Article

The Impact of Different Cultivation Practices on Surface Runoff, Soil and Nutrients' Losses in a Rotational System of Legume – Cereal and Sunflower

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Abstract: Soil erosion is one of the biggest problems in the agricultural sector that can affect ecosystems and human societies. A field of 50 slope was selected to study the runoff, soil and nutrients' loss as well as crop productivity in different treatments (conventional tillage (CT) vs. no-tillage (NT), plant vs. no plant cover, contour cultivation (CC) vs. perpendicular to the contour cultivation, (PC) under natural rainfall. The experiment was conducted in central Greece in two cultivation periods. In autumn, the field was cultivated with intercropping *Triticosecale and Pisum sativum* and in spring with Sunflower. The total rainfall was 141.4 mm in the 1st year and 311 mm in the 2nd. We found that runoff in the treatment of no tillage with contour cultivation was 85% lower in both years compared to the no tillage-no plant control. Therefore, the contour cultivation-no tillage treatment had a positively effect in decreasing phosphorus and potassium concentrations lost from soil: indeed, there was a decrease by 55% and 62% in P and K, respectively, in the NT compared to the CC treatments. We conclude that the NT-CC treatment with plant cover was the most effective in reducing water runoff, soil nutrients' loss and increasing yield.

Keywords: cropping system; rotation; tillage; natural rainfall; Greece

1. Introduction

In recent years the need of world's growing population for more food has led to the exploitation of greater areas of agricultural fields [1]. One of the most important global problems of the agricultural land in use is soil erosion. It has been found that 80% of the agricultural fields suffer from severe erosion impacts [2] (Pimentel and Burgess, 2013). The sloping lands cause more than the 60% of the soil erosion [3]. The factors which can affect the soil erosion are divided into two categories: those occurring naturally and those human-induced. A number of studies have shown that slope gradient is the main natural factor which affects tillage erosion, and tillage erosion increases along with the increase of slope gradient [4]. The usual form of soil erosion in agriculture is caused by rainfall (water-induced erosion) and causes land degradation, surface runoff, soil and nutrients' loss [5, 6].

The human factors involved in the soil erosion process are farming practices and the cropping systems. Proper tillage direction can affect the runoff, the soil and nutrients' nutrients' loss. The contour tillage is a more sustainable practice in comparison to that usually expected in flat fields (in straight lines) or that along-the-slope tillage. Adverse effects become more pronounced under intensive rainfall events. Contour cultivation on fields with high inclination percentage can decrease soil erodibility, increasing thus topsoil resistance [7]. Due to soil erosion, pollution by NPK borne onto eroded soil particles has become a major threat to surface waters. Globally, due to soil erosion, about 95% of phosphorus, 55% of nitrogen and up to 40% of carbon are being carried in rivers and deposited in their sediments [8]. In Europe 12% of the agricultural fields are negatively affected by erosion caused by water and the cost for the EU-27 is about 0.7–14.0 billion euro [9].

Soil erosion can cause ecological problems such as eutrophication of the surface waters, lakes and reservoirs and can have severe negative impacts on the aquatic biota. It can also lead to economical losses for farmers as well to the reduction of the agricultural productivity [9-11].

In recent years, conservation tillage has been mentioned as an effective way to reduce soil erosion and therefore to minimize the soil and nutrients' losses [12, 13]. Conservation agriculture has three main principles, no – tillage cultivation, crop rotation and use of permanent cover crops [14, 15].

Regardless of the above reported advantages of the conservation agriculture, especially for the Mediterranean countries, very often farmers and local communities believe that a field with continuous cover crops or intercropping, as well the use of minimum or no – tillage cultivation is considered to be a "dirty" action [16, 17].

The farmers should understand the benefits of the sustainable agricultural management which is necessary for the success of the soil loss and nutrients reduction as well as for the improvement of the physical and chemical soil characteristics [12, 17].

Greece, as part of the Mediterranean area, is a country with a high risk of soil and nutrients' loss due to soil erosion. This is due to the many sloping cultivated fields and the climate that is characterized by warm and rainy winters and erosive rains in many periods. The intensive rains in combination with the hot and dry summers have intensified the soil erosion problem [17, 18].

Although some studies have been conducted to evaluate the influence of soil tillage systems on surface runoff, soil and nutrients' transport from agricultural fields [19-22] worldwide, not much information concerns Greece. Furthermore, studies that assess the effect of soil tillage (contour farming, CF, and non-CF) on the surface runoff are also rare.

Additionally, only a few studies have been conducted regarding the effects of a rotation system with legume-cereal and sunflower on runoff, soil, nutrients' loss and plant biomass.

For that reason, the aim of this work was to study the effect of tillage (conventional and no tillage), planting direction (parallel and perpendicular to the contours), and vegetation cover (with or without crops of autumn and spring cultivations) to the runoff, to the soil loss, to the nutrients' loss (recorded with Olsen P and exchangeable K) and to plant total biomass.

2. Results

2.1. Meteorological data

The meteorological data were recorded from an automatic station installed next to the experimental area (Fig. 1).

Air temperature was at least 2 – 3 ^{o}C higher during the 2ndyear of the experiment in almost all months. The total precipitation from March to October was 314.9 and 340 mm in 2015 and 2016, respectively.

