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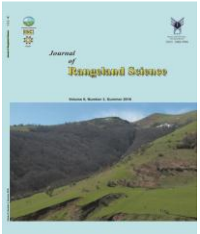

Research and Full Length Article:

Studying the Relationship between Environmental Factors, Runoff Characteristics and Infiltration Depth Using Rainfall Simulator in Northwestern Rangelands of Iran

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Abstract. Runoff leads to the leaching of soil nutrients, transports the topsoil particles and deposits the sediments in water reservoirs. Recognition of different environmental factors affecting the runoff properties and water infiltration depth has a great importance concerning soil for the integrated management of watershed and the distinguishment of complex hydrological processes. Thus, this research aims to determine the environmental factors related to the infiltration depth (ID) and runoff properties including runoff coefficient (RC), time to runoff (TR) and time to stop runoff (TSR) after stopping rainfall using a rainfall simulator. Three catchments involving Shahrchy, Zanjanrood and Glinak were selected based on the rain intensity in 30 minute duration with a 10 year return period in northwestern rangelands of Iran in 2013. The rainfall simulator was established in the rangeland units of each district to operate regarding 30 mm/h rainfall intensity for 30 minutes. Afterwards, data collection with respect to the environmental factors including vegetation (canopy cover and four species diversity indices), topography (slope, height and direction) and soil factors (from 0-30 cm horizons) was fulfilled. Data analysis (71 samples) was done using Pearson correlation and multivariate stepwise regression method. The validity of regression models (18% gathering data equivalent to 15 samples) was tested by R^2 and other statistic indices. Results indicated that 77% variations of RC variable were accounted for canopy cover, sand content, organic carbon, clay content and nitrogen content of soil. Such factors as soil moisture, sand content level, lime content level, species number and Shannon diversity indices explained 73% variations of runoff after rainfall. Similarly, clay content, organic carbon and gypsum content of soil explained 82% variations of time to stop runoff (TSR) and such parameters as slope, latitude, organic carbon and silt content of soil explained 60% variations of infiltration depth (ID).

Key words: Runoff coefficient, Time to runoff, Time to stop runoff, Infiltration depth, Species diversity, Rangeland

Introduction

Runoff is one of the most complex parameters in hydrological processes that should be considered in the optimal water management. Concentrated runoff in a flood form will end up with annual loss of life and detriment of financial, industrial, urban and rural areas. Runoff includes a basic process in soil erosion (Quansah, 1981) that leads to the leaching of soil nutrients, transports the subsoil particles and deposits the sediments in water reservoirs (Perez-Latorre *et al.,* 2010). Runoff Coefficient (RC), Time to Runoff (TR) and Time to Stop Runoff (TSR) after stopping rainfall are very important to introduce the characteristics of surface runoff complex features (Merz and Blölchl, 2009; Norbiato *et al.,* 2009). These three parameters associated with Infiltration Depth (ID) can be studied by a rainfall simulator (Singh *et al.,* 1999) and have major roles in determining the soil moisture content regarded as the most effective factor in controlling vegetation structure and biogeochemical processes in the arid and semiarid ecosystems (Stavi *et al.,* 2008).

Rainfall property considered as an effective factor in producing runoff has been highlighted and focused by several researchers in runoff estimation in wet regions in comparison to the arid and semi-arid areas (Aqil *et al.,* 2007; Nayak *et al.,* 2005; Salajegheh *et al.,* 2009; Dastorani *et al*., 2011; Jafari *et al.,* 2012). For the reason that in the arid areas, only seasonal flood flow data will be recorded, it is not possible to apply the rainfall-runoff simulated models (Lang *et al.,* 1999). Due to financial and time limits, physical conditions of watershed, variations of climate and long-time droughts, the data collection related to different aspects of runoff will be hard under natural conditions. Thus, rainfall simulator as a useful tool has been utilized mainly in these studies (Sadeghi, 2010) and its replication possibility has prevailed over the world (Seeger, 2007). Rainfall simulators can provide the measurements with different replications for determining the effective factors in runoff. Due to repeatability of measurements of simulator, investigating the relationships between runoff and ecological factors will be possible that is extremely important for reducing flood hazard by the watershed managers. Matinez (1998) had described the factors producing runoff in small watersheds and reported that fine texture soils with low infiltration and low organic matter had high runoff and low time of runoff in comparison to coarse texture soils with high infiltration and moderate organic mater. Santos *et al.* (2003) found that sandy soil produced few runoffs due to more infiltration. Foltz *et al.* (2009) pointed out that the changes in soil physical properties and decrease in vegetation led to the increased runoff in forest ecosystems with trampled roads. Zhao *et al.* (2014) concluded that time to runoff indicated a negative and exponential relationship with rainfall intensity and antecedent moisture content and a negative and linear relationship with slope degree. In above mentioned research, runoff coefficient indicated a positive and linear relationship with rainfall intensity and antecedent moisture content and a positive and powerful functional relationship with slope degree.

