Influence of Pasture and Rainfed Agriculture Land Uses on Soil Loss in Dojag-Chay Subwatershed (Ardabil Province-NW Iran)

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Abstract. One of the main resonator factors in watershed soil erosion is inappropriate land management including conversion of pasture land to dry-land farming. Unfortunately, the changes of Gara Su watershed usages have been very common. Thus, in order to understand the influence of land use on runoff rate and soil loss, soil losses were investigated and determined under both pasture and dry-land agricultures at sub-watershed of Dojag chay in southern west Qara Su Basin (within Ardebil province). In this Research, using a drop maker rainfall simulator device, 18 treatments under the said watershed were conducted using an artificial rain with the intensity of 6 mm/ min for 6 minutes and soil loss rate was measured due to the rainfall in two user types in dry-land and rangeland under natural humidity conditions and approximately the same as the raining season in three slope classes of 5 to 12, 12 to 20 and greater than 20. The results showed that with the cultivation, cultivated soils get empty and their porosity and permeability increase so, with the increase of water penetration ability, their runoff compared to the pasture lands starts with delay. Comparing the amount of runoff shows that after runoff gets started in rain-fed agriculture lands, the flowing speed and amount of water become more than those of pasture lands and the statistical analysis also verified the significant relationship, especially in slopes of more than 20% between the amount of soil loss and land use. The soil loss under rain-fed agriculture was 8.8 times more than the pasture. As the soil loss was compared for different slope classes of 5-12, 12-20, and more than 20 slope percent, the results indicated that the soil losses under rain-fed agriculture were 4.5, 5.6, and 12 times more than the pasture. The study results, therefore, can be utilized for proper management of area through devoting necessary attention into land uses.

Keywords: Pasture land, dry-land farming, Soil loss, Dojag Chay watershed, Rainfall simulator and Runoff

Introduction

Dojag Chay sub-watershed is one of the watersheds of Qara Sue basin in Ardebil province. It is of great nationally and locally ecological, environmental and economic importance. Feed production for the cattle containing lands which are suitable for producing strategic agricultural crops and its role in supplying part of water and sediments which fill large dams such as Sabalan makes the management and prevention of soil erosion of this watershed a necessity and an important task. During the past century, in this watershed, like the other watersheds of Qara Sue basin, the population has increased and the desire to have their own land has turned much of the pastures into rain-fed cultivation. This has not only produced good agricultural lands but at the same time has taken away the land's pasture value. Currently, some lands are used but with very low useful return, and some other lands have been abandoned and covered with weak and less useful plants (Consulting engineers of Boomabad, 1996). Moreover, the unmethodical plowing of pastures topped with the decrease in their area has increased the grazing of cattle on the remaining pastures. Also, despite the agriculture mechanization in this area, there has been a 20 to 40% decline in the crop (Talaei *et al.*, 2005) which the soil erosion of sloped agricultural lands and destruction of grass could be one of the most important causes of it. In this study, the amount of sediment production due to the conversion of pastures into the rain-fed agricultural lands is investigated.