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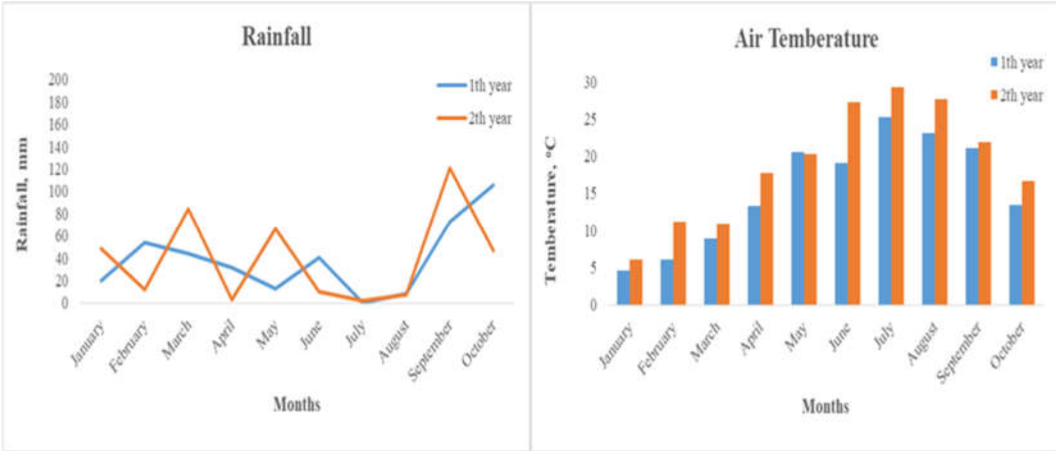

Figure 1. Average monthly air temperature and total rainfall occurring in studied area during the growing periods (1st and 2nd growing years).

2.2. Soil Analyses

The soil was clay loam (38.41% sand, 36.11% clay, 25.48% silt), with a pH of 8.21 and organic matter contest of 1.65%. The physicochemical properties of the soil are showed in Table 1.

Table 1. Physicochemical properties of the used soil.

pH	**8.21**
E.C.(μS cm^{-1})	435
$CaCO_3$	16.5
Organic matter (%)	1.65
Total Nitrogen (%)	0.08
Olsen P (mg kg^{-1})	21.24
Exchangeable K (mg kg^{-1})	216.06
Sand (%)	38.41
Clay (%)	36.11
Silt (%)	25.48

2.3. Runoff events results

In total, 11 runoff events were conducted over the rainy season between the beginning of March to the end of May for the autumn cultivation and from the mid-September to the mid - October for the two experimental years. Specifically, 3 (March to May) and 2 (September to October) runoff were measured the 1st year, and 3 (March to May) and 3 (September to October) the 2nd year. The rainfall a characteristic from which runoff was generated is shown in Table 2. The total amount of rainfall that resulted in runoff was 141.4mm in 2015 and 310.9 mm in 2016, representing the 45% and 91% of the total precipitation from March to October.

Table 2. Characteristics of the rainfall events generating runoff volumes.

Runoff event	Days of rain	Sampling day	Rainfall amount (mm)	Runoff event	Days of rain	Sampling day	Rainfall amount (mm)
1st year				**2nd year**			
Intercropping *Triticosecale – Pisum sativum* cultivation (2014/2015)				**Intercropping *Triticosecale – Pisum sativum* cultivation (2015/2016)**			
RE1	19/3/15-31/3/15	1/4/15	44.2	**RE6**	7/3/16-16/3/16	17/3/16	68.9
RE2	1/4/15-4/5/15	5/5/15	31.6	**RE7**	18/3/16-31/4/16	1/5/16	16
RE3	6/5/15-18/5/15	19/5/15	12.6	**RE8**	2/5/16-1/6/16	2/6/16	66
	Total		**88.4**		**Total**		**150.9**
***Helianthus annuus* (2015)**				***Helianthus annuus* (2016)**			
RE4	1/9/15-31/10/15	1/10/15	35.8	**RE9**	1/9/16-12/9/16	13/9/16	110.7
RE5	2/10/15-8/10/15	9/10/15	17.2	**RE10**	14/9/16-24/9/16	25/9/16	20
				RE11	26/9/16-15/10/16	14/10/16	29.3
	Total		**53**		**Total**		**160**

In order to evaluate the reduction in runoff, the RRB % was calculated. The values of the RRB % confirmed that the no – tillage treatments presented a decrease in runoff volumes in comparison to conventional blocks. In all total 4 runoff events the no - tillage parallel to the contours caused greater reduction than the tillage perpendicular to the contours (Table 3).

Table 3. Runoff Reduction Benefit (RRB) at the 4 cultivation periods.

Cultivation period	Runoff event	Runoff Reduction Benefit (RRB) in %	
		tillage parallel to contour	tillage perpendicular to contour
winter rotation of legume-cereal (2014/2015)	**88.4 mm**	2.0	1.8
summer sunflower (2015)	**53 mm**	29.3	0.6
winter rotation of legume-cereal (2015/2016)	**150.9 mm**	13.4	12.3
summer sunflower (2016)	**160 mm**	15.3	12.7

The results of the runoff volumes are illustrated in Table 4. The runoff volumes of all treatments were lower in comparison to the control plots (no – tillage and no plant) and in 10 out of the 11 runoff events the difference was statistically significant. The runoff values follow the order below from lower to higher: TR1<TR2<TR4<TR5<TR3<TR6<Control. The TR1 (no tillage – planting parallel to the contour direction – plant) plots had the lower runoff volume. The perpendicular in the contour were performed the higher runoff. Also, better results in runoff volume were observed in NT (no – tillage) plots than in CT (conventional tillage), regardless of the cultivated soil directions (parallel or perpendicular to the contour). During the first year, in total rainfall (141.4mm), the runoff values ranged from 5.004 (TR1) – 13.396 m^3 ha^{-1} (Control), while during the second year the runoff volumes ranged from 3.4112 (TR1) – 21.096 m3/ha (Control, total precipitation 310.9 mm).

