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Effects of Land Use/Land Cover changes on surface runoff (A case study in Siahroud Watershed, Iran)

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ABSTRACT

Human activities such as development of urban area and reducing vegetation cause dramatic changes in surface runoff generation. In the present study effects of Land use and Land cover (LU/LC) changes on surface runoff in Siahroud watershed in north of Iran has been assessed. LU/LC was derived from an Aster imagery (acquired in 2002) and a Landsat 8 imagery (acquired in 2013) for two different periods using object-oriented classification. For this purpose preprocessing and Image enhancement on remotely sensed data were applied. The images were segmented to objects and then objects assigned into 5 classes based on spectral features and physical characteristics such as texture and size of the segmented objects. Accuracy assessment of Classifications was computed by calculation of total accuracy for each classification, user, producer`s accuracy for individual classes and also KAPPA index. In order to determine the average Curve Number for each year, LULC maps were combined with Soil Hydrologic Groups map of study area in ArcGIS. The surface runoff was calculated for 7 events in each year using SCS-CN method. Finally direct runoff has been calculated from the same rainfall for both years. Results showed that urban area has increased during the last 11 year resulting in 5to 40 percent increase in surface runoff.

Introduction

Floods are one of the most common natural hazards which cause a lot of damages all over the world. Knowing about changes in surface runoff helps researchers to lessen the devastating effects of floods by prediction of hydrological behavior of watersheds. Land use and land cover changes such as increase in urban area and destruction of forests have considerable impact on intensity and volume of runoff. Remote Sensing technology by collecting multi-temporal and multi-spectral data from various satellite and sensors is a powerful instrument to monitor the changes in surface of the earth. Because hydrological processes are multi- dimensional, GIS technology with a flexible environment is a helpful tool to analyze data from various sources.

SCS-CN is one of the popular methods used by researchers to estimate runoff. Land use and Land cover are important parameters in SCS-CN model (Pandey and Sahu, 2002). Many researches have been developed on effects of land use and land cover changes on surface runoff. Melesse and Shih (2002) revealed an Increase in average curve number of three different periods in south Florida using Landsat imagery. Nayak et al (2012) used remotely-sensed data and SCS-CN method to indicate that destruction of forests in order to increase agricultural area drastically increased the surface runoff in Narmada basin in India. Sun et al. (2013) investigated long term effects of LU/LC changes on surface runoff in urban area of Beijing using Landsat TM/ETM+ imagery and L-THIA model. They resulted a dramatic increase in surface runoff due to the rapid urbanization of study area. The same results came out from an investigation in Nowshahr and Chaloos in north of Iran (Mahini et al, 2012).

Study Area

The study was carried out in Siahroud watershed with area of 122.65 km^2 which is located in The Mazandaran Province, in north of Iran. Mean temperature in Mazandaran varies between 12.5 to 20°C, and mean annual rainfall is 791 mm. Elevation of study area vary from 40 m in lowest region to 600 m in the highest. Figure1

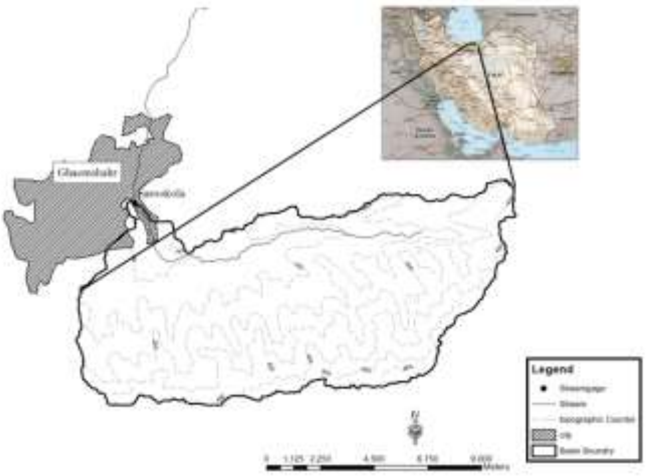

Figure 1. Study Area

Methodology

SCS-CN

In the present study the SCS curve number method was applied for estimation of runoff from rainfall. SCS-CN is an

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empirical method developed by USDA Soil Conservation service. The essential data needed in this method are as follow: Rainfall data, Land use and Land cover information, Soil information. The SCS-CN method calculates direct runoff using following equations:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where Q = runoff (mm) , P = rainfall (mm), Ia = is the initial abstraction and S= potential maximum retention (mm). Through studies of many small agricultural watersheds, Ia was found to be approximated by the following empirical equation:

$Ia = 0.2S$

The runoff curve number (CN) is based on Land use and Land cover, hydrologic soil group and Antecedent Moisture Condition of study area (USDA, 1986). S is related to CN by:

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

Data collection and Processing

In the present study an ASTER image obtained in September 2002, a Landsat 8 image obtained in May 2013, soil hydrologic group data, precipitation data and runoff data were used.

