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Original Article

Impact of Wheat Residue on Soil Erosion Processes

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Abstract

Soil erosion is one of the key challenges in soil and water conservation. Vegetation that covers soil and organic and inorganic mulch is very useful for the control of erosion processes. This study examined treatment with wheat residual (as agriculture mulch) on infiltration, time to runoff, runoff coefficient, sediment concentration and soil erosion processes. The study has been conducted for sandy-loam soil taken from summer rangeland (Northern Iran) with simulated rainfall intensities of 50 and 100 mm h^{-1}. The experiment was conducted in slopes of 30% in three replications with two amounts of wheat residual of 50 and 90 %. The results showed that conservation percent of soil erosion for wheat residual 50 and 90% was 61.68 and 73.25%, respectively (in rainfall intensity of 50 mm h^{-1}). Also, the conservation percent of soil erosion for wheat residual of 50 and 90% cover was 70.68 and 90.55, respectively (in rainfall intensity of 100 mm h^{-1}). It was concluded that the conservation treatments could reduce runoff coefficient, sediment concentration and soil erosion and increase the time to runoff and infiltration coefficient. This effect was significant on time for infiltration, sediment concentration and soil erosion variables (R^2=0.99), time to runoff and runoff coefficient variables (R^2=0.95). The interaction effects of rainfall intensity and soil conservation was significant for sediment concentration and soil erosion variables (R^2=0.99).

Keywords: agricultural plants; runoff; rainfall duration; soil conservation; soil loss

Introduction

Soil erosion is one of the most widespread and a major environmental threat which decreases agricultural productivity and affects water quality (Nearing *et al*., 2005; Khaledi Darvishan *et al.,* 2012 and 2016; Spalevic *et al*., 2013; Mohammadi and Kavian, 2015; Kavian *et al*., 2017; Spalevic *et al*., 2017). There are many methods for soil conservation with different performances and mechanisms, but the vegetation is the best method. Sometimes, the vegetation cannot be established in natural lands and in such cases we have to use organic and inorganic conditioners (Cerdà *et al*., 2016 and Jimenez *et al*., 2016). Organic and inorganic mulches, crop residues, leaf litter, woodchips, bark chips, biological geotextiles, gravel and crushed stones have been applied as conservation measure successfully (Smets *et al*., 2008; University of Tennessee Institute of Agriculture, 2018).

The effect of mulches depends on many factors including raindrops erosivity, soil condition, steepness and length of slope, and the mulch rate and type (Amimoto, 1981; Cogo *et al*., 1984; Poesen and Lavee, 1991; Morgan, 1995; Auerswald *et al*., 2003; Safari *et al*., 2016). Among organic conservations, residual can be more effective in preventing soil erosion (Centre for Watershed Protection, 2001). The straw mulch can protect soil moisture (Ji and Unger, 2001) and this conditioner adds organic matter to soil (García-Orenes *et al*., 2010), has potential in runoff reduction (Poesen and Lavee 1991) and soil erosion controls (Morgan, 1986; Gholami *et al*., 2016a). The wheat residual may increase cultivation amount, improving at the same time infiltration, reducing runoff and soil erosion; as well as increasing water storage capacity (Mannering and Meyer, 1963; Shi *et al*., 2013; Wang *et al*., 2017) and decreasing evaporation (Mooers *et al.* 1948).

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Mannring and Meye (1963) used straw mulch to control soil loss and infiltration for slope of 5% with cover amount of 1, 2 and 4 t ac^{-1}. The results revealed that the straw mulch could increase but also reduce infiltration and soil erosion. In the early phases of the subject research Adams (1966) studied influence of rice straw mulch on runoff and soil loss in 0.4 m^2 plots on a 4% slope in USA. His team observed that the straw mulch could reduce runoff and soil loss. Meyer *et al.* (1970) applied wheat residual with rates of 0.56, 1.12, 2.24, 4.48 and 8.96 t ha^{-1} on soil loss in USA. The straw mulch with rates of 0.56 and 1.12 t ha^{-1} could decrease soil loss about 33%. Lal (1976) investigated rice straw mulch with the rates of 4 and 6 t ha^{-1} on runoff and soil loss in tillage and no-tillage soils and slope of 15%. The results showed that the straw mulch application in tillage soil was highly effective in reducing runoff and soil loss. He applied the straw mulch with cover of 60 and 90% for sandy loamy, sandy silty loamy and loamy sandy on changes of soil loss. The soil loss is reduced with application of straw mulch by about 70, 86 and 80% (with cover of 60%) and by 86 and 95% (with cover of 90%). Loch and Donnollan (1988) successfully reported the effect enhancement of wheat residual at plot scale for rates of 0.1 and 3 t ha^{-1} in the Australia.

Lal (1998) showed that the runoff decrease in field plots after application straw mulch because this conditioner could reduce runoff and soil concentration. Poulenard *et al.* (2001) studied the infiltration, runoff and soil erosion under rainfall simulation of andisols for the *páramos* in Colombia effect of tillage and burning in plot scale. The results presented that the infiltration rate was very high and sediment loss very low. Results for infiltration rate and runoff indicated that land use change on *páramos* increased runoff flow and sediment losses from natural undisturbed *páramos* were very low. Ruy *et al.* (2006) studied the effect of corn crop residual on runoff and soil loss in la Tinaja (Mexico-State of Jalisco). Four treatments were analysed: bare soil no till and no plant with 1.5 t ha^{-1}, direct drilling of corn with 1.5 and 4.5 t ha^{-1}. They stated that the corn mulch could decrease runoff and soil loss.

Adekalu *et al.* (2007) investigated *Pennisetum purpureum* mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria for two types of slopes. Runoff and soil loss were decreased with the use of mulch; increased with increase of slope. In the cases of the highest cover, infiltration was increased and soil loss was reduced. Groen and Woods (2008) investigated the role of straw mulch at 2.24 mg ha^{-1} in reducing post-wildfire erosion in 0.5 m^2 plots in northwestern Montana. Their results showed that the straw mulch application was highly effective in reducing erosion in the first year after fire. Larney *et al.* (2009) conducted to ascertain the effects of simulated erosion on soil productivity and methods for its amendment. They showed that the soil erosion reduced after application of wheat residual. Kukal and Sarkar (2010) observed the effect of rice straw mulch with rate of 600 g m^{-1} could decrease soil loss.