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Table 4. Mean values of runoff volumes (m3 ha-1) in the seven treatments of the two cultivation years.

Runoff event	Rainfall amount (mm)	Runoff (m^3/ha)							
		Control	**TR1**	**TR2**	**TR3**	TR4	TR5	TR6	LSD
1st year									
RE1	44.2	1.6040 **b**	1.2776 **a**	1.3086 **ab**	1.514 6 **ab**	1.4441 **ab**	1.4639 **ab**	1.5381 **ab**	0.09969
RE2	31.6	2.0535 **c**	1.8167 **a**	1.8453 **ab**	2.0209 **c**	1.9285**abc**	1.9849 **bc**	2.0345 **c**	0.05032
RE3	12.6	0.7255 **c**	0.5582 **a**	0.5702 **a**	0.6533**ab**	0.6414 **ab**	0.6402 **ab**	0.6745 **ab**	0.04357
Total 1 (RE1, RE2, RE3)	**88.4**	**4.383 d**	**3.6503 a**	**3.7241 ab**	**4.1888 cd**	**4.0140 abc**	**4.0890 bcd**	**4.2471 cd**	0.12064
RE4	35.8	2.8133 **b**	0.3514 **a**	0.4059 **a**	0.5488 **a**	0.4585 **a**	0.5230 **a**	0.6890 **a**	0.17033
RE5	17.2	6.2000 **d**	1.0027 **a**	1.5089 **ab**	2.0018 **bc**	1.8643 **b**	1.8138 **b**	2.7221 **c**	0.26517
Total 2 (RE4, RE5)	**53**	**9.0133 d**	**1.3540 a**	**1.9148 ab**	**2.5506 cd**	**2.3228 ab**	**2.3368 ab**	**3.4111 c**	**0.32597**
2nd year									
RE6	68.9	2.0503 **d**	0.6763 **a**	0.7813 **ab**	1.0563 **bc**	0.8823 **ab**	1.0065 **b**	1.3260 **c**	0.09997
RE7	16	1.0400 **c**	0.1570 **a**	0.1814 **ab**	0.2453 **ab**	0.2049 **ab**	0.2337 **ab**	0.3079 **b**	0.04255
RE8	66	4.4460 **c**	0.6478 **a**	0.7484 **a**	1.0118 **ab**	0.8452 **a**	0.9642 **ab**	1.3517 **b**	0.16488
Total 3 (RE6, RE7, RE8)	**150.9**	**7.5363 d**	**1.4811 a**	**1.7110 ab**	**2.3133 bc**	**1.9324 ab**	**2.2044 b**	**2.9857 c**	**0.23789**
RE9	110.7	7.0743 **d**	1.0865 **a**	1.2552 **ab**	1.6971 **bc**	1.4176 **ab**	1.6171 **abc**	2.1305 **c**	0.19230
RE10	20	1.2610 **c**	0.1963 **a**	0.2268 **a**	0.3066 **ab**	0.2561 **a**	0.2922 **ab**	0.3849 **b**	0.03651
RE11	29.3	5.2243 **c**	0.6478 **a**	0.7484 **ab**	1.0118 **ab**	0.8452 **ab**	0.9642 **ab**	1.270 **b**	0.18231
Total 4 (RE9, RE10, RE11)	**160**	**13.560 c**	**1.9306 a**	**2.2304 a**	**3.0155 ab**	**2.5190 a**	**2.8735 ab**	**3.7857 b**	**0.40142**

Different letters within each line indicate statistically significant differences between the treatments at the P <0.05 level.

2.4. Soil loss results

The results of the soil loss concentrations are reported in Table 6. In all 6 treatments (TR1, TR2, TR3, TR4, TR5, TR6), the soil loss was lower in comparison to the control (no – tillage and no plant) and in 10 out of the 11 runoff events the difference was statistically significant (RE3, RE4, RE5, RE6, RE7, RE8, RE9, RE10, RE11). The soil loss rates followed the order of TR1<TR2<TR4<TR5<TR3<TR6<Control. The TR1 plots had statistically significant difference only in RE9 runoff event (110.7mm rainfall). Larger soil losses were generally measured in the plots in which the tillage was performed perpendicular in the contour. Furthermore, the NT (no – tillage) produced lower soil loss amounts in comparison to the CT (conventional tillage), regardless of the direction of cultivation (either parallel or perpendicular to the contours).During the first year out of a total rainfall of 141.4 mm, the soil loss values ranged from 0.953 (TR1) to 12.325 $m^3 ha^{-1}$ (Control). During the second year the runoff volumes ranged from 2.3399 (TR1) – 43.691 $m^3 ha^{-1}$ (Control) in total a total precipitation of 310.9 mm. The different land treatments decreased the sediment loss by 71-92% the 1st year and by 67-95% the 2nd year. The measurement of the Sediment Reduction Benefit (SRB in %) showed that the no -tillage reduced the soil loss to a greater amount in comparison to conventional tillage. That reduction in no – tillage parallel to contour ranged from 15.7 to 60.3%, while in perpendicular to contour treatments the decrease ranged from 18 – 43.1% (Table 5).

Table 5. Sentiment Reduction Benefit (SRB) at the 4 cultivation periods.

Cultivation period	Runoff event	Sediment Reduction Benefit (RRB) in %; tillage parallel to contour	tillage perpendicular to contour
winter rotation of legume-cereal (2014/2015)	**88.4 mm**	15.7	18.0
summer sunflower (2015)	**53 mm**	52.1	36.4
winter rotation of legume-cereal (2015/2016)	**150.9 mm**	57.8	43.1
summer sunflower (2016)	**160 mm**	60.3	39.9

Table 6. Mean values of soil loss (kg ha^{-1}) volumes in the seven treatments of the two cultivation years.

