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ORIGINAL ARTICLE

Runoff modeling of Sebou watershed (Morocco) using SCS curve number method and geographic information system

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Abstract The Sebou watershed is considered as one of the most important drainage basins in Morocco. This basin had been exposed to frequent flood hazards which were responsible for many damages in several areas of the basin. In the present study, the curve number method was implemented to assess the runoff based on hydrologic modeling method. The use of geographical information system allow us facility in the mapping and geo processing of spatial data for the factor affecting runoff such as land use, hydrologic soil group, digital elevation model and rainfall. The average annual rainfall is 582 mm, and we distinguish two hydrological soil groups with the dominance of group D, the largest land use found in the area is agriculture class. The average curve number is 85. This high value means a high degree of runoff and a low degree of infiltration. The average annual runoff depth for Sebou watershed is 543.6 mm which represents 91.5 % of the total annual rainfall. These results revealed that hydrologic model can be used efficiently to support integrated watershed management.

Keywords Sebou watershed · Curve number · Runoff · Geographic information system

Introduction

The coverage of water needs in Morocco has increased in recent years. Water demand increases dramatically, while supply remains fixed with a considerable waste, both in agriculture and in industry, and in the domestic supply. By 2030, if nothing is done, the deficit will be 5 billion m^3.

The water issue is essential, bearing in mind that Morocco has exceeded the period of availability of abundant water. A new era of water scarcity and irregularity of contributions has begun, which makes water management and planning of its use, especially in the medium and long term, essential to ensure the sustainability of water and food security (AHBS 2011).

The Sebou watershed, located in north-west of Morocco, covering an area of about 40.000 km^2, representing 6 % of the area of the national territory, it is one of the most important agricultural region and currently contains a total population of about 6 million.

This basin which generally contributes with 30 % of the national potential of surface water resources and 20 % of the ground water resources is drained by the Sebou river that originates in the Middle Atlas and travels about 500 km before reaching the Atlantic Ocean near Kenitra. The climate prevailing in the whole basin is of type Mediterranean with oceanic influence, and inside the basin the climate becomes more continental. The Sebou basin has an important agricultural and industrial economy which contributes significantly to the national economy.

Many issues and barriers against sustainable development of the Sebou basin are recognized. These problems are due to human activity (erosion, deforestation, uncontrolled urbanization, pollution.), others are more of natural order (spatial and temporal variation in precipitation, droughts, floods etc…).