Inside the country, significant effects of soil parent materials on runoff coefficient and start time to runoff in Golabad watershed of Ardestan have been previously reported (Sheklabadi *et al.,* 2003). Sharifi *et al.* (2004) investigated the effective factors in determining the threshold of runoff in the arid and semi-arid regions in the country while utilizing the simulation and rainfall-runoff data. Variables such as height of rainfall, rainfall intensity, vegetation cover, sand, clay and slope (with constant initial moisture content) were reported as the effective factors. Vaezi *et al.* (2008) found that runoff coefficient could be predicted by coarse sand, soil calcareous content and organic matter. Orsham *et al.* (2010) concluded that the antecedent moisture content of soil is one of the most important factor affecting runoff and deposition. The results obtained by Abdinejad *et al*. (2010) demonstrated that time to runoff in marl formation of Zanjan might be short when silt content of marl was increased.

Najafian *et al.* (2010) suggested that grass vegetative form produced the least runoff volume in comparison to the other vegetative forms. Kavian *et al.* (2010) suggested that the prediction of runoff coefficient (R^2=0.64) could be possible by soil moisture, organic matter and clay content. Rezaei (2011) studied the effect of slope length on infiltration variable and revealed that infiltration factor increased to 22 m and for more than 22 m length, it is slightly decreased with a linear trend. Zare Khormizi *et al.* (2012) reported that runoff volume increased from 0.38 to 0.41 (Litter) when slope percent shifted from 0-10% to above 30%. Habibzade *et al.* (2013) illustrated the significant relationship between slope degree and runoff volume. Environmental factors affecting different parameters of runoff and infiltration depth have a great importance in watershed integral management and recognition of complex hydrological processes. Thus, this research was carried out to determine the environmental factors' relationship to Runoff Coefficient (RC), Time to Runoff (TR) and Time to Stop Runoff (TSR) after stopping rainfall and Infiltration Depth (ID) using a rainfall simulator.

Materials and Methods

Study area

This research was carried out to establish a rainfall simulator in northwestern rangelands of Iran (Fig. 1) while applying the rain intensity in 30 minute duration with a 10-year return period (Saghafian, 2002). So, three catchments including Shahrchy, Zanjanrood and Glinak that have the same rain intensity in 30 minute duration with a 10-year return period (equal to 30 mm/h intensity based on Intensity-Duration–Frequency (IDF) graph of meteorological stations) were chosen for the study. Location map (Fig. 1), physical characteristics (Table 1) and Meteorology properties (Table 2) of three studied regions have been illustrated. Field operations were conducted by providing the rainfall simulator from Research Centre of Soil Conservation and Watershed Management. This tool with 110 kg weight is a kind of non-pressure simulator which has Plexiglas genus and 89 ×120 cm dimensions. Maximum height of this tool is 1.5 m and can be regulated by its adjustable legs in the desirable slope. There are 216 droppers on the raining sheet (Fig. 2).

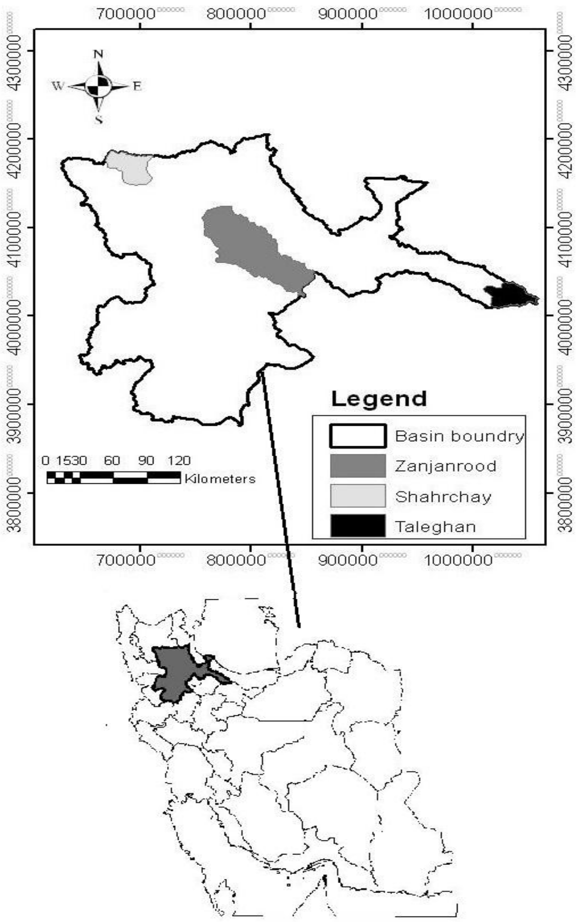

Fig. 1. Map of studied watersheds in northwest of Iran and Sefidrood basin

Table 1. Physical characteristics of studied regions

watershed name	Area (km^2)	Perimeter (km)	Watershed length (km)	slope (%)	Elevation (m)	Horton coefficient	Slope of major river (%)	Susceptive formations to erosion in pre-quaternary (%)	Quaternary Formation (%)	rangeland Land use (%)	Mean-year discharge (m^3/s)	Peak discharge (m^3/s)
Zanjanroud	4539.61	351.64	128.48	10.32	1806.94	0.27	0.51	16.66	47.93	0.56	4.21	94.89
Shahrchay	1041.96	154.70	49.29	14.04	1876.07	0.43	0.84	46.89	17.50	0.55	2.95	74.28
Glinak	828.11	142.22	41.69	41.23	2732.98	0.48	2.13	26.36	4.05	0.95	12.42	116.19