Runoff event	Rainfall amount (mm)	Soil loss (kg ha^{-1}) Control	TR1	TR2	TR3	TR4	TR5	TR6	LSD
		1st year							
RE1	44.2	2.504 **d**	0.311 **a**	0.323 **a**	0.699 **bc**	0.367 **a**	0.475 **ab**	0.867 **c**	0.08552
RE2	31.6	0.723 **c**	0.256 **a**	0.350 **ab**	0.463 **b**	0.353 **ab**	0.413 **ab**	0.644 **c**	0.05817
RE3	12.6	0.563 **d**	0.057 **a**	0.068 **a**	0.141 **b**	0.125 **ab**	0.144 **b**	0.232 **c**	0.02403
Total 1 (RE1, RE2, RE3)	**88.4**	**3.789 e**	**0.624 a**	**0.741 ab**	**1.303 c**	**0.8456 ab**	**1.0312 bc**	**1.7440 d**	0.11603
RE4	35.8	5.283 **e**	0.269 **a**	0.592 **ab**	1.287 **c**	0.726 **b**	1.183 **cd**	1.647 **d**	0.14450
RE5	17.2	3.252 **b**	0.059 **a**	0.095 **a**	0.126 **a**	0.102 **a**	0.120 **a**	0.194 **a**	0.10938
Total 2 (RE4, RE5)	**53**	**8.535 d**	**0.328 a**	**0.686 a**	**1.412 cd**	**0.828 ab**	**1.303 bc**	**1.841 c**	**0.16696**
Total 1,2	**141.4**	**12.32**	**0.95**	**1.43**	**2.72**	**1.67**	**2.33**	**3.59**	
		2nd year							
RE6	68.9	10.070 **e**	0.519 **a**	1.319 **ab**	2.277 **c**	1.397 **b**	2.477 **cd**	3.171 **c**	0.27725
RE7	16	2.331 **e**	0.120 **a**	0.284 **ab**	0.575 **cd**	0.325 **b**	0.529 **c**	0.736 **d**	0.06338
RE8	66	7.046 **b**	0.497 **a**	1.091 **a**	2.181 **a**	1.338 **a**	2.372 **a**	3.037 **a**	1.14313
Total 3 (RE6, RE7, RE8)	**150.9**	**19.447 d**	**1.136 a**	**2.394 ab**	**5.034 bc**	**3.06 ab**	**5.378 bc**	**6.944 c**	**1.12578**
RE9	110.7	16.137 **e**	0.833 **a**	2.187 **b**	3.889 **c**	2.245 **c**	3.979 **cd**	5.094 **d**	0.39169
RE10	20	3.263 **d**	0.151 **a**	0.364 **ab**	0.736 **c**	0.406 **b**	0.719 **ac**	0.920 **c**	0.07830
RE11	29.3	4.844 **e**	0.221 **a**	0.484 **ab**	1.053 **cd**	0.728 **bc**	0.923 **bcd**	1.260 **d**	0.16329
Total 4 (RE9, RE10, RE11)	**160**	**24.244 d**	**1.204 a**	**3.035 b**	**5.677 c**	**3.379 b**	**5.621 c**	**7.275 c**	**0.59079**
Total 3, 4	**310.9**	**43.69**	**2.34**	**5.43**	**10.71**	**6.44**	**11.00**	**14.22**	

Different letters within each line indicate statistically significant differences between the treatments at the P <0.05 level.

2.5. Nutrients' loss results

The results of the concentrations of the K and P losses are presented in Tables 7 and 8. According to the results in all treatments the potassium and phosphorus losses were lower in comparison to the control plots (no – tillage and no plant). The reduced potassium values ranged from 39% (TR1) to 72% (TR6) the 1st year and from 47% (TR1) to 89% (TR6) the 2nd year in total rainfall 141.4 and 310.9 mm, respectively. In the case of phosphorus values the decrease ranged from 35% (TR1) to 86% (TR6) the 1st year and from 40% (TR1) to 82% (TR6) the 2nd year. Compared to the direction of planting tillage (parallel

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and perpendicular to the contour), the concentrations of potassium and phosphorus losses were reduced in parallel to the contour tillage. Additionally, the decrease of potassium and phosphorus losses were lower in no - tillage plots in comparison to the conventional planting. Analyses of variances were used to compare the amount of potassium and phosphorus losses of the different treatments for the two cultivation years in which total precipitation during the studied periods (March to October) were 141.4 and 310.9 mm in the 1st and in the 2nd year, respectively. The results (Table 7 and 8) show that there is a significant difference between all the different treatments and the control plots.

Table 7. Mean values of potassium loss (mg kg^{-1} soil) in the seven treatments of the two cultivation years.