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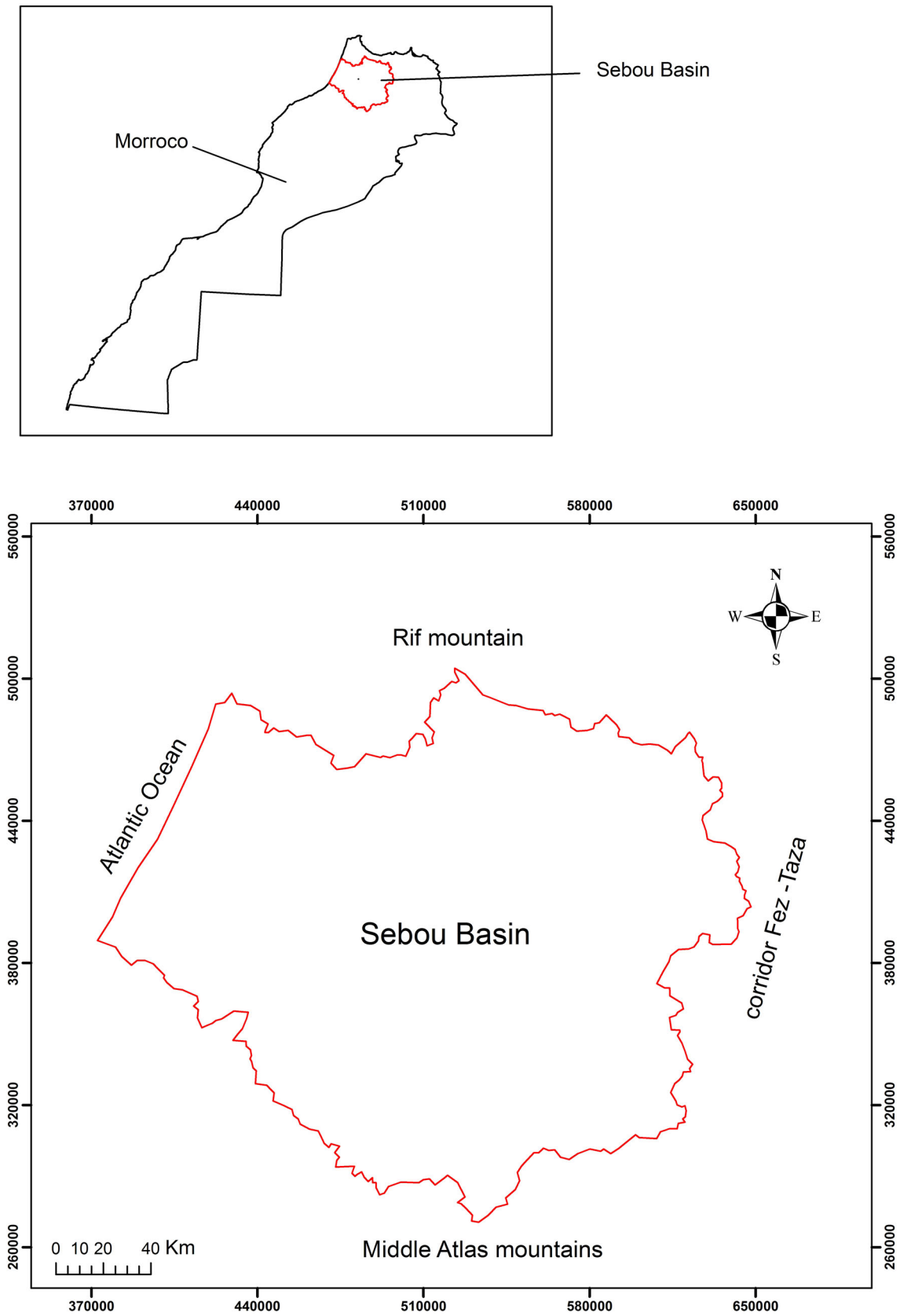