Table 2. Meteorology characteristics of studied regions

Watershed name	Station name and type	Station code	Longitude	Latitude	Elevation (m)	Temperature (ºC)	Fournieh Erosivity index	Annual precipitation (mm)	24 hour Precipitation (mm)	Actual annual evaporation (mm)
Zanjanroud	Zanjan (synoptic)	17-032	48 12	37 03	1750	10.15	21.14	318.35	26.59	2203.26
Shahrchay	Myaneh (data logger rain gauge)	17-027	47 21	37 32	1480	10.1	22.4	328.41	30.52	1621
Glinak	Zidasht (data logger rain gauge)	17-060	50 41	36 10	1751	10.34	29.54	473.38	33.27	1666.23

Fig. 2. Image of rainfall simulator used

Before establishing the rainfall simulator in each site, soil samples were taken in four corners of simulator plot at depths of 0 to 30 cm and were mixed together as one sample. It is because of eliminating the heterogenic effects of soil. Totally, 88 soil samples were moved to the pedology laboratory of Department of Environment and Natural Recourses of Tehran University for analyzing the following characteristics:

- The soil organic carbon percent was determined using wet burning test procedures (Walkley and Black, 1934).
- Total nitrogen percent was determined by titration with dilute sulfuric acid at a concentration of 0.05 (McGill and Figueiredo, 1993).
- Absorbable phosphorous was determined using Olsen *et al*. (1954) method.
- Absorbable potassium was determined at pH 7 in buffered ammonium acetate solution (Simard, 1993).
- Acidity was measured by a pH meter.
- Soil lime content was measured by calcimetry method (McLeen, 1982).
- Soil moisture was measured by an oven (70ºC for 47 h) based on pre and post weights.
- Electrical conductivity (EC) of soil was determined using the Carter method (Zarinkafsh, 1993).
- Soil texture measurements (sand, silt and clay percent) were conducted using a standard lab hydrometer method (Zarinkafsh, 1993).

Prior to establishing rainfall simulator in each site, the sampling of vegetation attributes (such as canopy cover, gravel of subsoil, and presence of species) was done in the simulator plot. Abundance of species was used by PAST package to determine different diversity species indices such as species number, Simpson index, Shannon and Weiner index and dominance index; the related formulas have been presented in Table 3.

Table 3. Introducing the diversity species indices (Ghehsareh Ardestani *et al*., 2010)

Index	Formula
Species number	$\frac{S}{\text{Area Sampled}}$
Simpson index	$\text{ë} = \sum_{i=1}^{s} \frac{n_i(n_{i-1})}{n(n-1)}$
Shannon and Weiner index	$H' = -\sum_{i=1}^{s}\left[[\frac{n_1}{n}] Ln[\frac{n_1}{n}] \right]$
Dominance index	PAST software

Where:
S= number of species
n= total number of people in the sample and
n_i= number of individuals in species

Altitude and slope percent of rainfall simulator plots were recorded. To rain the intensity of 30 mm/h for 30 minutes, the rainfall simulator was established in each site. Then, such dependent variables as Infiltration Depth (ID) and runoff properties including Runoff Coefficient (RC), Time to Runoff (TR) and Time to Stop Runoff (TSR) were measured after stopping rainfall using the rainfall simulator. Runoff coefficient (RC) was calculated through dividing the amount of runoff by rainfall content. Infiltration Depth (ID) was measured with a ruler (with an accuracy of 1 mm) in the center of each plot at the end of sampling.

The collected data of 86 sites were considered as independent variables including pedology, vegetation and topography data and depended variables involving the measurements of rainfall simulator provided as a matrix. SPSS 16 software was utilized for the correlation and regression analyses (71 sites). The best regression model was introduced using multivariate linear regression at stepwise method based on R^2. Validation test was performed on data for 15 sites (5 sites from each region) using RMSE (root of mean square error), MBE (mean bias error) and MAE (mean absolute error) indices with the following formulas (Issak and Srivastava, 1989).

Results

Statistical characteristics of all dependent and independent variables are shown in Table 4. Variation ranges of dependent variables such as RC (%), TR (min), TSR (min) and ID (cm) were given as 89, 35.5, 1.5 and 9.2, respectively. Higher range of variation estimated as 1124 m in the independent variables was belonged to altitude.