Runoff event	**Rainfall amount (mm)**	**K (mg kg^{-1} soil)**							
		Control	TR1	TR2	TR3	TR4	TR5	TR6	LSD
					1st year				
RE1	44.2	0.819 **f**	0.254 **a**	0.257 **a**	0.433 **d**	0.304 **b**	0.390 **c**	0.546 **e**	0.003425
RE2	31.6	0.624 **f**	0.195 **a**	0.246 **b**	0.304 **d**	0.281 **c**	0.289 **c**	0.340 **e**	0.003462
RE3	12.6	0347 **e**	0.153 **a**	0.179 **b**	0.251 **d**	0.195 **c**	0.250 **d**	0.261 **d**	0.004039
Total 1 (RE1, RE2, RE3)	**88.4**	**1.790 g**	**0.602 a**	**0.682 b**	**0.987 e**	**0.780 c**	**0.930 d**	**1.147 f**	0.005863
RE4	35.8	0.661 e	0.244 a	0.378 b	0.507 cd	0.438 bc	0.478 c	0.585 de	0.029260
RE5	17.2	0.787 e	0.353 a	0.410 b	0.585 d	0.414 b	0.476 c	0.598 d	0.004537
Total 2 (RE4, RE5)	**53**	**1.448 e**	**0.658 a**	**0.731 a**	**1.091 d**	**0.848 b**	**0.954 c**	**1.184 d**	**0.030488**
Total 1,2	**141.4**	**3.24**	**1.26**	**1.41**	**2.08**	**1.63**	**1.88**	**2.33**	
					2nd year				
RE6	68.9	1.273 **f**	0.394 **a**	0.405 **a**	0.844 **d**	0.477 **b**	0.608 **c**	1.140 **e**	0.005334
RE7	16	0.319 **f**	0.099 **a**	0.124 **b**	0.172 **d**	0.145 **c**	0.146 **c**	0.189 **e**	0.002560
RE8	66	1.815 **e**	0.935 **a**	1.028 **b**	1.315 **d**	1.123 **c**	1.309 **d**	1.354 **d**	0.018415
Total 3 (RE6, RE7, RE8)	**150.9**	**3.407 g**	**1.428 a**	**1.557 b**	**2.330 e**	**1.745 c**	**2.063 d**	**2.683 f**	**0.022885**
RE9	110.7	2.511 **e**	1.164 **a**	1.353 **b**	1.826 **c**	1.482 **b**	1.997 **c**	2.193 **d**	0.005711
RE10	20	0.674 **e**	0.407 **a**	0.413 **a**	0.696 **d**	0.471 **b**	0.551 **c**	0.703 **e**	0.005952
RE11	29.3	0.989 **e**	0.577 **a**	0.597 **a**	0.956 **d**	0.668 **b**	0.778 **c**	0.976 **de**	0.006863
Total 4 (RE9, RE10, RE11)	**160**	**4.174 f**	**2.147 a**	**2.364 b**	**3.478 d**	**2.622 c**	**3.326 d**	**3.872 e**	**0.061679**
Total 3, 4	**310.9**	**7.58**	**3.58**	**3.92**	**5.81**	**4.37**	**5.39**	**6.74**	

Different letters within each line indicate statistically significant differences between the treatments at the $P < 0.05$ level.

Table 8. Mean values of phosphorus loss (mg kg-1 soil) in the seven treatments of the two cultivation years.

Runoff event	Rainfall amount (mm)	P (mg kg-1 soil)							
		Control	TR1	TR2	TR3	TR4	TR5	TR6	LSD
				1st year					
RE1	44.2	0.260 **e**	0.103 **a**	0.184 **b**	0.222 **cd**	0.186 **b**	0.214 **c**	0.225 **d**	0.002800
RE2	31.6	0.396 **e**	0.130 **a**	0.161 **b**	0.188 **c**	0.164 **b**	0.196 **c**	0.366 **d**	0.003956
RE3	12.6	0.301 **f**	0.086 **a**	0.120 **b**	0.211 **d**	0.160 **c**	0.163 **c**	0.244 **e**	0.003644
Total 1 (RE1, RE2, RE3)	**88.4**	**0.957 g**	**0.319 a**	**0.465 b**	**0.629 e**	**0.510 c**	**0.565 d**	**0.835 f**	**0.006313**
RE4	35.8	0.092 **c**	0.044 **a**	0.049 **a**	0.065 **b**	0.058 **b**	0.063 **b**	0.088 **c**	0.002523
RE5	17.2	0.103 **d**	0.027 **a**	0.042 **b**	0.069 **c**	0.048 **b**	0.067 **c**	0.071 **c**	0.003850
Total 2 (RE4, RE5)	**53**	**0.195 f**	**0.085 a**	**0.087 b**	**0.130 d**	**0.113 c**	**0.121 cd**	**0.156 e**	**0.004596**
Total 1,2	**141.4**	**1.15**	**0.40**	**0.55**	**0.76**	**0.62**	**0.69**	**0.99**	
				2nd year					
RE6	68.9	0,402 **e**	0.159 **a**	0.249 **b**	0.334 **d**	0.284 **c**	0.287 **c**	0.345 **d**	0.004214
RE7	16	0.201 **e**	0.066 **a**	0.082 **b**	0.099 **c**	0.083 **b**	0.095 **c**	0.184 **d**	0.001881
RE8	66	1.571 **f**	0.621 **a**	0.833 **b**	1.066 **c**	0.837 **b**	1.010 **d**	1.272 **e**	0.017213
Total 3 (RE6, RE7, RE8)	**150.9**	**2.173 f**	**0.846 a**	**1.164 b**	**1.499 d**	**1.204 b**	**1.392 c**	**1.801 e**	**0.018579**
RE9	110.7	0.280 **d**	0.135 **a**	0.145 **a**	0.203 **c**	0.174 **b**	0.191 **bc**	0.205 **c**	0.006617
RE10	20	0.083 **c**	0.030 **a**	0.036 **a**	0.063 **b**	0.056 **b**	0.058 **b**	0.080 **c**	0.003761
RE11	29.3	0.079 **c**	0.027 **a**	**0031 a**	0.049 **b**	0.042 **b**	0.045 **b**	0.071 **c**	0.003343
Total 4 (RE9, RE10, RE11)	**160**	**0.443 e**	**0.192 a**	**0.212 a**	**0.314 c**	**0.271 b**	**0.294 bc**	**0.357 d**	**0.008032**
Total 3, 4	**310.9**	**2.62**	**1.04**	**1.38**	**1.81**	**1.48**	**1.69**	**2.16**	

Different letters within each line indicate statistically significant differences between the treatments at the P <0.05 level.