Fig. 1 Study area
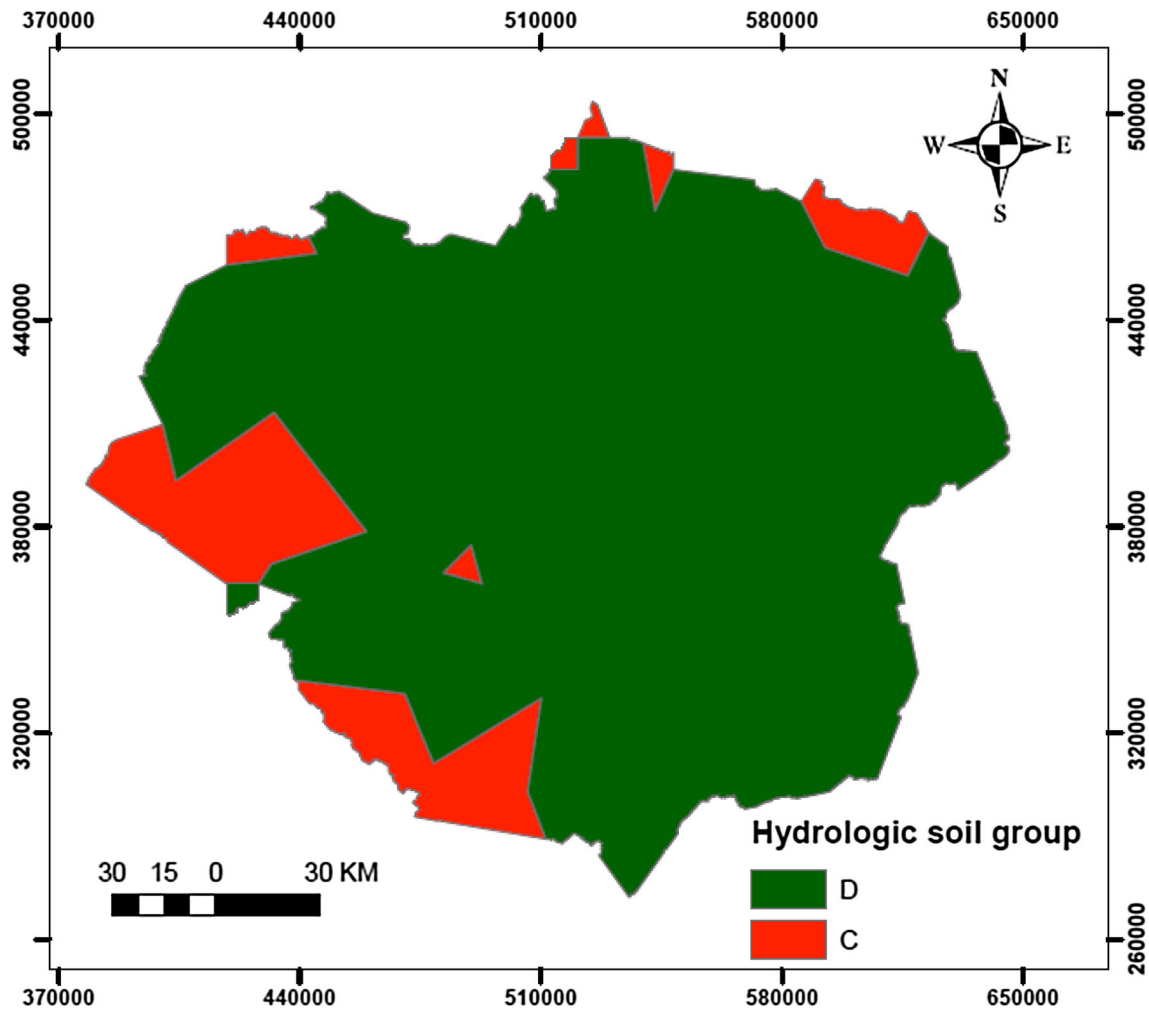
Fig. 2 Hydrologic soil group map

