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Study on Impact of Changes of Watershed Geomorphic Features on Runoff

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Abstract

China has been undergoing rapid urbanization, which in turn greatly affects the watershed geomorphology and surface runoff. Estimation of surface runoff is essential for the assessment of runoff potential of a watershed, planning of water conservation measures and reducing the flooding hazards of downstream by utilizing appropriate hydrologic model. Qiantang Estuary, well-known for its giant tidal, has few observed and experimental runoff data. Therefore, Soil Conservation Service Curve Number (SCS-CN) model was used to determinate surface runoff in this study watershed, integrating Geographic Information System (GIS) based on this field's the long-term data owing to its few data requirements and clearly stated assumptions.Results indicated that rapid urbanization really altered watershed geomorphic features and surface runoff. Simulated data demonstrated that the average annual runoff depth has been increased by 35.85mm from 1975 to 2010, an increase of 1.37×108m3 of total annual runoff volume. It is revealed that the Geomorphic features of watershed is one of the important factors influencing runoff.This study provided significant hydrologic parameters for city flood measures and watershed environment protection.

Keywords

Geomorphic Features; Surface Runoff; Numerical Modeling.

1. Introduction

China has been undergoing urbanization at an unprecedented rate since 1978[1], and the urbanization rate increased from13.6% in 1980 to 52.6% in 2012 and it will maintain to be one of the most important driving forces for China's future economic growth[2]. The rapid urban development, however, has changed natural hydrological ecosystem of watershed, such as increase of construction land, whereas declines of agricultural land and water areas [3].The impervious surfaces have greater rates and volumes of surface runoffcompared to natural land cover, which caused more flood events [4]. China is one of the typical cases, and many cities have been suffering from flood,especially waterlog with the development of urbanization.

The runoff in a watershed is one of the most parameters in designing of hydraulic structures and flooding control measures. Therefore, quantification of the impacts of geomorphological changes of watershed on the runoff is crucial . Although many hydrologic models are available for the estimation of runoff, most models are limited due to their large number of input parameters and complicated calibration requirements[5]. However, the most of the observed runoff data in this study area are not available and the experimental data are limited due to its macro tidal flow and complicated flow structure. Therefore, it is vital to select appropriate hydrologic model to estimate direct surface runoff of watershed from rainfall in order to predict its likely responses to geomorphologic features changes induced by urban development and to provide important values for planning of water conservation measures and reducing of the flooding hazards. The Soil Conservation Service Curve Number (SCS-CN) model, originally

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developed by the USDA-Soil Conservation Service in 1972 [6], is probably a good choice for the estimation of runoff because of its few data requirements and clearly and reasonable stated assumptions of the catchment[7].

2. Study Area and Sources of Date

This study is a part of the Qiantang River,Fuchun River, located at upstream of the Hangzhou center, capital city of Zhejiang Province in the east of China with the location of 119025'~120019' east longitude,29044'~30011' north latitude. The runoff change in this study area has a significant influence on flood-happen of central Hangzhou and local areas. The study area mainly consists of Fuchun River and two subcatchments, namely Fuyang and Tonglu catchments.

Main data sources include land use map and river network from Bureau of surveying and mapping Zhejiang Provence and Department of Water Conservation. Long-term monthly precipitation data are obtained from 13 rainfall stations during the period of 1978 to 2010, covering Fuyang River and all of its tributaries (Hydrology bureau of Zhejiang Province).

3. Methodology and Calculation

3.1. SCS-CN Model

The SCS-CN method builds on empirical studies and calculates only direct surface runoff mainly based on rainfall, soil and vegetation areas e.g. It assumes that the runoff volumes (Q) are proportional to the rainfall volumes (P). The relationship of Q and P can be represented as following equation (1) and (2)[6].

$$P = I_a + F + Q \tag{1}$$

$$\frac{Q}{P - I_a} = F / S \tag{2}$$

where Q is runoff (mm),

P is precipitation (mm),

F is cumulative infiltration,

and S is the potential maximum soil moisture retention (mm).

I_a is initial abstraction, where Ia= λS, λ is mainly influenced by the geography and weather, and its value is often equal to 0.2.

The SCS-CN model can be represented by rewriting equation (1) and (2) as following:

$$\begin{cases} Q = \dfrac{(P - 0.2S)^2}{P + 0.8S}, P \geq I_a \\ Q = 0, P < I_a \end{cases} \tag{3}$$

For convenience and standardization application of Eq. 3, S can be expressed as equation (4):

$$S = 25400/CN - 254 \tag{4}$$

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where CN is the runoff curve number, which governed by land cover, soil groups and soil antecedent moisture condition (AMC).

3.2. Determination of Average Precipitation (P)

It is need to calculate average precipitation (P) in study area due to the different precipitation in different sub-streams. It was estimated by using the weighted average of the Tyson polygon based on the long-term mean monthly rainfall data from 13 rainfall hydrological stations from 1975 to 2010.