Jiang *et al.* (2011) investigated the wheat residual effect on soil erosion in the Midwestern United States. Compared with bare soil, cover with straw reduced soil erosion by 95%. Shi *et al.* (2013) studied the effect of straw mulch on runoff and soil loss with rates of 15, 30, 50, 70 and 90%. They stated that the cover of 90% was more effective on runoff and soil loss control. Fernandez and Vega (2014) investigated effects of straw mulch after wildfire in Spain on erosion control at plot scale with rate of 70%. They pointed out that the straw mulch could decrease soil erosion. They reported the better effect of straw mulch toward bark strands. Recently, Cerdà *et al.* (2015) used the straw cover that applied 3 days before the experiment at doses that cover more than 50% of the soil surface using 75 gr of straw per m^2. Rainfall simulations under 55 mm h^{-1} rainfall intensity during one hour on 0.25 m^2 plots were carried out on paired plots: bare covered with straw, on paired plots, under very dry soil moisture (contents ranging from 4.65 to 7.87%). The results show that the 3% of cover vegetation of the control plots moved to more than 60% due to the application of the straw.

Wang *et al.* (2017) studied the effects of wheat stubble on runoff, infiltration, and erosion of farmland on the Loess Plateau, China with three slope gradients (5, 10, and 15°) under simulated rainfall at 80 mm h^{-1}. The runoff reduction with wheat stubble ranged from 91.92 to 92.83%. The infiltration amount was higher with application of wheat stubble (94.8-96.2% of rainwater infiltrated) than control treatment (35.4-57.1%). The sediment loss reduced dramatically in wheat stubble (2.41-3.78 g m^{-2}).

Reviewing the literature, it was concluded that the variable behaviours and effectiveness of different mulches requires further studies under different conditions. Only few studies are available on straw mulch effects with different rates for studying infiltration, runoff and soil loss. The present study aims to determine the efficiency of wheat residual as agricultural residual on infiltration, runoff coefficient, sediment yield and soil loss for a sandy-loam soil taken from summer rangeland in Alborz Mountains, Northern Iran.

Wheat residual as mulch could improve the physical and chemical properties of soil as well as reduce runoff and soil losses in cultivated land (Jordán *et al.* 2010). The study was undertaken in the laboratory conditions with simulated rainfall intensities of 50 and 100 mm h^{-1}, the slope of 30% and the wheat residual with rates of 50 and 90%. Further research is recommended to find the right doses to be also sustainable from the economical point of view, and it is necessary to convince the farmers about the need of soil protection (Cerdà *et al.*, 2015).

Materials and Methods

This study was conducted with the idea to test the effects of wheat residual on changing infiltration, time to runoff and runoff volume, time to infiltration and infiltration volumes, sediment yield and soil erosion in the experimental plots of the Sari Agriculture Sciences and Natural Resources University, Iran. The experiments were carried with two rainfall intensities (Ghahramani *et al.*, 2011; Sadeghi *et al.*, 2015), 50 and 100 mm h^{-1}; straw mulch rates of 50 (Shi *et al.*, 2013; Cerdà *et al.*, 2015; Jimenez *et al.*, 2016) and 90% and using rainfall simulation at plot scale of 2 m^2 in three treatments.

Site description

The soil samples were collected from layer of 0-20 cm (Kukal and Sarkar, 2010; Ghoalmi *et al*., 2013) in Sari rangeland with eroded soil (longitude from 51°46'24" to 51°46'27" and latitude from 36°27'14" to 36°27'16"; average elevation of 1663. The soil samples were broth to laboratory; air-dried up to optimum moisture content to maintain the relative stability of soil aggregates (Kukal and Sarkar, 2011). The soil texture is sandy-loam, organic carbon 1.07%; EC 293 and pH value of 7.73.

Rainfall simulation

The rainfall simulator has two nozzles, the drops falling from a constant height of 2 m (Fig. 1) which ascertains the average terminal velocity of 1.1 (diameter of 0.4 mm) to 7.1 (diameter of 4.4 mm) m s^{-1} in optimal pressure of 60KPa. For each rainfall intensity, time to runoff recorded as the elapsed time between the start of rainfall and the time at which surface runoff began entering the runoff collection at the end plot. The rainfall intensities of 50 ± 5 and 100 ± 5 mm h^{-1} with duration of 10 min (Gholami *et al*., 2013; Khaledi Darvishan *et al*., 2014; Safari *et al*., 2016) considered the specific climate (through Intensity-Duration-Frequency) with return period – incidence of 20 years (Cerdà *et al*., 2016; Jimenez *et al*., 2016). Characteristics of water used for the experiment were measured as pH, EC and temperature with rates of 6.99, 712 uS cm^{-1} and 8.21 °C, respectively.

Plots preparation

The plot area is 0.5 m^2 with depth of 0.2 m, slope of 30% and each run was conducted using new soil and or wheat residual (Adams, 1966; Liu *et al*., 2012). For removing pebbles and gravels we used sieve with the diameter of 8 mm (Defersha *et al*., 2011; Gholami *et al*., 2016a and b). Then, the layer of artificial pumice grain and another layer of pumice with total thickness of 5 cm were used as a filter layer under the experimented soil for the creation of infiltration layer and decreasing plot weight (Defersha *et al*., 2011). In the next step, the soil was compacted to achieve the bulk density almost equal to the soil under natural conditions (Cerdà *et al*., 2016).

For each plot, the wheat residual was used: the surface cover and thickness of about 50 (Shi *et al*., 2013 and Cerdà *et al*., 2015) and 90% (Adekalu *et al*., 2007; Kukal and Sarkar, 2010; Shi *et al*., 2013). The control treatment was then performed and corresponding variables viz. time to infiltration and infiltration volume, time to runoff, runoff volume, sediment concentration and soil erosion were measured. Consequently, the study wheat residual was applied to the plots with eroded soil and infiltration volume, runoff volume, sediment concentration and soil erosion were ultimately measured after 5 days and running artificial rainfalls.

The control plot was monitored under identical laboratory conditions on bare soils and just before applying the wheat residual (Cerdà *et al*., 2015, 2016).

Measuring soil erosion processes

In this study, the plot 1×0.5 m^2 was used to measure infiltration, runoff, sediment concentration and soil erosion amounts in laboratory conditions and under rainfall intensities of 50 and 100 mm h^{-1} and wheat residual with rates of 50 and 90 percent. For performance of experiments, a plot had the same primary conditions and also soil surface cover, which controls the detachment and transport of sediment (Siepel *et al*., 2002; Ghahramani *et al*., 2011), infiltration (Adekalu *et al*., 2007; Choi *et al*., 2012; Lee *et al*., 2012) and the generation of runoff (Castillo *et al*., 1997; Cerdan *et al*., 2002; Ghahramani *et al*., 2011).