Procurement of LULC data

Thanks to Remote Sensing technology, researchers are able to obtain LULC data from different periods. In the present study, two different images from two different periods were used to extract LULC data. For this purpose object –oriented classification has been performed on images after preprocessing steps.

Preprocessing of Remotely sensed data

Before processing images need to be prepared by geometric and atmospheric correction. Moreover, to enhance the spatial resolution of Landsat 8 image data fusion was applied using IHS method. For this purpose a natural band composition (RGB) was converted into IHS color components. The band number 8 in Landsat 8 OLI sensor which is a panchromatic with 15 meter of spatial resolution was matched and replaced to Intensity component of transformed composite. Finally, the fused image converted back to RGB with spatial resolution of panchromatic band (Sarp, 2013).

Object-Oriented Classification

The Classification unit in Object-oriented approach is segments rather than pixels (Benz et al 2004, Blaschke 2013).The segments are a group of neighboring pixels which resemble features such as spectral Value of pixels, texture, shape, length and location of objects.(Blaschke and Lang, 2006). The object-oriented analysis method is based on Hierarchical patch dynamics (Burnett and Blaschke 2003).The relationship between patches in a certain level and also relationship between levels can provide an enormous amount of information about the landscape (Lewis,2004).This is the reason why Objects have greater potential to represent landscapes than pixels. In order to perform Object-Oriented classification the following steps were implemented:

Image segmentation

The segmentation of the images into objects was influenced by three parameters: scale, color/shape ratio and form/spatial properties (Baatz et al., 2004). According to visual characteristics of the objects, Best values for each parameters was chosen from different values (Baatz et al., 2004). Value of the parameters determines the homogeneity criterion for the objects.

Class Hierarchy

A class hierarchy was created in next step and the segmented objects were assigned to 5 classes (forest, urban area, orchards, dry farming and irrigated farming). Each class was defined by specific color.

Training samples

Samples for each class were picked up by GPS from the study area. The related segment for each samples were selected as a representative of Land Use/Land Cover classes.

Classification

The classification in object-oriented method is based on Fuzzy logic .It means the image objects have degree of memberships in range of 0 to 1 for each class. The value of 0 represents The minimum and 1 represent the maximum probability of belonging an object to a certain class (Baatz et al , 2004).