2.6. Total Biomass results

As shown in Table 9 and 10, during the 1St and the 2nd year the total biomass of the intercropping *Triticosecale - Pisum sativum* in no - tillage treatment, with planting direction parallel to the contour was greater than the total biomass in the other 3 treatments. The NT-PPACD-P treatment had a statistically significant difference with the CT-PPECD-P plots, for both cultivated years. That treatment was higher by 17%, 25% and 33% in comparison to the CT-PPACD-P, NT-PPECD-P, CT-PPECD-P during the 1st year and 18%, 26% and 31% during the 2nd year, respectively.

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Table 9. Biomass of the intercropping *Triticosecale – Pisum sativum* cultivation (kg ha^{-1}) under different soil practices during the 1st year.

	Yield, kg ha^{-1}		CV %
Treatment	***Triticosecale - Pisum sativum***		
NT-PPACD-P	3034	**b**	16.4
CT- PPACD -P	2508	**ab**	8.3
NT-PPECD-P	2275	**ab**	23.6
CT- PPECD-P	2018	**a**	19.7
LSD		**251.5**	

Different letters at each column denote statistically significant difference of means according to the LSD test for 95% significance level ($p < 0.05$).

NT-PPACD-P: no tillage – planting parallel to the contour direction – plant
CT- PPACD -P: conventional tillage - planting parallel to the contour direction – plant
NT-PPECD-P: no tillage – planting perpendicular to the contour direction – plant
CT- PPECD-P: conventional tillage - planting perpendicular to the contour direction – plant

Table 10. Biomass of the intercropping *Triticosecale – Pisum sativum* cultivation (kg ha^{-1}) under different soil practices during the 2nd year.

	Yield, kg ha^{-1}		
Treatment	***Triticosecale - Pisum sativum***		**CV %**
NT-PPACD-P	3239	**b**	15.4
CT- PPACD -P	2646	**ab**	9.1
NT-PPECD-P	2412	**a**	12.6
CT- PPECD-P	2226	**a**	4.4
LSD		**184.61**	

Different letters at each column denote statistically significant difference of means according to the LSD test for 95% significance level ($p < 0.05$).

NT-PPACD-P: no tillage – planting parallel to the contour direction – plant
CT- PPACD -P: conventional tillage - planting parallel to the contour direction – plant
NT-PPECD-P: no tillage – planting perpendicular to the contour direction – plant
CT- PPECD-P: conventional tillage - planting perpendicular to the contour direction – plant

As illustrated in Table 11 and 12, during both cultivation years the plots with no – tillage and planting direction parallel to the contour (NT-PPACD-P) have presented higher total yield, 5350 and 5970 kg ha^{-1} during 1st and 2nd year, respectively. Statistically significant differences were observed between the NT-PPACD-P and CT-PPECD-P treatments.

Table 11. Biomass of the *Helianthus annuus* cultivation (kg ha^{-1}) under different soil practices during the 1st year.

	Yield, kg ha^{-1}		CV %
Treatment	***Helianthus annuus***		
NT-PPACD-P	5350	**b**	23.4
CT- PPACD -P	5230	**b**	10.5
NT-PPECD-P	4933	**ab**	5.1
CT- PPECD-P	3750	**a**	4.0
LSD		**403.03**	

Different letters at each column denote statistically significant difference of means according to the LSD test for 95% significance level ($p < 0.05$).

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NT-PPACD-P: no tillage – planting parallel to the contour direction – plant
CT- PPACD -P: conventional tillage - planting parallel to the contour direction – plant
NT-PPECD-P: no tillage – planting perpendicular to the contour direction – plant
CT- PPECD-P: conventional tillage - planting perpendicular to the contour direction – plant

Table 12. Biomass of the *Helianthus annuus* cultivation (kg ha^{-1}) under different soil practices during the 2nd year.

	Yield, kg/ha		**CV %**
Treatment	***Helianthus annuus***		
NT-PPACD-P	5970	**b**	12.0
CT- PPACD -P	5337	**ab**	9.3
NT-PPECD-P	5037	**ab**	3.6
CT- PPECD-P	4597	**a**	18.7
LSD		**356.92**	

Different letters at each column denote statistically significant difference of means according to the LSD test for 95% significance level ($p < 0.05$).

NT-PPACD-P: no tillage – planting parallel to the contour direction – plant
CT- PPACD -P: conventional tillage - planting parallel to the contour direction – plant
NT-PPECD-P: no tillage – planting perpendicular to the contour direction – plant
CT- PPECD-P: conventional tillage - planting perpendicular to the contour direction – plant

Furthermore, during the 2nd year the total biomass was greater compared to the 1st year in both cultivations (intercopping *Triticosecale - Pisum sativum* and *Helianthus annuus*). The increase in total yield was probably attributed to the positive impact of the residues which were incorporated into the field after the harvest of the intercopping Triticosecale - Pisum sativum.

3. Discussion

The runoff values according to the results was lower to the no tillage – planting parallel to the contours– with plant treatment. Specifically, the first year, the runoff values ranged from 5.004 (TR1) – 13.396 m^3 ha^{-1} (Control), while during the second year the runoff volumes ranged from 3.4112 (TR1) – 21.096 m^3 ha^{-1} (Control). Similar results were observed by other researches [7, 23]. On the other hand, Kebede et al. [24] reported lower reduction in runoff (12-39%), using alternative soil erosion amendments (Anionic polyacrylamide, gypsum, lime, biochar) in comparison to the current investigation results (reduction from 62 to 86%).