Hydrological soil group	Description	Distribution (%)
Goupe C	Low infiltration rate	13.35
Goupe D	Very Low infiltration rate	86.64

Table 1 Hydrological soil group properties and their distribution in study area

The Sebou Basin (especially in its northern part) is characterized by intense erosion caused by many factors: ground fragility, heavy rainfall intensities, low vegetation cover, human activities (deforestation), steep slopes, unorganized exploitation of forests (Chadli 2016). The consequences of erosion are the most direct loss of land capital and sedimentation of downstream reservoirs.

The Sebou basin has witnessed major flooding in the past, particularly in the Gharb plain. Construction of the dam Al Wahda allowed mitigation of over 90 % of the flood plain. However the 2009 and 2010 floods have demonstrated that the problem still persists.

Runoff is the most important component of water cycle; this coefficient means the flowing off or drainage of precipitation from a catchment area through a surface channel. Its importance lies in the fact that it is used as water resources (maintaining the dams), or in the design drainage network in cities (against flood).

The determination of runoff requires historical record from hydrologic station for the basin, but this data are often not available particularly in developing countries. To solve
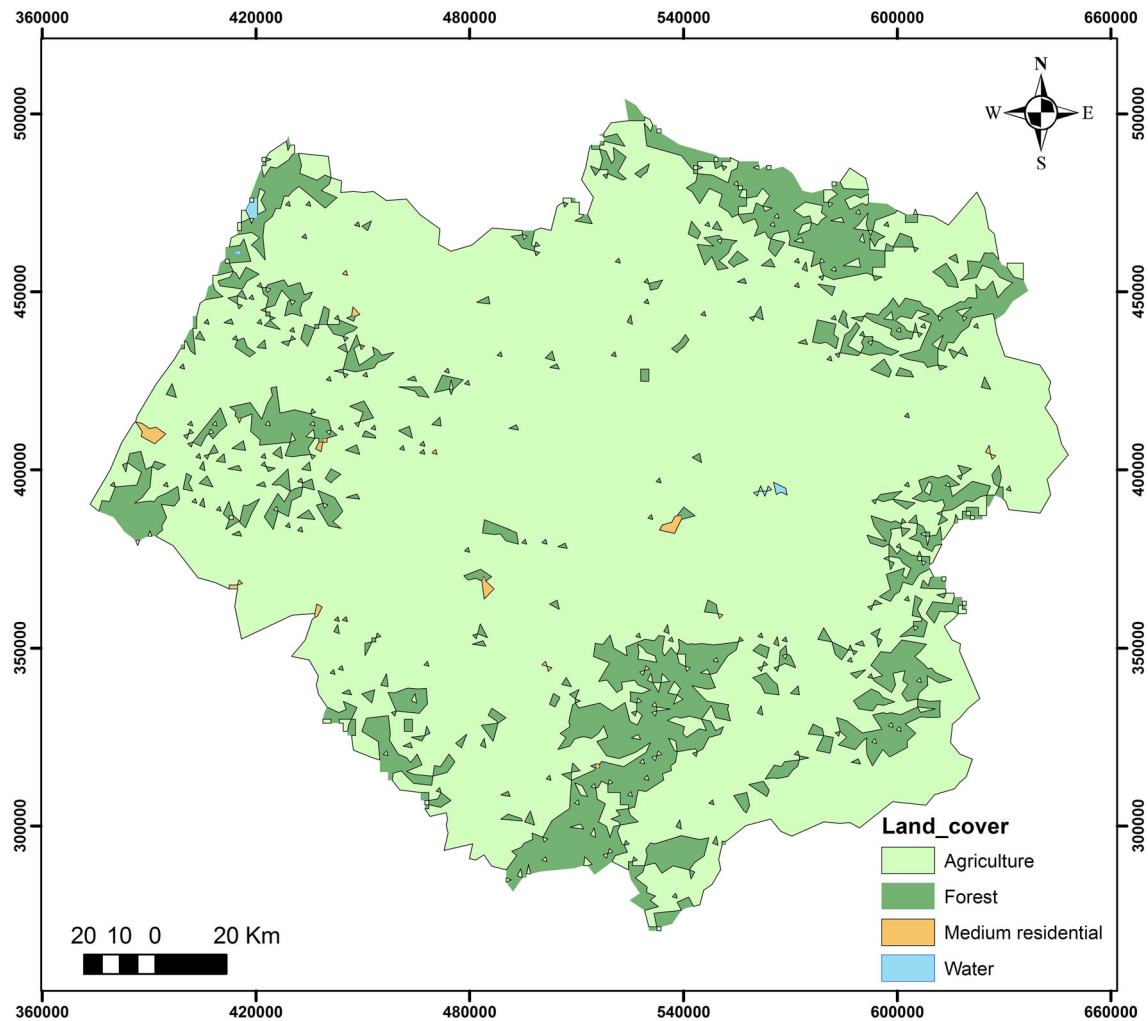
Fig. 3 Land use map

this problem, the hydrologist developed empirical technique from the simplest to the most complex with several variables. The curve number method developed by the USDA Soil Conservation Service (USDA 1986), uses of a series of simple equations with input data like hydrologic soil group, land use type, and precipitation. In addition, the use of the method is facilitated by its implementation in a geographical information system (Al-Jabari et al. 2009; Mohammad and Adamowski 2015; Mahmoud et al. 2014; Taher 2015).

This study aims to evaluate the potential runoff coefficient of Sebou watershed using curve number method integrated with geographic information system.

Description of the study area

The Sebou watershed (Fig. 1), located in north west of Morocco between parallels 33° and 35° north latitude and 4°15′ and 6°35′ west longitude, covers nearly 40.000

km², and situated between the Rif mountain chain to the north, the Middle Atlas mountains in the south, the corridor Fez–Taza to the east, and Atlantic Ocean to the west.

Data needs and methods

Soil map

Soil dataset has been extracted from Digital soil map of the world (FAO 2003) and the hydrological soil group was derived from the database for each soil type.

Soils are classified into four HSG's (A, B, C, and D) depending on their degree of infiltration rate.