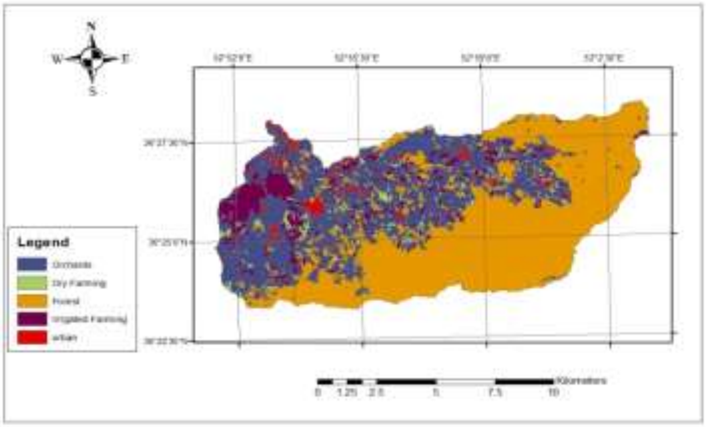

Figure 2.LULC map of Siahroud Watershed in 2002

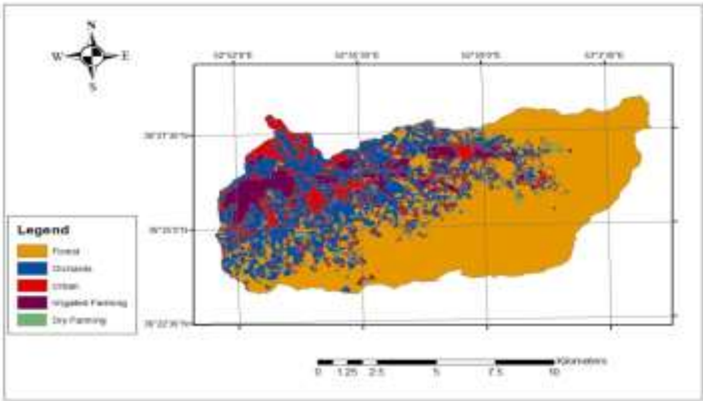

Figure 3.LULC map of Siahroud watershed in 2013

Accuracy assessment

The Accuracy of classification was assessed by construction of confusion matrix for both images. In order to calculate the overall accuracy, total correct pixels were divided by the total number of pixels in the error matrix (Congalton, 1990). The user`s accuracy and producer`s accuracy were calculated in the same way the total accuracy for individual class was (Story and Congalton, 1986). The result of accuracy assessments is shown in table1.

Soil data

Soil data was obtained from Natural resource and watershed management organization of Mazandaran province as a soil hydrologic group map. The map was digitized and rectified to

Table 1. Result of accuracy assessments

Imagery	*Classes*	*Forest*	*Orchards*	*Urban*	*Irrigated Farming*	*Dry Farming*	*Total (%)*	*KAPPA*
Aster	User`s Accuracy (%)	98.06	95.65	94.44	83.33	82.35	93	0.90
(2002)	Producer's Accuracy (%)	99.01	95.65	89.47	75	82.35		
andsat8	User`s Accuracy (%)	96.15	81.82	100	93.33	87.33	91.33	0.86
(2013)	Producer's Accuracy (%)	95	87.80	71.43	87.5	100		

Table 2. SCS-CN parameters for the year 2002 and 2013

SCS-CN parameters	*Antecedent Moisture Condition*			
Curve Number	Year	AMC-I	AMC-II	AMC-III
	2002	42.34	63.61	80.08
	2013	45.24	66.3	81.9
Potential retention	2002	34.59	14.53	6.32
	2013	30.75	12.91	5.61

Table 3. Land Use and Land Cover changes

Classes	*LULC (2002)*	*LULC (2013)*	*Changes (ha)*	*changes (percent)*
Forest	6384	6389	5	0.08
Orchards	2952	2651	-301	-10.20
Urban	1036	1556	520	50.19
Irr- Farming	1404	1258	-146	-10.40
Dry Farming	488	409	-79	-16.19

Table 4. Result of runoff Calculation for 2002

Date 2002	*Rainfall(mm)*	*AMC*	*Computed Runoff*	*Observed Runoff*	*Variation %*
16-Apr	24.3	AMC-I	4.1	4.3	4.88
9-Oct	20.4	AMC-II	1.3	1.2	-7.69
14-Nov	42.6	AMC-II	26.7	29.1	8.99
28-Nov	19.2	AMC-II	1	1.1	10
12-Dec	21.7	AMC-II	12.9	12.8	-0.78
20-Dec	25.4	AMC-II	7.5	7.2	-4
29-Dec	28.3	AMC-III	21	19.9	-5.24

Table 5. Result of runoff calculation for 2013

Date	*Rainfall(mm)*	*AMC*	*Computed Runoff*	*Observed Runoff*	*Variation %*
24-Apr	23.4	AMC-I	0.4	0.3	12.97
9-Apr	35.3	AMC-II	19.6	20.1	-7.25
6-Nov	22.3	AMC-II	2.1	2.3	-8.39
11-Nov	27.6	AMC-III	19.1	16.7	12.35
12-Dec	30.1	AMC-II	5.9	5.3	10.81
21-Dec	24.4	AMC-II	15.2	13.5	10.98
29-Dec	20.1	AMC-II	2.8	3.1	-10.44