Soil losses results showed that the different tillage practices decreased the sediment loss by 71-92% the 1st year and by 67-95% the 2nd year. The lowest reduction was obtained by the no tillage – planting parallel to the contours– with plant treatment. Berihun et al. [6] found that different land management practices (no crop cultivation on steep slopes >30%, Khat plantation, Forage production, Reforestation on communal and hilly croplands resulted in a reduction in the soil loss by 32-95%. Comparing our results with other studies, it can be verified that the NT cultivation in lands with slope can significantly reduce the soil loss [7, 15, 19, 20]. Furthermore, the parallel to the contour cultivation is more affectively to the decrease of the sediment loss [29].

Furthermore, the no tillage practice – planting parallel to the contour had a positive effect to the decrease of potassium and phosphorus content. The same results are mentioned by Peri et al. [25]. It can be said that agricultural management practices such as soil tillage play a significant role in the nutrients' loss [8, 26]. According to literature, there are no studies which have been conducted for the investigation of positive or negative impacts of conventional tillage and no – tillage in combination with parallel and perpendicular to the contour cultivation, to the reduction of exchangeable potassium and extractable phosphorus.

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At this point, it should be mentioned that a crop rotation system (intercopping *Triticosecale* - *Pisum sativum* and *Helianthus annuus*) with no – tillage cultivation promotes the advantageous increase of the crop production. Our results are in agreement with other studies [27, 28].

4. Materials and Methods

4.1. Study area

In a field with a slope of at least 5% at the Experimental Station of the University of Thessaly (Larissa - Greece) an experiment was established. The studied area which has latitude of 39°37'30'' and a longitude of 22°22'51'', was located at an altitude of 80 m above sea level (Fig. 1). Its climate is characterized as Mediterranean with hot and dry summers as well as cold and wet winters.

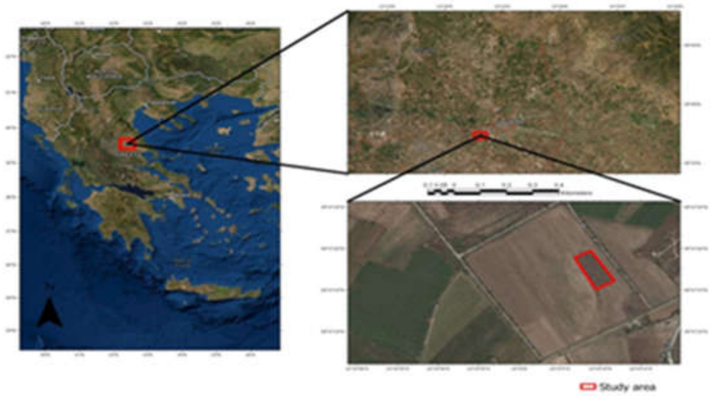

Figure 2. Location of the study area.

4.2. Soil analyses

Soil sample of the field was taken from a depth of 0-30 cm using a steel auger, before sowing. The soil sample was transported to the soil laboratory, air-dried and then was sieved through a 2-mm sieve. Soil was analyzed for pH (1:2.5 d. H_2O), electrical conductivity (1:5 d. H_2O), calcium carbonate ($CaCO_3$) using a calcimeter, the percentage (%) of sand, clay and silt using the Bouyoukos method, organic matter with Walkley – Black method, total nitrogen (Kjeldahl method), available soil P (Olsen method, analyzed with ammonium vanadomolybdate / ascorbic blue and measured in a UV spectrophotometer at 882 nm) and exchangeable K (1:10 at 1M CH_3COONH_4 pH 7, analyzed in a flame photometer). All the analyses were carried out according to Rowell (1994) [30].

4.3. Field experiment

The experiment included various combinations of cultivation treatments (conventional tillage and no - tillage), different cultivated soil directions (parallel and perpendicular to the contours), and vegetation covers (with and without crops), resulting in 7 treatments with three replicates each (treatments are explained in Table 1). The plots were 132 m^2 in size (6m in width x 22m in length). The split-plot experimental design was implemented.

Table 13. Abbreviations and description of the treatments.

Treatments	Abbreviation	Treatment description
Control	NT-WP	no tillage - without plant
TR1	NT-PPACD-P	no tillage – planting parallel to the contours– with plant
TR2	CT-PPACD-P	conventional tillage – planting parallel to the contours– with plant
TR3	CT-PACD-WP	conventional tillage – planting parallel to the contours– without plant
TR4	NT-PPECD-P	no tillage - planting perpendicular to the contours– with plant
TR5	CT-PPECD-P	conventional tillage – planting perpendicular to the contours–with plant
TR6	CT-PECD-WP	conventional tillage perpendicular to the contours- without plant

The experiment was conducted in two cultivated years. During the experiments all the necessary cultivation practices were conducted. The conventional tillage included ploughing to a depth of about 25cm in both autumn and spring. For the autumn cultivation tillage took place on the 6th of December in the first year and on the 8th of November in the second year. For the spring crop tillage was carried out on the 30th of June in2015 rand on the 12th of June in 2016.

All the plots were sprayed with herbicide glyphosate (at 5 L/ha) at least one month before the autumn cultivation in the 1st year of the experiment. Also, during the autumn cultivation the no-tillage plots were sprayed using herbicide glyphosate (3L/ha) in late March, during both cultivation years.

The plots were sown with the intercopping *Pisum sativum* (140 kg ha^{-1}) and *Triticosecale* (60 kg ha^{-1}) in the autumn period and with *Helianthus annuu*s (85.000 seeds ha^{-1}) in the spring period.