Figure 2 and Table 1 indicate the hydrologic group covering study area and their properties, and show dominance of hydrologic soil group D (86.64 %) that means strong predisposition to runoff.
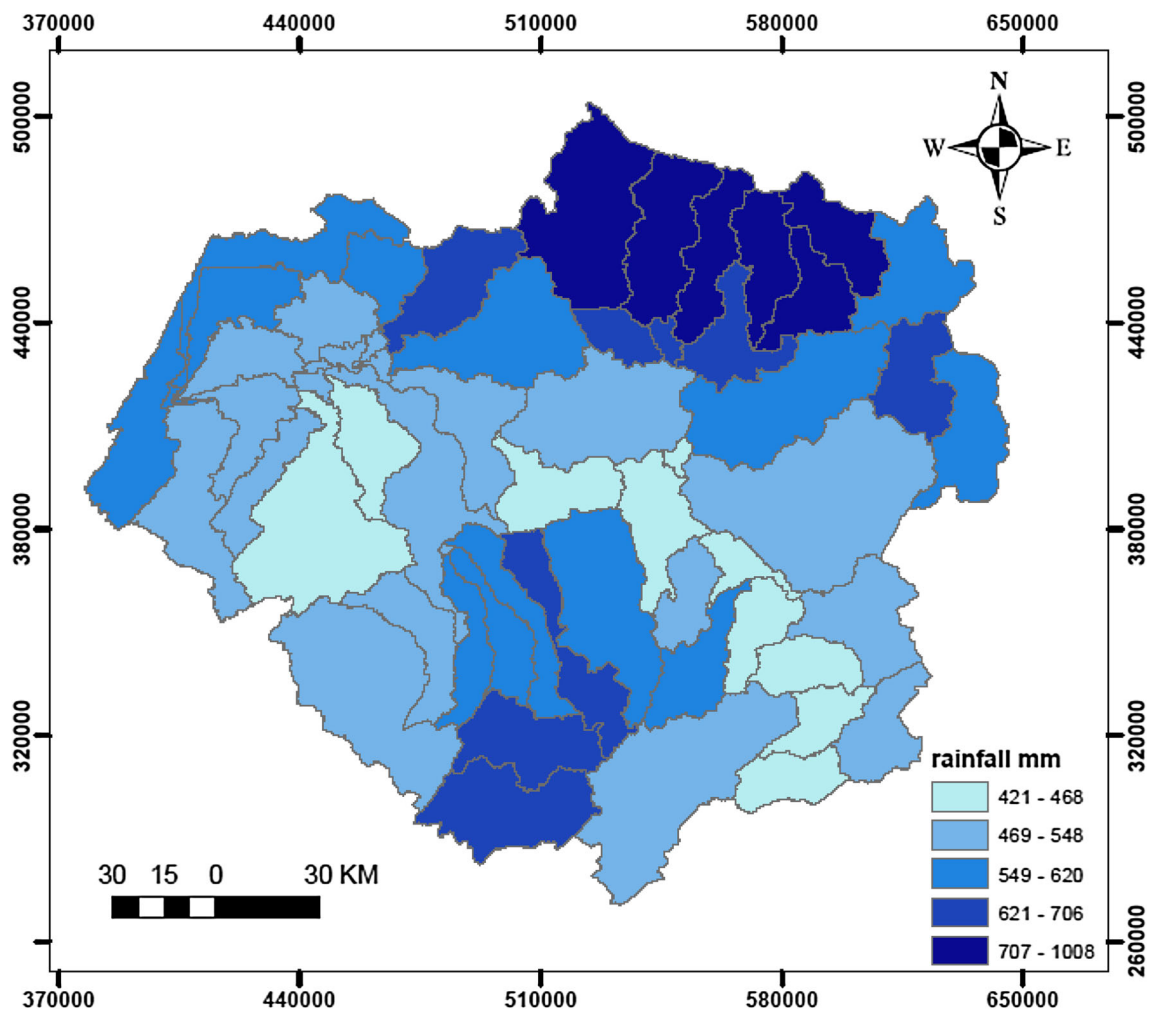
Fig. 4 Average rainfall distribution

Land use map

Land use map for the study region has been downloaded from Global Land Cover Characterization database (Loveland et al. 2000). The original GLCC was reclassified in four new classes which are: water, medium residential, forest and agriculture.

The dominant land cover types (Fig. 3) are agriculture (83.83 %), forest (15.91 %), medium residential (0.18 %) and water (0.06 %).

Rainfall data

Rainfall is the fundamental driving force and pulsar input behind most hydrological processes. The annual rainfall data for the period 1973–2013 have been obtained from the hydraulic agency basin of Sebou (AHBS).

Figure 4 shows that the mean average annual rainfall of Sebou watershed is 582 mm, the maximum is 1008 mm and the minimum is 421 mm. The rainfall increase from the centre of watershed to the south and to the north (mountainous area).