Table 6. Calculation of runoff from same rainfall for both scenarios

Date 2002	*AMC condition*	*Rainfall*	*Runoff 2002*	*Runoff 2013*	*Variation (mm)*	*Variation (percent)*
16-Apr	24.3	AMC-I	4.1	4.3	0.2	4.88
9-Oct	20.4	AMC-II	1.3	1.83	0.53	40.77
14-Nov	42.6	AMC-II	26.7	31.19	4.49	16.82
28-Nov	19.2	AMC-II	1	1.4	0.4	40.00
12-Dec	21.7	AMC-II	12.9	15.58	2.68	20.78
20-Dec	25.4	AMC-II	7.5	8.83	1.33	17.73
29-Dec	28.3	AMC-III	21	25.2	4.2	20
Date 2013	*AMC condition*	*Rainfall*	*Runoff 2002*	*Runoff 2013*	*Variation (mm)*	*Variation (percent)*
24-Apr	23.4	AMC-I	0.21	0.25	0.04	19.39
9-Apr	35.3	AMC-II	1.66	1.96	0.30	17.82
6-Nov	22.3	AMC-II	0.15	0.21	0.06	36.96
11-Nov	27.6	AMC-III	1.76	1.92	0.16	9.09
12-Dec	30.1	AMC-II	1.28	1.52	0.24	18.60
21-Dec	24.4	AMC-II	0.21	0.28	0.07	31.97
29-Dec	20.1	AMC-II	0.49	0.59	0.10	20.56

UTM coordinate system (Figure 3). Soil hydrologic group data is an essential input to estimate CN.

Rainfall and runoff data

Daily precipitation of study area and runoff data were obtained from Regional Water organization of Mazandaran province. Runoff data in this study are used to compare results with the observed runoff.

Computation of Average Curve Number

Average Curve Number was calculated for two different periods in this study. For this Purpose LULC map for each year has been combined with Soil hydrologic group. Then, Curve Number for each polygon was assigned using SCS Standard table. Antecedent moisture condition (AMC) is the other effective parameter on CN in SCS method (table2). CN was calculated for AMC-II and then other antecedent moisture condition was computed according to the following formulae:

$$CN\ (AMC\text{-}I) = 4/2CN\ (II) / [10-0.058*CN\ (AMC\text{-}II)]$$

$$CN\ (AMC\text{-}III) = 23\ CN\ (II) / [10+0.13*CN\ (AMC\text{-}II)]$$

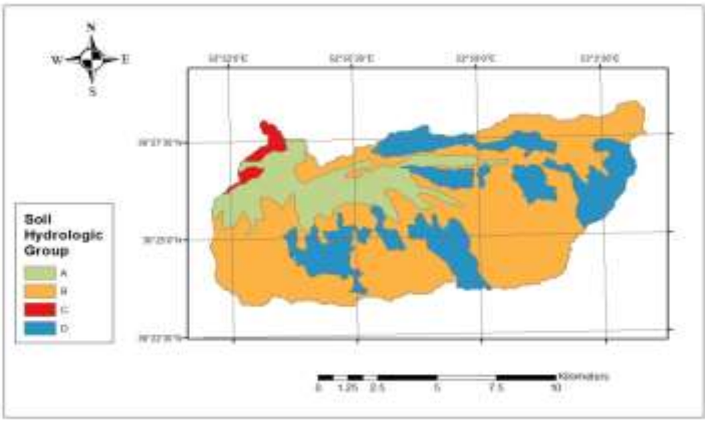

Figure 4. **Soil Hydrologic Group**

Results and Discussion

In this study, the impact of Land Use and Land Cover changes on direct runoff has been assessed. The changes in Land Use and Land Cover during 2002 to 2013 are shown in table 3.A dramatic increase in urban area with 50.19 percent causes increase in direct runoff .Urbanization causes reduction in infiltration due to using rough material such as cement and asphalt on the earth`s surface. There was no reduction in forest cover of watershed due to conservation plans to preserve forests in Mazandaran province during last years. The result of runoff calculations for each period was shown in table 4 and table 5.

Comparison between computed runoff and observed runoff shows that SCS method has a great potential for the estimation of runoff in Siahroud watershed. To assess changes in direct runoff from 2002 to 2013 resulted by the same rainfall 5 to 40 percent increase have been calculated (table 6). In conclusion, the following findings have been resulted in this study:

1. Results confirmed that urbanization highly affects direct runoff.
2. Results of accuracy assessment showed that Object-Oriented classification has a great potential in extracting Land Use and Land Cover data from Satellite imagery.
3. GIS with a flexible environment is a useful tool to prepare input data for SCS method.
4. A good correlation between computed and observed runoff in the study area shows that SCS-CN is a reliable method in the calculation of direct runoff.

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