Chapi (1997) by studying the role of agricultural land use in the production of sediments in watershed region of Chehel Gazi in Sanandaj has reached the conclusion that the produced sediment in the high-slopped agricultural lands is three times more than the fair to good pastures. The result of Agarazi *et al.* (2000), Ebrahimi (2000), Ahmadi Ilkhchy *et al.* (2001), Davoodi Rad *et al.* (2001), Matin (2002), Reisian (2004) and Shabani Heidar Abadi *et al.* (2004) on the relationship of land use and its slope with the soil erosion and production of sediments has shown that it is the least when the land is used as pasture and it is the most when the land is plowed and left alone. The results of Sokooti Oskoei *et al.* (2004) and Sadeghi *et al.* (2004) on the conversion effect of pasture lands into rain-fed cultivations on the soil erosion and amount of sediment production show that using land as pastures and agricultural lands has not had a significant effect on the production of sediment, and only the soil erosion in rain-fed lands has been slightly higher than the pasture lands. Interactions between soil erosion, runoff, slope gradient, vegetation and land use conversion have received much attention during the last decades (Elliot, 1986; Jassa Dickey and Dickey, 1991; Poesen *et al.*, 1992; Cambardella and Elliott, 1993; Six *et al.*, 2000; Erskin *et al.*, 2002; Dunjó *et al.*, 2004; Yousefi Fard *et al.*, 2005; Celik, 2006). The research conducted by Walt (1983) in the area of soil conservation in New Sate Wales using universal soil loss equation (USLE) of erosion to estimate the potential soil erosion showed that natural pasture with wheat farming increased the soil erosion 18 times. During the last twenty years, many projects for quantifying the amount of erosion without any interference of various ecosystems have been carried out (Boix-Fayos *et al.*, 2006). In these researches, to measure the runoff and sediment yield resulted from various types of land use, many methods have been proposed in which the plots of different sizes as well as natural and artificial rainfall intensity and different duration periods have been used (Andraski *et al.*, 1985; Navas *et al.*, 1990; Nolan *et al.*, 1997; Walsh *et al.*, 1998; Hamed *et al.*, 2002; Mathys *et al.*, 2005, and Boix-Fayos *et al.*, 2006). Cerdà, Calvo and Ibáñez (1997) to measure the runoff and sediment yields in steep terrain used small and portable rainfall simulator with plots of

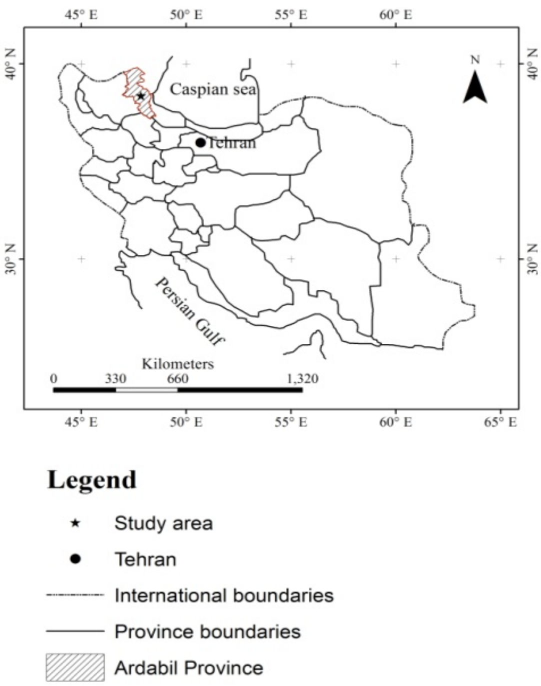
0.24 meter square, and the results were thoroughly evaluated.

Sum of background research expressed that this change of land use from forest and pasture to rain-fed farmlands increased the soil erosion and sediment production. Despite the fact that the results of some research including research results of Shabani and Sokooti Oskoei indicate insignificance of difference in the sediment produced in the poor pastures and converted lands, some other researchers have proven the increase of sediment yields because of the land use change. Since the conversion to agricultural lands, pasture and grazing areas in watersheds of Qara Su has been introduced as the main factor of soil loss and intensified erosion (Qara Su watershed feasibility studies) and since the amount of erosion in these areas has not accurately and quantitatively been measured, therefore, the study of runoff amount and produced sediment yields in pastures and mountainous farmlands of this region of our country is necessary. Performing any corrective action and its economic justification require having some accurate information on the amount of damages. By relying on the results of this study, the necessity of taking fundamental actions and their implementation along with speedy crisis management to protect the fertile soil of pastures and its restoration of degraded lands could be justified.