Digital elevation model

Digital elevation model of Sebou watershed was collected from global digital elevation data ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) NASA with 30 meters resolution (ASTER GDEM Validation Team 2009). The DEM was processed for delineation of the whole watershed and sub-basins. The slope map derived from the topography (Fig. 5) indicates the slopes are steep in the north and the south (mountains areas) and are gentle in the ouest (plain area).
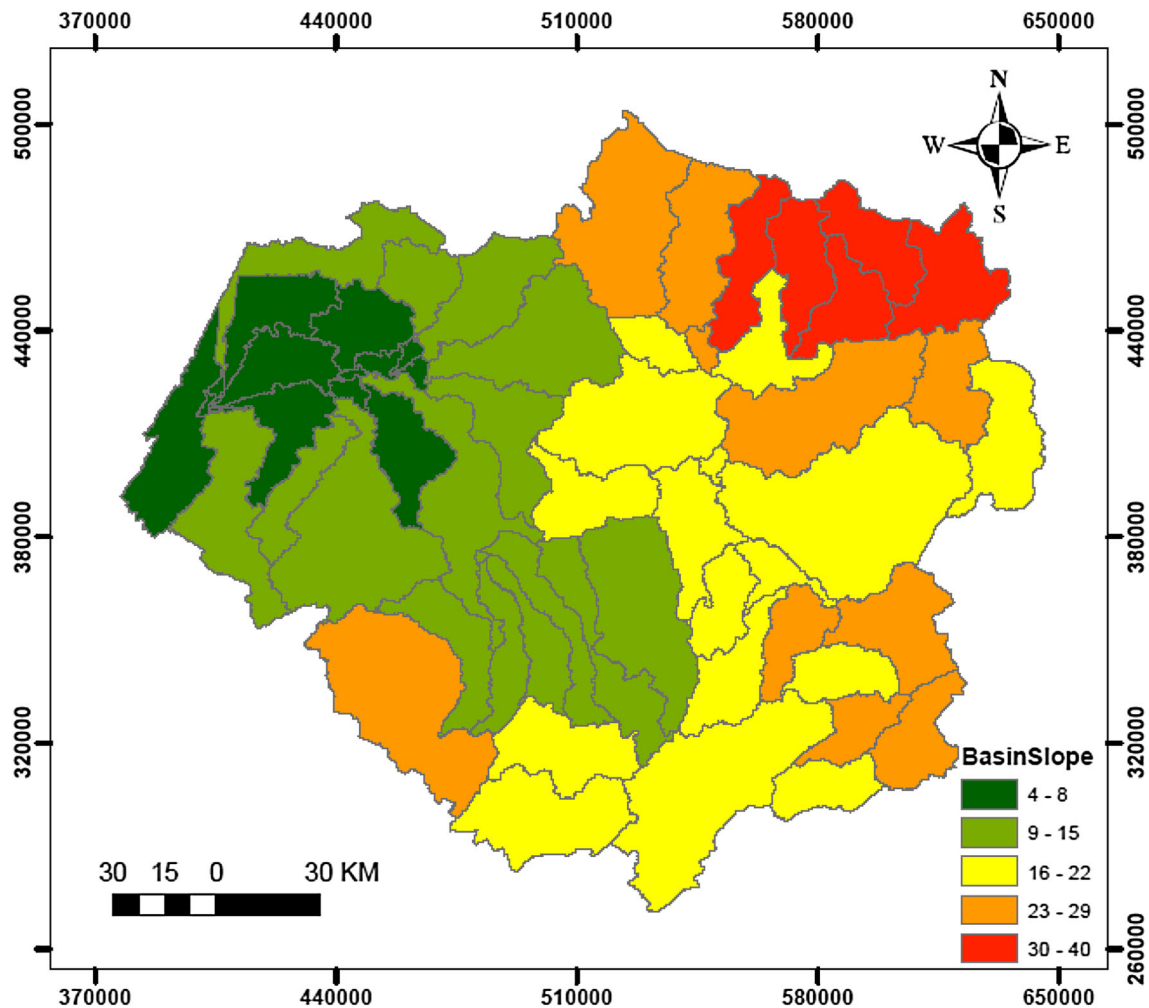
Fig. 5 Slope map

Methods

To create the CN grid map, we used a tool in the extension HEC-HMS which is integrated in Arcgis 10.2 interface. This tool requires hydro dem, soil landuse polygons, and curve number lookup. The soil map and land use map were combined and the appropriate CN value for each polygon of the soil-land use map was assigned using CN Lookup table (Table 2) where their numbers are obtained from SCS TR55 (USDA 1986). The CN Lookup table is like an index can relate the land use and soil group attribute with CN.

CN is a dimensionless parameter that varies between 0 and 100. If CN values tend to a 100, that indicates impervious surface and their high ability to generate runoff and if values tend to 0, that implies surface is pervious and low potential of runoff.