Infiltration, runoff and soil erosion were measured after time to runoff (runoff and soil erosion measurement) and time to infiltration (infiltration measurement) in intervals of 1 (for 4 first minutes) and 2 (for 6 minutes) before mulching (Ruiz-Sinoga *et al*., 2010) as control treatment for intensities of 50 and 100 mm h^{-1} and 2 straw mulch amounts of 50 and 90 percent. Then, the soil surface covered with straw mulch and infiltration runoff and soil erosion were measured in intervals of 2 minutes after mulching for the same of intensities and the straw mulch. The volume of the infiltrated water was calculated as difference between the volume of water added and the runoff volume (Adekalu *et al*., 2007), difference between dry-weight and wet-weight of the straw mulch (Adekalu *et*

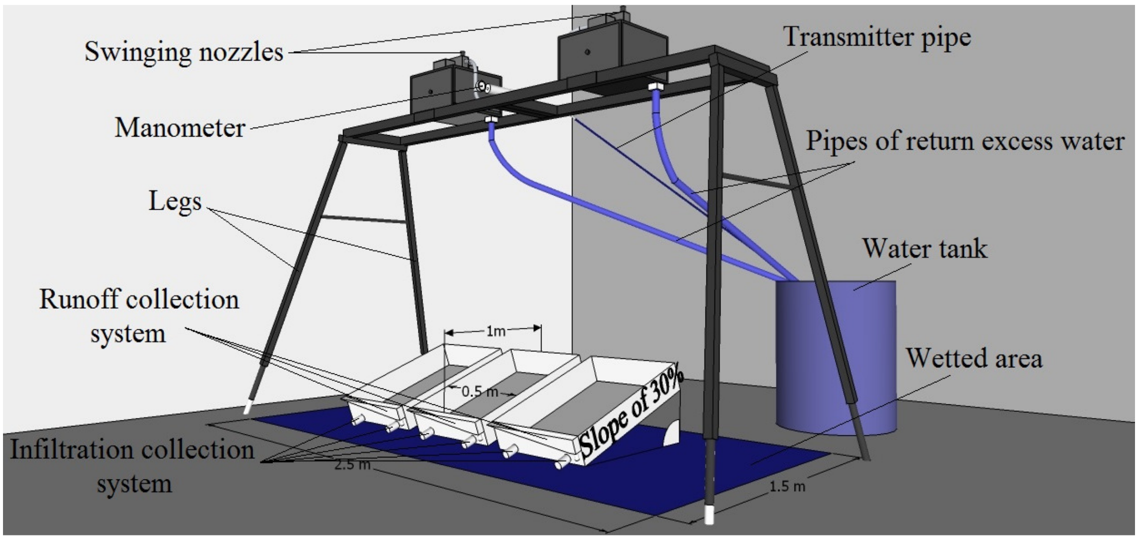


Fig. 1. The schematic from simulator with runoff and infiltration collection systems in laboratory condition

al., 2007; Li *et al*., 2011). The amounts of sediment yield were then measured using decantation procedure and oven dried at 105 °C for 24 h (Spalevic, 2011; Kukal and Sarkar, 2011; Cerdà *et al*., 2016).

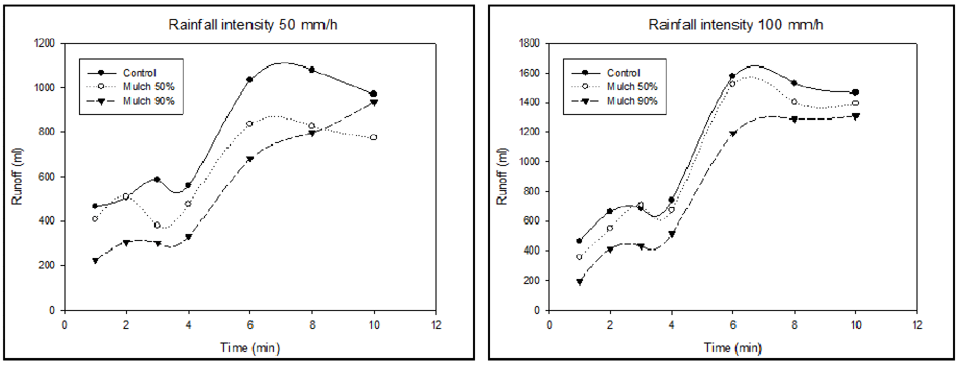
Statistical analysis

Two studied factors (two rainfall intensities or two soil covers), one-way and two-way ANOVA are used in General Linear Model (GLM) test in SPSS 19 software package. Duncan test has been applied for determination of homogeneous subgroups.

Results

Runoff component

The results of time to runoff and runoff coefficient for the lab plot before and after application of wheat residual are presented in the Table 1. Changing runoff amounts before and after wheat residual in different time intervals of measurement are presented in the Fig. 2. Measured time to runoff for the covered treatments with wheat residual in terms of the percentage of deviation from the bare soil treatment (average the two repetitions toward control) are presented in the Fig. 3.



A) B)

Fig. 2. Changing runoff amount in covered plots with wheat residual toward control plots in rainfall intensities of 50% (A) and 100% (B)

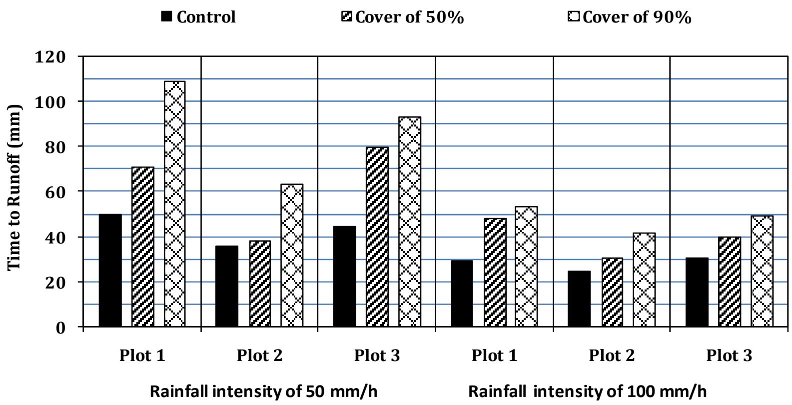


Fig. 3. Results of measured time to runoff for the wheat residual treatments in terms of the percentage of deviation from the bare soil treatment (average the two repetitions toward control)

