is shown in Table 9.4, indicates the changing trends of urban growth in Duhok watershed and their role in surface water increase. As can be seen, the increment in runoff volume is largely correlated with the shift in land cover. Specifically, the built-up and bare soil land increased from 4,598.6 to 7,478.2 ha. This variation is primarily attributed to the alteration in the type and area of land cover. The runoff potential increased following the reduction in natural vegetated land cover, in particular, grassland coverage. The economic development of the last decades had resulted in widespread residential and commercial expansion, especial after 2003 when the Iraqi government changed.

The effect of land cover change runoff was tested by comparing the predicted runoff depth in 1990 with that in 2016. The runoff depth image of 2016 was subtracted from that of 1990. The resulting image of change indicated that the average runoff depth had increased by 48 mm during the 26-year period due to land cover changes. This number points to a uniform runoff depth for the whole study area, and it has a standard deviation of 65.5. In order to understand the impact of land cover change on surface water production, the spatial pattern of the runoff depth changes image was reclassified into three categories as shown in Fig. 9.8. The first category refers

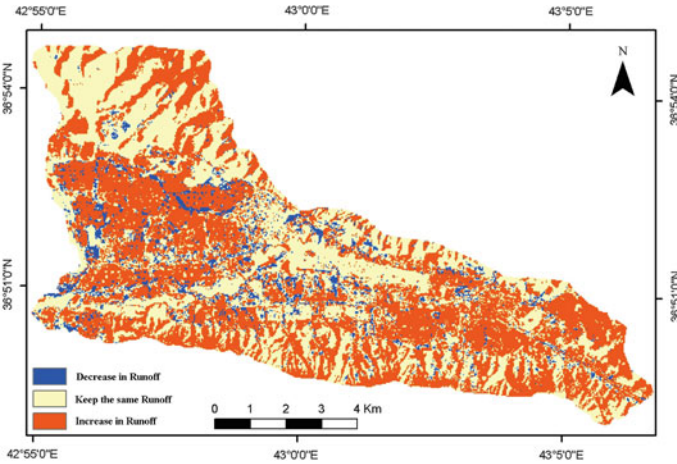


Fig. 9.8 The runoff volume changes from 1990 to 2016

to values of runoff depth less than zero which indicate decreasing surface water due to the expansion of vegetation land, while the second zone indicates no change in runoff depth from 1990 to 2016. The third area indicates increasing runoff depth because of land cover change to barren soil and built-up areas. The study concluded that 50.3% of the Duhok sub-basin belongs to the third category. These changes will directly affect the amount of runoff volume.

The Duhok watershed has been exposed to significant land cover change, in particularly urban growth and bare land in the period from 1990 to 2016. The land cover had changed over the study period. Grassland and forest land decreased from 44.1% to 12% and from 3.3 to 2.3 respectively, in the catchment area from 1990 to 2016, while urban growth and bare land increased from 9.4 to 32.1% and 43.2 to 53.5% respectively, in the same period. Both urban areas and bare land caused an increase in runoff of around 89%. There is a positive correlation between the increase in impervious area and runoff simulation results. Urban growth increased around 241%, more than that of population growth (82%). The average increase in land growth being faster than the population growth is due to the investment in land for building, which increased significantly from 1990 to 2016. The land cover factor directly affected the surface water (runoff), where the volume of runoff increased 30% from 1990 to 2016. Also, land cover changes caused changes in the stream networks of the watershed and changed the flow direction of surface runoff. This process also leads to an increase in runoff volume in some areas and a decrease in other areas.

9.4 Conclusions

This chapter focused on some possible method to use the SCS-CN approach to estimate runoff for monthly rainfall events. A GIS-based SCS-CN model was applied to estimate surface runoff in Duhok sub-watershed. According to the simulation results of two events of rainfall-runoff analysis, the land cover condition is an important factor that affects the volume of runoff. The Duhok sub-basin was subjected to significant land cover changes in the period from 1990 to 2016. Satellite images were regrouped into four classes (built up, grassland and open wood, forest and barren soil). The increase in urbanized areas and bare land and the decrease in other land covers are significant reasons for the increase in surface runoff. Built-up land and bare land increased from 53% in 1990 to 86% in 2016, while vegetation land decreased from 47 to 14% in the same period. The research has also shown that both built-up and bare land caused an increase in runoff volume from 59 to 89% in 2016, while the vegetation area decreased in runoff volume from 41 to 11%. The result of this chapter shows that the sub-basin of Duhok has experienced major changes which have affected the environment of the watershed and changed the land cover pattern. The result of this chapter supports the idea that decision-makers would be well advised to improve plans for increased vegetation cover particularly upstream of the watershed to decrease surface runoff.

9.5 Recommendations

The chapter recommends that the future studies should use high-resolution satellite images and different techniques to clarify impact of climate change and urban growth on the Run-off. The new studies should be adopted object-based analysis to classify imagery. It is called a segment that is a cluster of the pixel with comparable spectral, spatial and texture attributes for urban detection. Additionally, the studies focus on the relationship of raise the rate of the urban runoff and chemical contaminants and make diseases.

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