Table 2 CN lookup number for each combination landuse hydrologic soil group

Landuse	Hydrologic group			
Description	A	B	C	D
Water	100	100	100	100
Medium residential	57	72	81	86
Forest	30	58	71	78
Agriculture	67	77	83	87

The runoff was estimated using SCS curve number method (USDA 1972, 1986). The hydrologic relation between rainfall (P) and runoff (Q) is given by Eqs. (1) and (2):
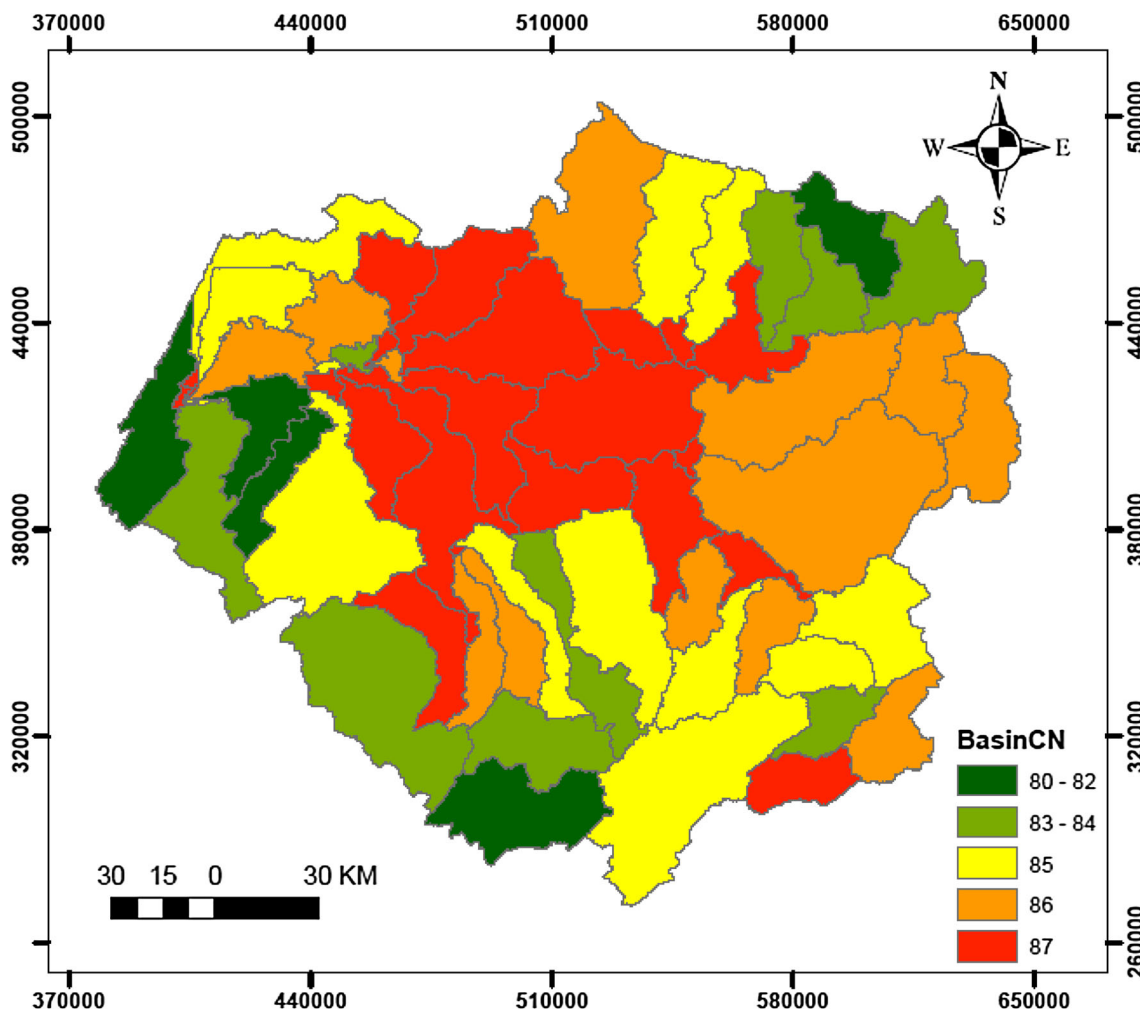
Fig. 6 Curve number map

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

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

where, Q is the Runoff depth (mm), S is the maximum potential abstraction (mm), CN is the Curve Number, P is the Rainfall depth (mm).

Results and discussion

The curve number for normal condition (Fig. 6) varies from 80 to 87 and mean is 85. A high CN represents a high degree of runoff, and therefore, the risk of flood in these areas is very serious.

The average annual runoff depth (Fig. 7) is equal to 543.6 mm which represents 91.5 % of the total annual rainfall. The variability in the mean runoff coefficient, which ranges from 378.8 to 951.1 mm, is correlated with the distribution of mean annual precipitation. The mountainous area has the largest runoff (north and the south).