Table 1. Values of runoff threshold and runoff coefficient before and after application of wheat residual in the plot outlet

Rainfall intensity (mm h^{-1})	Plot	Time to Runoff (s)			Runoff Coefficient (%)		
		Control	Treated wheat residual 50%	Treated wheat residual 90%	Control	Treated wheat residual 50%	Treated wheat residual 90%
50	1	49.67	70.80	108.78	26.38	22.97	16.15
	2	35.60	38.54	63.35	35.52	29.49	25.70
	3	44.38	80.10	93.27	25.56	16.52	14.149
Average		43.22	63.15	88.47	29.15	22.99	18.67
Conservation (%)		---	-46.12	-104.70	---	21.13	35.97
100	1	29.24	48.26	53.26	18.51	16.61	11.99
	2	24.87	30.50	41.74	22.40	19.47	14.95
	3	30.47	39.87	49.49	20.31	19.72	17.57
Average		28.19	39.54	48.16	20.41	18.60	14.84
Conservation (%)		---	-40.26	-70.83	---	8.85	27.30

Infiltration component

The time to infiltration and infiltration coefficient is presented in the Table 2 and Fig. 4; all related to the measured time to infiltration for the wheat residual treatments in terms of the percentage of deviation from the bare soil treatment (average the two repetitions toward control).

Soil erosion component

The sediment concentration and soil erosion amounts before and after application of wheat residual in each plot are shown in the Table 3 and Fig. 5. That is presenting soil erosion amount in covered treatments with wheat residual toward control plots in rainfall intensities of 50 mm h^{-1} (A) and 100 mm h^{-1} (B). Fig. 6 shows the results of measured soil erosion for the wheat residual treatments in terms of the percentage of deviation from the bare soil treatment (average the two repetitions toward control).

Statistical analysis

The statistical analysis treatments on runoff and infiltration parameters, sediment concentration and soil erosion was done by GLM test. The results of one way and two ways ANOVA are presented in the Table 4.

The results of ANOVA for time to runoff, runoff coefficient, time to infiltration, infiltration coefficient, sediment concentration and soil erosion are presented in the Table 5.

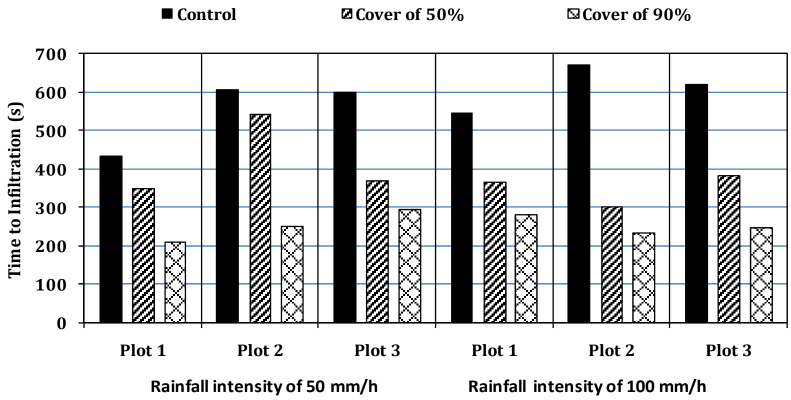


Fig. 4. Results related to the measured time to infiltration for the wheat residual treatments in terms of the percentage of deviation from the bare soil treatment (average the two repetitions toward control)

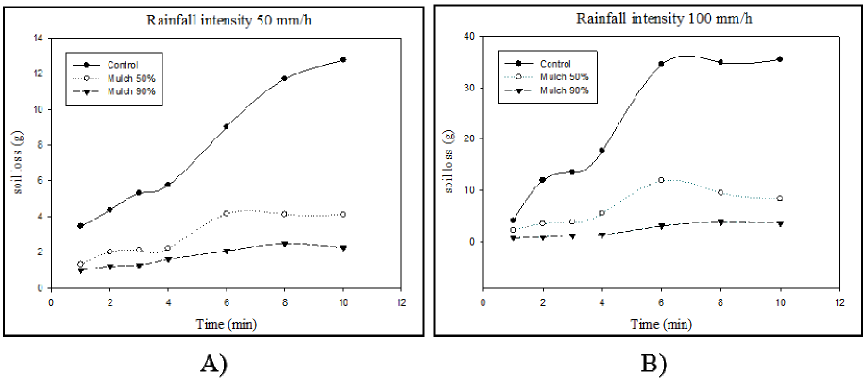


Fig. 5. Changing soil erosion amount in covered treatments with wheat residual toward control plots in rainfall intensities of 50% (A) and 100% (B)

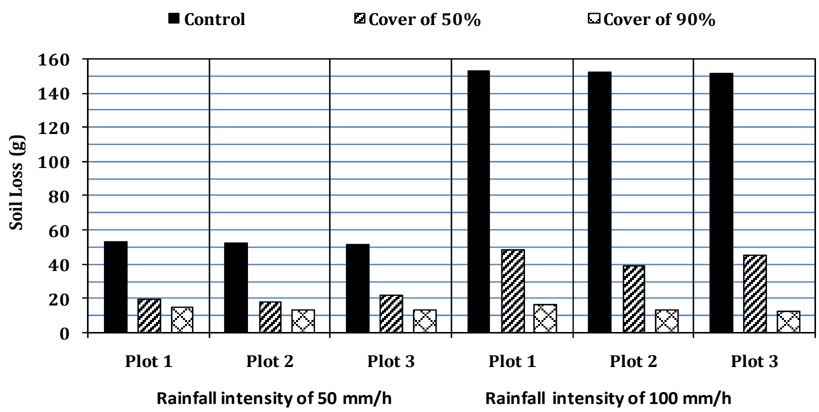


Fig. 6. Results of measured soil erosion for the wheat residual treatments in terms of the percentage of deviation from the bare soil treatment (average the two repetitions toward control)

Table 2. The time to infiltration and infiltration coefficient resulted before and after application of wheat residual