Table 4. Descriptive Statistics of all studied variables

Variable type	Variables	Mean	Minimum	Maximum	Standard deviation
	Altitude (m)	1899	1187.0	2311.0	241.06
Independent	Slope (%)	30.6385	9.00	51.00	11.61
	Pavement (%)	13.2064	0.00	70.00	16.06
	Canopy cover (%)	35.64	0.00	80.00	19.47
	Soil moisture (%)	5.49	2.00	16.00	3.08
	Electrical conductivity (ds/m)	0.77	0.25	6.10	1.21
	Calcareous content (%)	13.82	1.70	28.30	8.36
	Gypsum content (%)	57.53	1.60	76.40	23.35
	Organic carbon (%)	1.013	0.11	1.94	0.532
	Total nitrogen (%)	0.058	0.02	0.13	0.028
	Available phosphorus (mg/kg)	18.91	9.70	30.00	6.28
	Available potassium (mg/kg)	307.25	144.0	779.0	126.78
	Sand (%)	48.70	10.00	76.00	21.02
	Silt (%)	26.25	6.00	42.00	9.63
	Clay (%)	25.04	2.00	56.00	15.91
	Na^+ cation	2.151	0.29	18.90	4.48
	Ca^{++} cation	6.087	1.40	41.60	9.26
	Species number	4.297	1.00	10.00	1.81
	Dominance index	0.461	0.13	1.00	0.206
	Shannon and Weiner index	1.007	0.00	2.17	0.463
	Simpson index	0.539	0.00	0.87	0.206
	Runoff Coefficient (RC)	34.04	5.50	95.00	23.76
Dependent	Time to Runoff (TR) (min)	14.25	4.50	40.00	7.32
	Time to Stop Runoff (TSR) (min)	1.03	0.30	1.80	0.386
	Infiltration Depth ID (cm)	5.84	1.80	11.00	2.28

The Pearson correlation was estimated for soil variables (Table 5), the correlation between pedology, vegetation, topography plant diversity and runoff characteristics (Table 6) and the correlation between environment, plant diversity, runoff characteristics and soil properties (Table 7).

Pearson correlation of soil variables (Table 5) showed that soil moisture was negatively correlated with organic carbon. A positive correlation was obtained between soil moisture and K ($P<0.01$). Soil EC was negatively associated with total nitrogen ($P<0.05$) and sand content ($P<0.01$). There were also positive correlations between EC and silt percent, Na^+ and Ca^{++} ($P<0.01$). Calcareous content had positive correlations with gypsum, clay and silt content and a negative correlation with sand content ($P<0.01$). Gypsum was negatively correlated with sand percent, total nitrogen and positively correlated with clay and silt content ($P<0.01$). Organic carbon was ppositively correlated with total nitrogen ($P<0.01$) and negatively correlated with Ca^{++} ($P<0.05$). Total nitrogen was negatively correlated with Na^+ and Ca^{++} ($P<0.05$) and positively related to P and K ($P<0.01$). P had positive correlations with K and clay percent and was negatively correlated with Na^+ ($P<0.01$). K had a negative correlation with sand percent ($P<0.05$) and was positively correlated with clay percent ($P<0.01$). Sand percent was negatively correlated with silt, clay and Ca^{++}. Silt percent was positively correlated with clay percent ($P<0.01$) and Na^+ and Ca^{++} ($P<0.05$). A positive correlation was observed between clay percent and Ca^{++} ($P<0.01$).

Pearson correlation between pedology, vegetation and topography plant diversity and runoff characteristics was illustrated in (Table 6). There was a negative relationship between the altitude and dominance index. Altitude had positive relationships with canopy cover ($P<0.05$), species number, Shannon Weiner index and Simpson index ($P<0.01$). There was a negative correlation between Altitude and ID. Slope degree was negatively correlated to ID and TSR. A negative relationship was seen between pavement percent and canopy cover ($P<0.05$). Canopy cover was negatively correlated with dominance index and positively correlated to species number, Shannon Weiner index and Simpson index ($P<0.05$). Canopy cover was negatively correlated with RI and positively correlated with TR and TSR ($P<0.01$). Species number was positively correlated with dominance index, TR, TSR and negatively correlated with Shannon Weiner and Simpson indicators and RI ($P<0.01$). There was a negative relationship between dominance index, Shannon Weiner and Simpson indicators ($P<0.01$). Shannon Weiner index and Simpson index had a positive relationship ($P<0.01$). Runoff coefficient had negative relationships with TR, TSR and ID. A positive relationship was observed between TR and TSR. Pearson correlation between environment, plant diversity, runoff characteristics and soil properties (Table 7) showed that soil moisture was negatively associated with canopy cover and dependent variables (including RI, TR and TSR). EC was negatively correlated with Altitude, pavement percent, species number, Shannon Weiner and Simpson index and positively correlated with dominance index ($P<0.01$). Calcareous had negatively correlated with slope and pavement percent. Organic carbon was positively correlated with TR, TSR and ID and negatively correlated with RI, canopy cover and species number ($P<0.01$). Total nitrogen had positive relations to Simpson index and RI and a negative relation to dominance index ($P<0.05$). A negative correlation was observed between P and dominance index and positive correlation with altitude and Simpson index. P was negatively correlated with TR and positively correlated with RI. Results showed a negative relationship between K and pavement percent. K had also a negative relationship with TR and a positive relationship to RI. In spite of clay percent, sand percent had a negative relationship with TSR and positive relationship to pavement percent. There was a negative correlation between silt percent and pavement percent. There was a positive relationship between Na^+ and dominance index. Na^+ was negatively correlated with Altitude, species number, Shannon Weiner index and Simpson index.