3.3. Change of Watershed Geomorphic Features and Determination of CN Value

The watershed geomorphology is classified as seven types, water area, arable land, forest land, built-area, plant area (economic plants), grass land and unused land based on the topographic map in 1978 and satellite imagery in 2010. Rapid expansion of urban areas has dramatically altered the original watershed landscape features. The arable land has been reduced from 17.16% of the total land area in 1978 to 12.12% in 2010, and there have also been decreases in the water and the forest areas. On the contrary, the built land has dramatically increased from 2.13% in 1978 to 9.38% in 2010 of total area, an increase of 440% (see Fig.1).

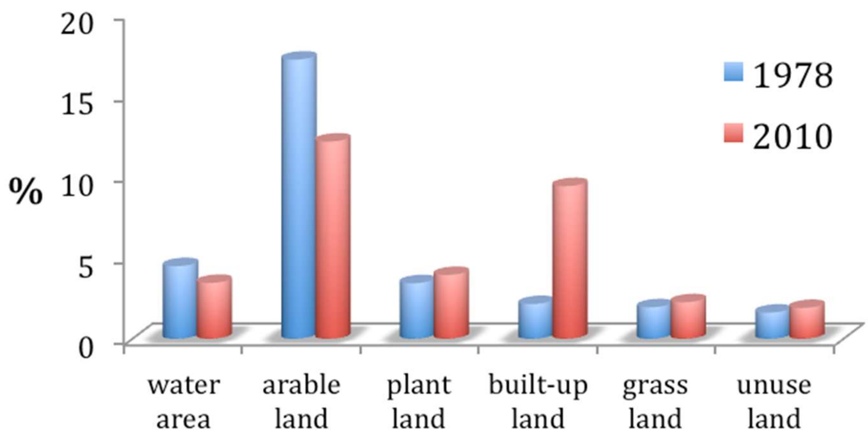

Fig. 1 Changes of watershed geomorphology from 1978 to 2010

The runoff curve number (CN) is based on the types of watershed geomorphology, hydrologic soil group and hydrologic condition. The soil groups have been classified as four categories, A, B, C or D . Group A soils are coarse and sandy ones, with the highest rate of infiltration and lowest potential runoff. Group D soils are heavy, clayey, poorly drained soils with the lowest rate of infiltration and highest potential for runoff. Group B and C soils are intermediate between group A and D. In general, the more moisture of the soil is, the bigger of the CN value is, the range from 0 to 100. For water, the value of CN is 100.The total antecedent moisture condition of soils is normal in the study area according to Qiantang River Record [8] and Water Conservancy Records of Fuyang[9]. The soil groups consist of the red loam, relative to "C" groups. It is up to 69.25% of the total areas in the Fuchun river catchments. Paddy Soil type accounts for 17.29% of the total area. And its hydrologic soil group is equivalent to groups "B". Other soil types are wet soil group and built land, the lowest rate of infiltration and highest runoff. Firstly, based on this field's land cover, soil properties, the value of the average weighted CN of different geomorphologic feature was estimated. Then it was input into SCS-CN model programming by Matlab with P and land use, and determined after modified many times by comparing simulated average runoff depth with observed one. Average value of CN of sorts of geomorphologic types is obtained.

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3.4. Result Analysis

To Analysis the impact of watershed geomorphologic change on runoff, the parameters of P, CN and Proportion of different land cover were input to the SCS-CN model programming by Matlab. The average monthly runoff and annual runoff depth before and after urbanization were estimated by SCS-CN model in the study area, given in table 2. Simulated annual runoff depth from 1975 to 1985(see Table 1) was compared with measured one in this study based on available runoff data from 1975 to 2000 and their areas of catchments.

Table 1. Comparison of modeled runoff depth with measured one and Change value of runoff

Period	Simulated average annual runoff depth (mm/year)	Measured average annual runoff depth (mm)	The relative error (%)
1975-1985	712.04	720.31	1.15
1986-2010	747.89		
Change value of Runoff depth (mm)	35.85		

The modeled result well agreed with the observed value, which indicated the modified SCS-CN model is available in this study area. It also showed that average annual runoff depth has been increased by 35.85mm, with an increase of total annual runoff volume by 1.37×108m3, indicating that the geomorphological features of watershed is one of the important factors influencing runoff.

4. Conclusion

The Soil Conservation Service Curve Number (SCS-CN) model is used to estimate surface runoff change causing by urbanization in this study watershed, integrating Geographic Information System (GIS). The parameters in model were determined using long-term hydrologic observed data, land cover types and soil groups in study watershed.

It was found that the urbanization clearly leads to negative impacts on watershed geomorphology and surface runoff. There are decreases of the areas of arable land, water area and forest land. On the contrast, built land has been dramatically increased after urbanization. Simulated results by SCS-CN model demonstrated that the average annual runoff depth has been increased by 35.85mm as a result of urbanization, with an increase of 1.37×108m3 of total annual runoff volume. A good agreement is obtained between the simulated annual runoff depth and measured one, with the relative error1.15%, which indicated that the model is available in this study area. This study provided very important hydrologic parameters for future flood control around city and local hydrological structure design, as well as reference to other watersheds.

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