Conclusion

This study has been carried out to estimate runoff in Sebou watershed using curve number method and geographical information system.

The results show that the dominance of hydrologic soil group D with low permeability and dominant land use is agriculture.

The CN numbers for Sebou watershed range from 80 to 87 that indicate the majority of surface is impervious and therefore generate high runoff.
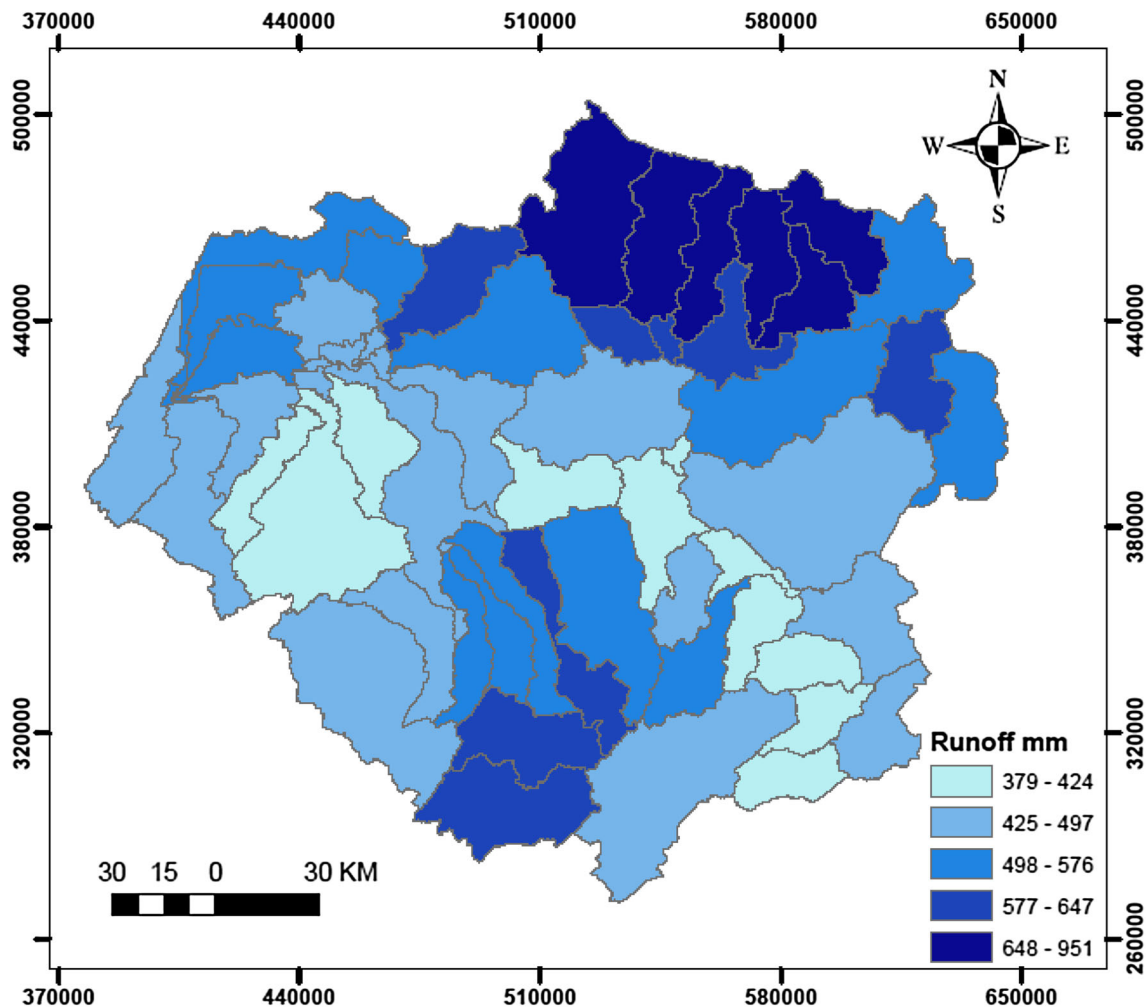
Fig. 7 Annual runoff depth

The distribution in the mean runoff coefficient, which ranges from 378.8 to 951.1 mm, follows the same trend of precipitation.

These results provide basic information for managers to evaluate potential runoff, and then propose solution to mitigate these problems.

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