The results of Pearson correlation indicated that all dependent variables of this research (as RC, TR, TSR and ID) had a significant correlation with soil organic carbon variable. Additionally, independent variables including canopy cover, number of species, soil moisture were correlated to all dependent variables of runoff properties (as RC, TR and TSR). Available soil K and P had a significant correlation to RC and TR. Soil texture properties such as clay and sand percent were correlated to TSR as a dependent variable and topographic factors such as height and slope had significant relationships with ID as a dependent variable.

The best regression models for four dependent variables including RC, TR, TSR and ID are illustrated in Table 8. According to the regression models, such factors as canopy cover, sand content, organic carbon, clay content and total nitrogen content of soil explained RC variations. Factors including sand content, soil moisture, soil calcareous content, number of species and Shannon species diversity index were involved in TR regression model. Additionally, such variables as clay, organic carbon and gypsum content of soil represented variations of TSR and such variables as slope, altitude, organic carbon and silt content of soil explained ID changes as a dependent variable.

The best equation fitted between the observed and estimated data in addition to the other validation indices was illustrated for all dependent variables in Fig. 3. According to the results, the highest coefficient of determination (R^2) was equivalent to 82% and related to TSR regression model.

Table 5. Pearson correlation between soil variables

Variables	Soil moisture	EC (ds/m)	Calcareous (%)	Gypsum (%)	OC (%)	N (%)	P (mg/kg)	K (mg/kg)	Sand (%)	Silt (%)	Clay (%)	Na^+ cation
EC (ds/m)	0.08											
Calcareous%)	0.12	0.22										
Gypsum (%)	-0.13	0.018	0.50**									
Organic carbon (%)	-0.62**	-0.22	-0.01	0.02								
N (%)	-0.07	-0.25*	-0.14	-0.31**	0.33**							
P (mg/kg)	0.163	-0.11	-0.08	-0.07	-0.10	0.47**						
K (mg/kg)	0.33**	0.31**	0.156	-0.07	0.01	0.26*	0.30**					
Sand (%)	-0.01	-0.31**	-0.67**	-0.47**	0.17	0.20	-0.18	-0.25*				
Silt (%)	-0.01	0.32**	0.61**	0.42**	-0.05	-0.09	-0.13	0.06	-0.69**			
Clay (%)	0.03	0.22	0.50**	0.36**	-0.20	-0.21	0.32**	0.29*	-0.90**	0.31**		
Na^+ cation	-0.01	0.84**	0.18	0.18	-0.16	-0.29*	-0.38**	0.21	-0.19	0.27*	0.09	
Ca^{++} cation	0.13	0.93**	0.18	0.18	-0.25*	-0.24*	0.07	0.34**	-0.35**	0.25*	0.31**	0.62**

*, **= Significant at 5%, 1%, respectively

Table 6. Pearson correlation between pedology, vegetation and topography plant diversity and runoff characteristics

Variables	Altitude (m)	Slope (%)	Pavement (%)	Canopy cover %	Species number	Dominance index	Shannon index	Simpson index	RC	TR (min)	TSR (min)
Slope (%)	0.17										
Pavement (%)	-0.18	0.12									
Canopy cover	0.25*	0.01	-0.29*								
Species No	0.53**	0.02	-0.09	0.43**							
Dominance index	-0.47**	-0.13	-0.10	-0.23*	-0.62**						
Shannon Weiner index	0.50**	0.16	0.03	0.29*	0.73**	-0.96**					
Simpson index	0.47**	0.13	0.10	0.23*	0.62**	-0.99**	0.96**				
Runoff Coefficient (RC)	0.12	-0.02	-0.13	-0.35**	-0.31**	-0.01	-0.04	-0.02			
Time to Runoff ((min)	0.20	-0.11	0.08	0.33**	0.53**	-0.10	0.11	0.11	-0.57**		
Time to Stop Runoff (min)	0.13	-0.25*	-0.14	0.36**	0.38**	-0.09	0.11	0.09	-0.51**	0.46**	
Infiltration Depth (cm)	-0.45**	-0.53**	0.05	-0.11	-0.13	0.16	-0.21	-0.16	-0.29*	0.15	0.26*

*, **= Significant at 5%, 1%, respectively

Table 7. Pearson correlation between environment, plant diversity and runoff characteristics and soil properties