Rainfall intensity (mm h^{-1})	Plot	Time to Infiltration (s)			Infiltration Coefficient (%)		
		Control	Treated wheat residual 50%	Treated wheat residual 90%	Control	Treated wheat r esidual 50%	Treated wheat residual 90%
50	1	432.1	348.83	209.07	73.62	74.88	78.72
	2	605.76	542.45	251.15	64.48	67.98	69.25
	3	597.71	370.95	294.11	74.44	81.31	80.89
Average		545.19	420.74	251.44	70.84	74.73	76.29
Conservation (%)		---	22.83	53.88	---	-5.48	-7.68
100	1	543.15	367.79	281.02	81.49	81.92	85.14
	2	670.02	301.77	234.25	77.60	78.73	82.30
	3	618.24	381.86	248.32	79.69	78.17	79.24
Average		610.47	350.47	254.53	79.59	79.61	82.23
Conservation (%)		---	42.59	58.31	---	-0.02	-3.31

Table 3. The sediment concentration and soil erosion in before and after application of wheat residual

Rainfall intensity (mm h^{-1})	Plot	Sediment Concentration (g/ l)			Soil Erosion (g)		
		Control	Treated wheat residual 50%	Treated wheat residual 90%	Control	Treated wheat residual 50%	Treated wheat residual 90%
50	1	11.15	4.69	4.76	53.1	20.09	15.13
	2	8.34	3.46	2.85	52.326	18.1	13.52
	3	11.26	7.04	4.78	51.54	21.96	13.34
Average		10.25	5.06	4.13	52.32	20.05	14.00
Conservation (%)		---	50.60	59.71	---	61.68	73.25
100	1	23.59	8.14	3.82	152.7	48.71	16.62
	2	19.51	5.74	2.56	151.675	39.145	13.64
	3	21.26	6.52	2.02	151.28	45.76	12.81
Average		21.45	6.80	2.80	151.89	44.54	14.36
Conservation (%)		---	68.30	86.95	---	70.68	90.55

Table 4. GLM test for one-way and two-way rainfall intensity and wheat residual on runoff and infiltration parameters, sediment concentration and soil erosion

Source	Dependent Variable	df	Mean Square	F-value	Sig.
Rainfall	Time to Runoff (s)	1	4796.12	24.435	0.00
	Runoff Coefficient (%)	1	143.99	6.895	0.02
	Time to Infiltration (s)	1	1.81	.000	0.99
	Infiltration Coefficient (%)	1	191.49	8.844	0.01
	Sediment Concentration (g l^{-1})	1	67.40	29.264	0.00
	Soil Erosion (g)	1	7739.09	1371.814	0.00
Soil Conservation	Time to Runoff (s)	2	1200.09	6.114	0.03
	Runoff Coefficient (%)	2	96.69	4.630	0.03
	Time to Infiltration (s)	2	160060.87	32.978	0.00
	Infiltration Coefficient (%)	2	24.45	1.129	0.36
	Sediment Concentration (g l^{-1})	2	257.92	111.991	0.00
	Soil Erosion (g)	2	12932.72	2292.424	0.00
Rainfall Intensity × Soil Conservation	Time to Runoff (s)	2	461.69	2.352	014
	Runoff Coefficient (%)	2	10.86	.520	0.61
	Time to Infiltration (s)	2	6905.75	1.423	0.28
	Infiltration Coefficient (%)	2	5.98	.276	0.76
	Sediment Concentration (g l^{-1})	2	64.03	27.801	0.00
	Soil Erosion (g)	2	4014.90	711.673	0.00

Table 5. The results of ANOVA test on time to runoff, runoff coefficient, time to infiltration, infiltration coefficient, sediment concentration and soil erosion in two amounts of wheat residual with rates of 50 and 90 percent

Variables		Sum of Squares	df	Mean Square	F	Sig.
Time to Runoff	Between Groups	8119.688	5	1623.938	8.274	.001
	Within Groups	2355.370	12	196.281		
	Total	10475.058	17			
Runoff Coefficient	Between Groups	359.082	5	71.816	3.439	0.04
	Within Groups	250.599	12	20.883		
	Total	609.681	17			
Time to Infiltration	Between Groups	333935.052	5	66787.010	13.760	0.00
	Within Groups	58242.994	12	4853.583		
	Total	392178.046	17			
Infiltration Coefficient	Between Groups	252.358	5	50.472	2.331	0.11
	Within Groups	259.823	12	21.652		
	Total	512.180	17			
Sediment Concentration	Between Groups	711.290	5	142.258	61.770	0.00
	Within Groups	27.637	12	2.303		
	Total	738.927	17			
Soil Erosion	Between Groups	41634.328	5	8326.866	1.476E3	0.00
	Within Groups	67.698	12	5.642		
	Total	41702.026	17			

Discussion

Runoff component

The results presented in the Table 1 and Fig. 2 show that the wheat residual in two amounts (50 and 90%) and two rainfall intensities (50 and 100 mm h^{-1}) had significant effect in level of 99% on increasing time to runoff and decreasing runoff coefficient (Adams, 1966; Lal, 1998; Smets *et al.*, 2008 and 2011; Jiang *et al.*, 2011 and Li *et al.*, 2011; Wang *et al.*, 2017) because straw mulch pieces could store more runoff and infiltration increased (Choi *et al.*, 2012 and Liu *et al.*, 2012). The result also stated that the percent of changes of time to runoff was increased and straw mulch for rainfall intensity of 50 mm h^{-1} (+43.76% for cover of 50% and +102.37% for cover of 90%) and in rainfall intensity of 100 mm h^{-1} (+39.51% for cover of 50% and +70.80 % for cover of 90%) had different effect. The percent of changes of runoff coefficient was decreased and straw mulch for rainfall intensity of 50 mm h^{-1} (-21.77% for cover of 50% and -36.58 % for cover of 90%) and in rainfall intensity of 100 mm h^{-1} (-8.76% for wheat residual with rate of 50% and -27.31% for wheat residual with rate of 90%) had different effect.

In the Table 1 is presented the response of the treated plots with two covers of wheat residual with rates of 50 and 90%; with the different runoff time and the runoff coefficient. The effect of wheat residual on the change of time to runoff and runoff coefficient with cover of 90% was more effective toward cover of 50%, but this efficient effect was observed in rainfall intensity of 50 mm h^{-1}. Ruy *et al.* (2006) presented that the runoff coefficient is reduced more with application of high straw mulch. Fig. 3 reveal that the runoff amount with different interval decreased in conserved plots toward control plots in rainfall intensities of 50% (A) and 100% (B). The straw mulch effects were less in second minute (rainfall intensity of 50 mm h^{-1} and wheat residual with cover of 50%) and third minute (rainfall intensity of 100 mm h^{-1} and wheat residual with cover of 50%). The wheat residual with amounts of 90% had more effect in various intervals for two rainfall intensities. Shi *et al.* (2013) observed that the effect of rice residual with rates of 90% was more effective on runoff control. Cerdà *et al.* (2015) showed that the application of straw mulch with rate of 50% could decrease the runoff.