For the two cultivation periods, the following crop sequence was used for the accomplishment of the experiments: (a) winter rotation of legume-cereal (2014/2015); (b) summer sunflower (2015); (c) winter rotation of legume-cereal (2015/2016); (d) summer sunflower (2016).

During the autumn cultivation N was applied as basic (1/3 at sowing) and as top dressing fertilizer (2/3 at the end of March). Phosphorus (270 kg P_2O_5 ha^{-1}) and K (270 kg K_2O ha^{-1}) were applied at the same time with the sowing. During the spring cultivation the blocks were broadcasted with N (40 kg N ha^{-1}), P (60 kg P_2O_5 ha^{-1}) and K (60 kg K_2O ha^{-1}) during the sowing time.

For the first year, the autumn cultivation was harvested on the 5th of June and the *Helianthus annuus* plants on the 17th of October. For the second year the harvest was performed on the 3rd of June for the intercropping cultivation *Pisum sativum* and *Triticosecale* and on the 16th of October for the *Helianthus annuus*. The harvest of the plots with plants was conducted using a frame of 1 m^2. The frame was placed in 4 random places within each plot and the total biomass from lying inside the frame was collected harvested at a height of 1 cm above soil level. In the case of the intercropping cultivation *Pisum sativum* and *Triticosecale* the two different crops were separated. Additionally, the plants of *Pisum sativum* were separated into stems, seeds and pods and the Triticosecale plants into to stems and spikes. After the harvest of the autumn cultivation, the crop residues of the intercropping *Triticosecale* and *Pisum sativum* were incorporated into the field.

4.4. Measurement of runoff, soil and nutrients' loss

The study was conducted under natural rainfall conditions. Every plot was enclosed by a metal pipes system, so that the runoff was discharged into large containers which were installed into the ground at the down slope edge of each plot. In each container, a plastic bag was used and the plastic bags were put in plastic boxes after a significant natural rainfall event and were transported to the laboratory where the harvested runoff was weighed per plot. Then, the runoff volume was removed from each box and the fresh sediment samples were collected and dried at 60 °C for 48 h. From these samples, the soil loss, the Olsen-P (extraction at 1:20 with 0.5 M sodium bicarbonate ($NaHCO_3$) and exchangeable K (extracted at 1:5 with 1 M $CH_3CHOONH_4$) were measured (methods according to Rowel 1994).

In order to evaluate the way that the different tillage treatments affect the runoff and the soil loss, two indices were chosen: a) Runoff Reduction Benefit (RRB) in %; and b) Sediment Reduction Benefit (SRB) in % [7].

The calculations of these indices have been measured using the following equations:

$$\text{If } (RCT - RNT) > 0 \text{ then } RRB = ((RCT - RNT)/RCT)*100 \quad (1)$$

$$\text{If } (RCT - RNT) < 0 \text{ then } RRB = ((RCT - RNT)/RNT)*100 \quad (2)$$

$$\text{If } (SCT - SNT) > 0 \text{ then } SRB = ((SCT - SNT)/SCT)*100 \quad (3)$$

$$\text{If } (SCT - SNT) < 0 \text{ then } SRB = ((SCT - SNT)/SNT)*100 \quad (4)$$

where:
RCT is the runoff volume (m3) in the conventional tillage blocks
RNT is the runoff volume (m3) in the no – tillage blocks
SCT is the soil loss (kg/ha) in the conventional tillage blocks
SNT is the soil loss (kg/ha) in the no - tillage blocks

4.5. Statistical analysis

The data was analyzed using the Statgraphics plus 8.1 statistical analysis software for the analysis of variance at the level of significance 95% ($p<0.05$) and the LSD test was employed as a means of indicating the significance of differences among treatments.

5. Conclusions

In this study, we evaluated the impacts of no-tillage on runoff, soil and nutrients losses under natural rainfall in comparison to conventional agriculture. In addition, we investigated the effect of planting direction (parallel and perpendicular to the contour).

The results showed that the runoff volumes, the soil and nutrients losses were generally higher in CT than those in NT plot, regardless of the cultivated soil directions. In the case of planting cultivated direction, the planting parallel to the contour tillage had positive impact on the investigated parameters (runoff, soil and nutrients' losses).

Furthermore, The RRB and SRB values confirm that the no - tillage parallel to contour caused a greater reduction than that in tillage perpendicular to contour in runoff and in soil loss.

Since potassium and phosphorus nutrients (K and P) are necessary for plant growth, their losses on the other hand, due to runoff, can lead to detrimental impact for the yield production, especially when the fertilizers are expensive. In the current study significant differences have been observed regarding the concentration of potassium and phosphorus losses between the different treatments. Specifically, in plots cultivating parallel to the contour and with no tillage, the decrease was higher.

Additionally, the plant biomass yield was affected by the tillage direction. The no – tillage planting parallel to the contour direction had positive impact on the crop productivity in comparison to the other treatments. Specifically, the intercopping *Triticosecale - Pisum sativu*m and *Helianthus annuus* yield was higher in the NT-PPACD-P plots, in comparison to the CT-PPACD-P, NT-PPECD-P, CT-PPECD-P during the 1st and the 2nd year.

Also, it should be that during the second year the plant biomass was better than that of the first year. This probably means that the residues that remained in the field after the 1st year harvest influenced positively the production of the 2nd year.

To sum up, for Greece's climate the best agriculture management for sloping fields is for them to be cultivated using the no tillage processing and the planting should be conducted parallel to the contour direction. Finally, the cultivated plant system ''Legume – Cereal and Sunflower'' is a promising crop rotational process in the reduction of the soil and nutrients' losses.

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