Variables	Soil moisture	EC (ds/m)	Calcareous (%)	Gypsum (%)	OC (%)	N (%)	P (mg/kg)	K (mg/kg)	Sand (%)	Silt (%)	Clay (%)	Na^{+} cation	Ca^{++} cation
Altitude (m)	-.027	-0.63**	0.03	0.13	0.08	0.21	0.32**	-0.16	-0.10	0.08	0.08	-0.66**	-0.50**
Slope (%)	-0.13	-0.11	-0.39**	-0.10	-0.15	-0.08	-.040	-0.22	0.20	-0.15	-0.18	-0.08	-0.10
Pavement (%)	-0.17	-0.23*	-0.30*	-0.13	0.06	0.05	-0.10	-0.41**	0.48**	-0.43**	-0.39**	-0.15	-.241*
Canopy cover (%)	-0.30**	-0.05	0.06	0.03	0.38**	0.27	-0.02	0.15	-0.16	0.22	0.08	-0.02	-0.04
Species No	-0.22	-0.31**	0.19	0.11	0.38**	0.08	-0.03	-0.07	-0.03	0.12	-0.02	-0.34**	-0.26*
Dominance index	0.03	0.32**	-0.11	-0.14	0-.09	-0.24*	-0.25*	-0.03	0.01	-0.07	0.04	0.30**	0.29*
Shannon Weiner	-0.04	-0.31**	0.11	0.08	0.10	0.22	0.22	0.04	-0.07	0.09	-0.04	-0.31**	-0.28*
Simpson index	-0.03	-0.32**	0.11	0.13	0.09	0.24*	0.25*	0.03	-0.02	0.07	-0.04	-.31**	-0.29*
Runoff Coefficient (RC)	0.76**	0.05	0.06	-0.14	-0.60**	0.23*	0.39**	0.27*	-0.11	0.06	0.14	-.039	0.10
Time to Runoff (min)	-0.47**	-0.22	0.07	0.15	0.54**	-0.11	-0.32**	-0.23*	0.10	-0.05	-0.10	-.198	-0.20
Time to Stop Runoff (min)	-0.61**	-0.08	0.19	0.07	0.79**	0.21	0.10	0.06	-0.25*	0.13	0.25*	-0.08	-0.09
Infiltration Depth (cm)	-0.11	0.010	-0.01	-0.10	0.37**	-0.01	-0.11	0.21	0.16	-0.20	-0.09	0.14	0.07

*, **= Significant at 5%, 1%, respectively

Table 8. The final regression equations of dependent variables using stepwise regression model

Dependent Variables	Regression model	Independent variables	R^2	F test
Runoff Coefficient (RC)	RC= 7.97+3.92X1-14.3X2+ 344.9X3-0.215X4+0.25X5	X1= Soil moisture (%) X2= Organic carbon (%) X3= Total nitrogen (%) X4=Canopy cover (%) X5= Clay content (%)	0.77	43.35^{**}
Time to Runoff (min)	TR=2.38+2.87X1-0.70X2- 4.29X3+0.099X4+0.19X5	X1= Species number X2= Soil moisture (%) X3=Shannon index X4=Sand content (%) X5= Calcareous content (%)	0.73	34.07^{**}
Time to Stop Runoff (min)	TSR=0.194+0.65X1+0.012X2- 0.002X3	X1= Organic carbon (%) X2= Clay content (%) X3= Gypsum content (%)	0.82	99.38^{**}
Infiltration Depth (cm)	ID=15.41-0.087X1-0.004X2+ 1.47X3-0.062X4	X1=Slope (%) X2=Height (m) X3= Organic carbon (%) X4= Silt content (%)	0.60	24.07^{**}