Infiltration component

The results presented in the Table 2 show that the stream mulch increased the infiltration (Duley and Kelly, 1939; Unger and Jones, 1981; Lado *et al.*, 2004; Adekalu *et al.*, 2007; Jordán *et al.*, 2010; Kukal and Sarkar, 2010; Ghahramani *et al.*, 2011; Li *et al.*, 2011; Lee *et al.*, 2012 and Liu *et al.*, 2012; Gholami *et al.*, 2016a; Wang *et al.*, 2017) but this enhancement was very high (Poulenard *et al.*, 2001). The percent of changes of time to infiltration reduced and stream mulch for rainfall intensity of 50 mm h^{-1} (-22.55% for cover of 50% and -41.83% for cover of 90%) and in rainfall intensity of 100 mm h^{-1} (-53.65% for wheat residual with rate of 50% and -57.71% for wheat residual with rate of 90%) had different effect.

The percent of changes of infiltration coefficient was increased: straw mulch for rainfall intensity of 50 mm h^{-1} (+5.46% for wheat residual with rate of 50% and +0.03% for wheat residual with rate 90%) and in rainfall intensity of 100 mm h^{-1} (+7.67% for wheat residual with rate of 50% and +3.32% for wheat residual with rate of 90%). The mulch is increasing soil surface protection, absorption of runoff and holding excess surface water of soil surface by mechanical impedance. The fast infiltration rate increased using of straw mulch and also the rapid movement of infiltrated water increased in the soil profile (Adams, 1966; Wang *et al*., 2017).

The wheat residual with rate of 90% had more effect on increasing infiltration in rainfall intensities of 50 and 100 mm h^{-1}. The applied mulch could increase the infiltration coefficient from 67.98 to 85.14%, but maximum infiltration coefficient appeared in the intensity of 100 mm h^{-1} high intensity (Adams, 1966) and soil cover of 90% with rate of 85.14%. Mulumba and Lal (2008) indicated that the mulch could increase the available water and the soil moisture.

Increasing infiltration in intensity of 100 mm h^{-1} and cover of 90% could be due to the stream mulch that operated physical barrier. Increasing of the soil moisture can reduce infiltration and increase the runoff depth, but the wheat residual collect much of runoff and influenced that runoff through the time.

Soil erosion component

The sediment concentration and soil erosion were reduced after wheat mulch (Table 1 and Fig. 4). These results followed the results of Adams (1966), Meyer *et al* (1970), Loch and Donnollan (1988), Adekalu *et al*. (2007), Groen and Woods (2008), Larney *et al.* (2009), Fernandez and Vega (2014), Cerdà *et al*. (2016) and Wang *et al.* (2017).

The percent of changes of sediment concentration was for rainfall intensity of 50 mm h^{-1} (-51.31% for wheat residual with rate of 50% and -60.23% for wheat residual with rate of 90%) and in rainfall intensity of mm h^{-1} (-68.47% for wheat residual with rate of 50% and -87.06% for wheat residual with rate of 90%) after mulching.

The results of sediment concentration more decrease in wheat residual with cover of 90%. The wheat residual more affect in rainfall intensity of 100 mm h^{-1}, wheat residual with rate of 90%. Lal (1976) also stated that, the soil erosion is reduced with application of straw mulch of about 80 % (wheat residual with rate of 60%) and 90% (wheat residual with rate of 90%). The percent of changes of soil erosion was for rainfall intensity of 50 mm h^{-1} (-61.66% for wheat residual with rate of 50% and -73.26% for wheat residual with rate of 90%) and in rainfall intensity of 100 mm h^{-1} (-70.68% for wheat residual with rate of 50% and -90.55% for wheat residual with rate of 90%). This indicates that the raindrops and runoff could not get enough power to detach particles (Poesen and Lavee, 1991) because the depth of the mulch trapped detaching soil aggregates (Cerdà *et al*., 2016). Poulenard *et al*. (2001) indicated that the sediment is very low; Ruy *et al*. (2006) in their research in La Tinaja (Mexico-State of Jalisco) discovered that runoff and soil erosion more decreased with high rates of mulch. Shi *et al*. (2013) studied the effect of straw mulch on runoff and soil erosion with rates of 15, 30, 50, 70 and 90% of cover. Wheat residual with cover of 90% was more effective on runoff and soil erosion control.

Sediment concentration and soil erosion were decreased because runoff and rainfall detachment were diminished and soil infiltration rates were increased (Jordan *et al*., 2010) in two covers of 50 and 90% and for rainfall intensities of 50 and 100 mm h^{-1}.

Poesen and Lavee (1991) also stated that the soil erosion had more effect on soil erosion in different intervals. This is explained by the fact that the mulch placed on soil surface, could infiltrate Hortonian overland flow as well as from the inter mulch areas. Then, the infiltration and runoff volume increased and reduced, respectively and finally the soil erosion declined (Poesen and Lavee, 1991; Wang *et al*., 2017).

Statistical analysis

The one way ANOVA results (Table 4) revealed that the effect of rainfall intensity was significant on time to runoff, infiltration coefficient, sediment concentration and soil erosion variables (R^2=0.99) and variable of runoff coefficient (R^2=0.95).

The wheat residual with the rate of 50 and 90 percent could reduce runoff coefficient, sediment concentration and soil erosion and increase the time to runoff and infiltration coefficient. This effect was significant on time to infiltration, sediment concentration and soil erosion variables (R^2=0.99), time to runoff and runoff coefficient variables (R^2=0.95). The interaction effects of rainfall intensity and soil conservation was significant for sediment concentration and soil erosion variables (R^2=0.99).

Determination of significant differences between rainfall intensities and soil conservation treatments using ANOVA analysis (Table 5) presented that the two covers of 50 and 90% in two rainfall intensities of 50 and 100 mm h^{-1} had the significant effects on time to runoff, time to infiltration, sediment concentration and soil erosion ($p<0.01$ and p-value= 0.00).