**= Regression coefficient is ssignificant at 1% probability leve.

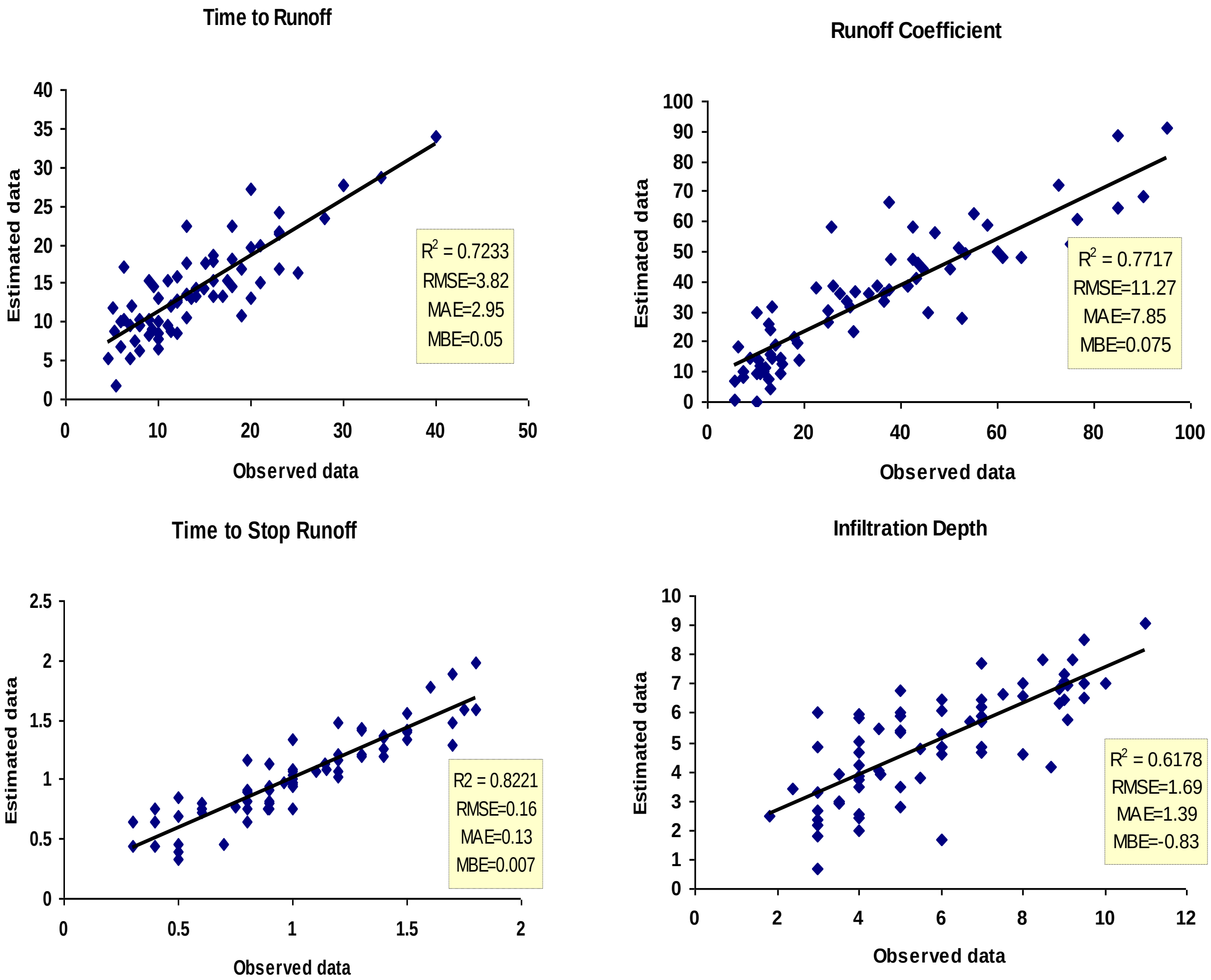

Fig. 3. Estimated and observed data of regression model

Discussion

Runoff Coefficient

Based on the constant rainfall intensity given as 30 mm/h for 30 min, the findings of runoff coefficient revealed that 77% runoff coefficient variations can be explained by such factors as canopy cover, sand content, organic carbon, clay content and total nitrogen content of soil. Runoff coefficient affectability from such variables as soil organic matter and soil texture (Santos *et al.*, 2003; Vaezi *et al.*, 2008; Kavian *et al.*, 2010), antecedent moisture content of soil (Castillo *et al.*, 2003; Kavian *et al.*, 2010), and vegetation type (Foltz *et al.*, 2009; Puigdefbregas, 2005; Wei *et al.*, 2007; Najafian *et al.*, 2010) has been previously reported. Thus, the results are consistent with these studies. Additionally, a regression model of runoff volume variable has been presented by antecedent moisture content of soil and vegetation density in Golestan of Alborze province (Vahabi and Mahdian, 2009). In fact, soil moisture content is an important factor for controlling and dictating the vegetation structure, soil processes (Li *et al.*, 2008), vegetation and biogeochemical processes (Stavi *et al.*, 2008) in the arid and semi-arid rangeland ecosystems. Thus, soil moisture content has been reported as an effective factor in runoff coefficient in the semi-arid ecosystem (Castillo *et al.*, 2003; Ceballos and Schnabel, 1998).

Regression model of runoff coefficient showed a significant relationship between runoff coefficient and total nitrogen of soil. Pearson coefficient test illustrated a meaningful relationship between runoff coefficient and four variables of soil chemical properties such as total nitrogen, organic carbon, K and P. Therefore, continuous management of soil and conservation of soil quality are suggested to all natural resources managers in order to decrease the runoff coefficient. Thus, a range manager could decrease the runoff coefficient not only through improving the vegetation in rangeland ecosystems via proper stocking rate, but also through enhancing the soil quality via this management tool.

Time to runoff

Results of this research indicate that soil factors such as sand content, moist content and calcareous content in addition to vegetation factors such as number of species and Shannon species diversity indices presented 73% variations of time to runoff beginning after rainfall. Effective roles of soil texture and soil organic matter in time to runoff (Matinez, 1998) and roles of soil antecedent moisture content in time to runoff (Zhao *et al.*, 2014) have been previously reported. Sharifi *et al.* (2004) noted that canopy cover and soil texture variables determined time to runoff factor. Thus, the results agreed with these studies.

Zhao *et al.* (2014) declared that time to runoff has been negatively related to antecedent moisture content of soil and has been changed according to the species type. Time to runoff has been increased in *Lolium perenne* vegetative type in comparison to *Triticum aestivum* and *Medicago sativa*.

Considering the existence of a significant relationship between time to runoff, species number and Shannon diversity indices, the results of this research were consistent with Zoa *et al.* (2014) studies. The interaction between diversity index and slope (Chaplot and Le Bissonnais, 2003) showed that slope variable had no significant impact on time to runoff in this research. Thus, identifying the interaction between diversity index and slope concerning the time to runoff is suggested.

Duo to the effect of Shannon diversity index on time to runoff through different systems of root and aerial part, we suggest that the effect of species type is separately investigated with respect to time to runoff. Also, managers and related offices should focus on species diversity index for decreasing the flood hazard.

Time to stop runoff after stopping rainfall

Results indicated that such variables as clay content, organic carbon and gypsum content of soil explain 82% variations of time to stop runoff after stopping rainfall. Considering the middling of both canopy cover and species diversity index concerning all runoff hydrologic variables including RC, TR and TSR, our findings suggest that the related operation offices have special plans regardless to the inherent relation between hydrological and range management factors. In order to decrease the runoff and flood by the related executive organs to natural ecosystems, all hazards such as overgrazing which may threaten species number, species diversity and canopy cover factors must be focused.

According to significant roles of soil structure factors including soil organic carbon and soil gypsum content in the related regression model, our results suggest that the time to stop runoff after stopping rainfall variable must be separately investigated in soils with different structures.

Infiltration depth

According to the results, 60% variations of infiltration depth were explained by such parameters as slope, altitude, organic carbon and silt content of soil. Despite organic matter when silt content, slope and altitude increased, the infiltration depth decreased. Actual effect of slope on runoff and sediment delivery ratio may depend on soil antecedent moisture content (Defersha and Melesse, 2012; Chaplot and Le Bissonnais, 2003). Perhaps, because of the rapid flow of water of rainfall in the first slope length in steep lands, the opportunity for infiltration is decreased (Rezaei, 2010). To investigate the interaction of slope length and slope percent to infiltration depth is suggested. Due to higher maintenance of water by soil organic carbon, infiltration depth increases in soil with higher soil organic carbon. Silt content of soil causes the increased soil erodibility as well as decreased infiltration depth.

Conclusion

Due to the acceptable accuracy and low error of regression models and the proximity of estimated data to the observed ones in validation section for parameters of RC, TR and TSR, the application of related regression models to determine the mentioned parameters for the same areas is possible.

It seems that considering more factors of soil structure such as soil particle size that are not included in this study as an input variable can enhance the accuracy of model related to depth of water infiltration in the soil.

Accordingly, it is suggested that besides organic carbon, gypsum and lime of soil that have fundamental roles in soil structure, and such parameters as soil particle size as an input variable should be considered in future studies regarding depth of water infiltration in the soil.

With regard to the significant correlation between species diversity index (species number) and TSR, maintenance of the Shannon species diversity index in TR regression model and focus on canopy cover in most of the related studies, there is a suggestion for the researchers to apply species diversity indices in future studies regarding runoff. There is also a suggestion for executive agencies to maintain species diversity indices in pasture ecosystems that can be considered as research innovations specified for this study.

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تعیین رابطه عوامل محیطی با خصوصیات رواناب و عمق نفوذ آب به کمک شبیه‌ساز باران در مراتع شمال غرب کشور

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چکیده. از آنجا که شـــناخت عوامل محیطی دخیل بر پارامترهای مختلف رواناب و عمق نفوذ آب در خاک جهت مدیریت جامع یک حوزه آبخیز و درک فرآیند پیچیده هیدرولوژیکی رواناب و نفوذ بســیار حائز اهمیت اســـت، بنابراین این تحقیق با هدف تعیین رابطه عوامل مختلف محیطی با پارامترهای ضـــریب رواناب، زمان شـروع رواناب پس از بارش و زمان قطع رواناب پس از قطع بارش و عمق نفوذ به کمک شـبیه سـاز باران (با توجه به قابلیت تکرار پذیری برداشــت داده‌ها) در ســال ۱۳۹۲ انجام شــد. ســه منطقه مطالعاتی شــهرچای، زنجان‌رود و گلینک بر اساس بارندگی نیم ساعته با دوره بازگشت ده ساله از مراتع شمال غرب کشور انتخاب شدند. باران ساز در واحدهای مرتعی منتخب هر منطقه جهت اعمال شدت بارندگی ۳۰ میلی‌متر در ساعت مستقر شد. سپس برداشت داده‌های محیطی شامل پوشش گیاهی (درصد پوشش تاجی و ۴ شاخص تنوع گونه‌ای)، توپوگرافی (در صد شیب، ارتفاع و جهت جغرافیایی) و نمونه‌های خاک از گوشه‌های پلات از عمق ۰-۳۰ ســانتی‌متری گرفته شــد. جهت آنالیز داده‌ها از همبســتگی دوگانه پیرســون و مدل رگرســیونی چند متغیره گام به گام (در ۷۱ نمونه) کمک گرفته شد. اعتبار سنجی مدل‌های رگر سیونی (۱۸ در صد داده‌های بردا شت شده معادل ۱۵ سایت از سه منطقه مطالعاتی) با شاخص R^2 انجام شد. نتایج نشان داد که ۷۷ درصد تغییرات ضریب رواناب توسط عواملی چون پوشش تاجی، رطوبت خاک، کربن آلی خاک، میزان رس و میزان ازت خاک، توجیه می‌شود. عواملی چون رطوبت خاک، میزان شن خاک، میزان آهک خاک، تعداد گونه و شاخص تنوع شانون ۷۳ در صد تغییرات مربوط به زمان شروع رواناب پس از بارش را تبیین می‌کنند. هم چنین عواملی چون میزان رس خاک، میزان کربن آلی خاک و میزان گچ خاک ۸۲ در صد تغییرات مربوط به قطع رواناب و عواملی چون ارتفاع ، شیب، کربن آلی و سیلت خاک ۶۰ در صد تغییرات مربوط به عمق نفوذ آب در خاک را توجیه می‌کنند.

کلمات کلیدی: ضریب رواناب، زمان شروع رواناب، زمان قطع رواناب، عمق نفوذ، تنوع گونه‌ای، مرتع