Conclusions

The experiments were performed in the plot scale with area of 1×0.5 m^2, in laboratory conditions and using wheat residual with rate of 50 and 90% and rainfall intensities of 50 and 100 mm h^{-1}. The results clearly indicated that wheat residual has a negative effect on infiltration rate and on time to runoff, while it has a positive effect on runoff volume, sediment concentration and soil erosion.

With application wheat residual in two covers of 50 and 90% and for two rainfall intensities of 50 and 100 mm h^{-1}, the results showed that the two covers had the significant effects on time to runoff, time to infiltration, sediment concentration and soil erosion. Use of wheat residue of agricultural plants is suggested for improving eroded soils; improving its chemical and physical characteristics in long term.

Finally, wheat residual is beneficial for reducing runoff coefficient, soil loss and sediment concentration; at the same time is increasing infiltration and time for runoff under simulated rainfall. The cover of wheat residual can be used as a management practice in control of soil erosion.

References

Adams JE (1966). Influence of mulches on runoff, erosion, and soil moisture depletion. Soil Science Society of America Journal 30(1):110-114.

Adekalu KO, Olorunfemi IA, Osunbitan JA (2007). Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria. Bioresource Technology 98:912-917.

Amimoto PY (1981). Erosion and sediment control handbook. California Department of Conservation Representative, No. EPA 4 40/3-78-003.

Auerswald K, Kainz M, Fiener P (2003). Soil erosion potential of organic versus conventional farming evaluated by USLE modelling of cropping statistics for agricultural districts in Bavaria. Soil Use Management 19:305-311.

Castillo VM, Martinez-Mena M, Albaladejo J (1997). Runoff and soil loss response to vegetation removal in a semiarid environment. Soil Science Society of America Journal 61:1116-1121.

Center for Watershed Protection (2001). Mats and blankets fact sheet in Stromwater Managers Resource Center. www.stormwatercenter.net. Ellicott City, MD.

Cerdan O, Le Bissonnais Y, Souchère V, Martin P, Lecomte V (2002). Sediment concentration in interrill flow: Interactions between soil surface conditions, vegetation and rainfall. Earth Surface Processes Landforms 27:193-205.

Cerdà A, Pelayo OG, Giménez-Morera A, Jordán A, Novara A, Pereira P, Mataix-Solera J (2015). The barley straw residues avoid high erosion rates in persimmon plantations. Eastern Spain. Geophysical Research Abstracts 17: EGU2015-2205-4, 2015 EGU General Assembly.

Cerdà A, Gonzalez-Pelayo O, Gimenez-Morera A, Jordan A, Pereira P, Novara A, … Ritsema C (2016). The use of barley straw residues to avoid high erosion and runoff rates on persimmon plantations in Eastern Spain under low frequency – high magnitude simulated rainfall events. Soil Research 54(2):154-165.

Cogo NP, Moldenhauer WC, Foster GR (1984). Soil loss reductions from conservation tillage practices. Soil Science Society of America Journal 48:368-373.

Defersha MB, Quraishi S, Mellese AM (2011). The Effect of slope steepness and antecedent moisture content on interrill erosion, runoff and sediment size distribution in the highlands of Ethiopia. Hydrology and Earth System Sciences 15:2367-2375.

Duley FL, Kelly LL (1939). Effect of soil type, slope and surface conditions on intake of water. Nebraska, Agricultural Experiment Station Research Bulletin, 112.

Fernandez C, Vega JA (2014). Efficacy of bark strands and straw mulching after wildfire in NW Spain: Effects on erosion control and vegetation recovery. Ecological Engineering 63:50-57.

García-Orenes F, Guerrero C, Roldán A, Mataix-Solera J, Cerdà A, Campoy M, … Caravaca F (2010). Soil microbial biomass and activity under different agricultural management systems in a semiarid Mediterranean agroecosystem. Soil and Tillage Research 109:110-115.

Ghahramani A, Ishikawa Y, Gomi T, Katsushige SH, Miyata SH (2011). Effect of ground cover on splash and sheetwash erosion over a steep forested hillslope: A plot-scale study. Catena 85:34-47.

Gholami L, Khaledi Darvishan A, Kavian A (2016a). Wood chips as soil conservation in field conditions. Arabian Journal of Geosciences 9:729.

Gholami L, Sadeghi SHR, Homaee M (2016b). Different effects of sheep manure conditioner on runoff and soil loss components in eroded soil. Catena 139:99-104.

Gholami L, Sadeghi SHR, Homaee M (2013). Straw mulching effect on splash erosion, runoff and sediment yield from eroded plots. Soil Science Society of American Journal 77:268-278.

Groen AH, Woods SW (2008). Effectiveness of aerial seeding and straw mulch for reducing post-wildfire erosion, north-western Montana, USA. International Journal of Wildland Fire 17(5):559-571.

Ji S, Unger PW, (2001). Soil water accumulation under different precipitation, potential evaporation, and straw mulch conditions. Soil Science Society of America Journal 65:442-448.

Jiang L, Dami I, Mathers HM, Dick WA, Doohan D (2011). The Effect of straw mulch on simulated simazine leaching and runoff. Weed Science 59(4):580-586.

Jimenez MN, Fernandez-Ondono E, Ripoll MA, Castro-Rodriguez J, Huntsinger L, Navarro FB (2016). Stones and organic mulches improve the *Quercus ilex* L. A forestation success under Mediterranean climatic conditions. Land Degradation Development 7(2):357-365.

Jordán A, Zavala LM, Gil J, (2010). Effects of mulching on soil physical properties and runoff under semi-arid conditions in Southern Spain. Catena 81:77-85.

Kavian A, Hoseinpoor Sabet S, Solaimani K, Jafari B (2017). Simulating the effects of land use changes on soil erosion using RUSLE model. Geocarto International 3(1):97-111.

Khaledi Darvishan A, Homayounfar V, Sadeghi SHR (2016). The impact of standard preparation practice on the runoff and soil erosion rates under laboratory conditions. Solid Earth 7(5):1293-1302.

Khaledi Darvishan A, Sadeghi SHR, Homaee M, Arabkhedri M (2012). Potential use of synthetic color-contrast aggregates and a digital image processing technique in soil splash measurements. ICCE 2012, International Symposium on "Erosion and sediment yields in the changing environment" pp 364-368.

Khaledi Darvishan A, Sadeghi SHR, Homaee M, Arabkhedri M (2014). Measuring sheet erosion using synthetic color-contrast aggregates. Hydrological Processes 28(15):4463-4471.

Kukal SS, Sarkar M (2010). Splash erosion and infiltration in relation to mulching and polyviny alcohol application in semi-arid tropics. Archives of Agronomy and Soil Science 56(6):697-705.

Kukal SS, Sarkar M, (2011). Laboratory simulation studies on splash erosion and crusting in relation to surface roughness and raindrop size. Journal of the Indian Society of Soil Science

59(1):87-93.

Lal R (1976). Soil erosion on alfisols in western Nigeria II effect of mulch rates. Geoderma 16:377-382.

Lal R (1998). Mulching effects on runoff, soil erosion and crop response on alfisols in Western Nigeria. Journal of Sustainable Agriculture 11(2/3):135-154.

Larney FJ, Janzen HH, Olson BM, Olson AF(2009). Erosion-productivity-soil amendment relationships for wheat over 16 years. Soil and Tillage Research 103(1):73-83.

Lee S, Won CH, Shin M, Park W, Choi Y, Shin J, Choi J (2012). Application of surface cover and soil amendment for reduction of soil erosion from sloping field in Korea. International Conference of Agriculture Engineering, July 8-12, Spain. http://cigr.ageng2012.org/comunicaciones-online/htdocs/principal.php?seccion=index-posters.

Li XH, Zhang ZY, Yang J, Zhang GH, Wang B (2011). Effects of bahia grass cover and mulch on runoff and sediment yield of sloping red soil in Southern China. Pedosphere 21(2):238-243.

Liu Y, Taoa Y, Wana KY, Zhanga GS, Liub DB, Xiongb GY, Chena F (2012). Runoff and nutrient losses in citrus orchards on sloping land subjected to different surface mulching practices in the Danjiangkou reservoir area of China. Agricultural Water Management 110:34-40.

Loch RJ, Donnollan TE (1988). Effects of the amount of stubble mulch and overland flow on erosion of a cracking clay soil under simulated rain. Australian Journal of Soil Research 26(4):61-672.

Mannering JV, Meyer LD (1963). Effects of various rates of surface mulch on infiltration and erosion. Soil Science Society of American 27:84-86.

Meyer LD, Wischmeier WH, Foste GR (1970). Mulch rates required for erosion control on steep slopes. Soil Science Society of America 34:928-931.

Mohamadi MA, Kavian A (2015). Effects of rainfall patterns on runoff and soil erosion in field plots. International Soil and Water Conservation Research 3:273-281.

Mooers CA, Washko JB, Young JB (1948). Effects of wheat straw, Lespedeza Sericea Hay and farmyard manure as soil mulches, on the conservation of moisture and the production of nitrates. Soil Science 66(4):307-316.

Morgan RPC (1986). Soil erosion and conservation. Longman Scientific and Technical, BurntMile, Harlow, UK.

Morgan RPC (1995). Soil erosion and conservation. Longman, Essex, England.

Mulumba LN, Lal R (2008). Mulching effects on selected soil physical properties. Soil and Tillage Research 98:106-111.

Nearing MA, Jetten V, Baffaut C, Cerdan O, Couturier A, Hernandez M, … Van Oost K (2005). Modelling response of soil erosion and runoff to changes in precipitation and cover. Catena 61:131-154.

Poesen JWA, Lavee H (1991). Effects of size and incorporation of synthetic mulch on runoff and sediment yield from interrills in a laboratory study with simulated rainfall. Soil and Tillage Research 21:209-223.

Poulenard J, Podwojewski P, Janeau JL, Collinet J, (2001). Runoff and soil erosion under rainfall simulation of andisols from the Ecuadorian Paramo: Effect of tillage and burning. Catena 45:185-207.

Ruy S, Findeling A, Chadoeuf J (2006). Effect of mulching techniques on plot scale runoff: FDTF modelling and sensitivity analysis. Journal of Hydrology 326:277-294.

Sadeghi SHR, Gholami L, Homaee M, Khaledi Darvishan A (2015). Reducing sediment concentration and soil loss using organic and inorganic amendments at plot scale. Solid Earth 6:445-455.

Safari A, Kavian A, Parsakhoo A, Saleh I, Jordán A (2016). Impact of different parts of skid trails on runoff and soil erosion in the Hyrcanian forest (northern Iran). Geoderma 263:161-167.

Shi ZH, Yue BJ, Wang L, Fang NF, Wang D, Wu FZ (2013). Effects of mulch cover rate on interrill erosion processes and the size selectivity of eroded sediment on steep slopes. Soil Science Society of America Journal 77:257-267.

Siepel AC, Steenhuis TS, Rose CW, Parlange JY, McIsaac GF (2002). A simplified hillslope erosion model with vegetation elements for practical applications. Journal of Hydrology 258:111-121.

Smets T, Poesen J, Bochet E (2008). Impact of plot length on the effectiveness of different soil-surface covers in reducing runoff and soil loss by water. Physical Geography 32(6):654-677.

Spalevic V (2011). Impact of land use on runoff and soil erosion in Polimlje. Doctoral thesis, Faculty of Agriculture of the University of Belgrade, Serbia.

Spalevic V, Djurovic N, Mijovic S, Vukelic-Sutoska M, Curovic M (2013). Soil erosion intensity and runoff on the Djuricka River Basin (North of Montenegro). Malaysian Journal of Soil Science 17(1):49-68.

Spalevic V, Lakicevic M, Radanovic D, Billi P, Barovic G, Vujacic D, Sestras P, Khaledi Darvishan A (2017). Ecological-Economic (Eco-Eco) modelling in the river basins of Mountainous regions: Impact of land cover changes on sediment yield in the Velicka Rijeka in Montenegro. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 45(2):602-610.

Unger PW, Jones OR (1981). Effect of soil water content and growing season straw mulch on grain sorghum. Journal of the American Water Resources Association 45(1):129-134.

University of Tennessee Institute of Agriculture (2018). Long-term economic impact of cover crops: 29-year study finds cover crops offer benefits with no-till cotton systems. ScienceDaily. Retrieved 2018 February 5 from www. Sciencedailycom/releases/2018/02/180205141107.html.

Wang L, Ma B, Wu F (2017). Effects of wheat stubble on runoff, infiltration, and erosion of farmland on the Loess Plateau, China, subjected to simulated rainfall. Solid Earth 8:281-290.