Materials and methods

Study area

Sub-watershed of Dojag Chay as one of the small sub-watersheds of Qara Su basin with an area of 188 km^2 is located in the northeast domains of Sabalan. The Dojag Chay sub-watershed is perched on 47˚ 57′ and 48˚ 03′ longitudes and 38˚ 22′ and 38˚ 27′ northern latitudes (Fig. 1).



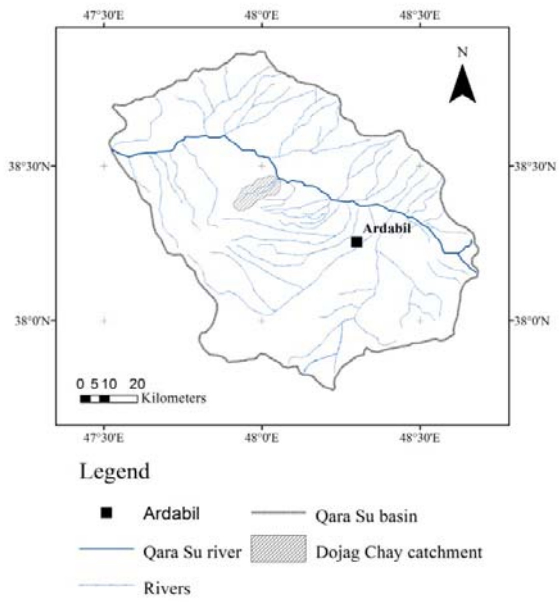


Fig. 1. Location of Study Area in the Country and Ardabil Province (left), Qara Su Basin and Dojag Chay Catchment Area (right)

The annual temperature mean is 7.8 ° C and annual precipitation is 500 mm which 33.1% percent of precipitation occurs during the spring (Dolati Mehrr *et al.*, 2003). The soil temperature and moisture regime maps of territory are located in the moist regime (wet) and Mesick thermal regime (mean annual soil temperatures between 8 -15°C) (Banai, 1998). The parent materials which make up the soil in this region are relatively homogeneous and are of extrusive igneous rocks type (Porphyritic latite and andesite related to the Eocene period and later) that as the result of being affected by weathering, have been crushed and degraded and as the result of mechanical, chemical and biological factors, have formed A or A, C soil horizons. The soils of this region because of not being too old and evolved are grouped with Intisols (Talaei *et al.*, 2005). Physical and chemical characteristics of soil in this region show a clay loam to sandy loam textures and some of farmland soil is poor in terms of absorbable phosphorous (Table 1). Land cover of pasture type in selected plots is made up of two types, *Trifolium* spp. and perennial grasses with moderate conditions and negative constant trends (Azimi *et al.*, 2005 and Consulting engineers of BoomAbad, 1996).

Table 1. Average of some surface soil properties and pasture crop in Dojag Chay sub-catchment

Landuse	Slope gradient (%)	Treatment	Soil texture	Field capacity	pH	Organic material (%)	Absorbable potassium (ppm)	Nitrogen (%)	Phosphorus (ppm)
Dry farming (a2)	5-12	b1	Clay loam	27.73	6.99	2.25	295.33	0.0183	25.73
	12-20	b2	Clay loam	23.68	6.54	2.22	330.00	0.0170	11.20
	>20	b3	Loam	19.62	7.42	1.13	170.66	0.0163	9.40
Pastures (a1)	5-12	b1	Sandy clay loam	28.00	6.68	3.36	326.00	0.0213	18.93
	12-20	b2	Clay loam	22.28	6.65	2.27	216.00	0.0163	15.13
	>20	b3	Sandy clay loam or Loam	16.72	6.94	1.64	158.00	0.0153	22.80

Methodology

This study was carried out using the experimental plot method in nine spots of Dojag Chay watershed, and in each spot, the amount of soil degradation due to 6 minute simulated rainfall in pastures and rain-fed farmlands was measured. In this study, sections of rain-fed farmlands which at least have been converted for ten years, and the pastures adjacent to them with slopes of 5 to 12%, 12 to 20% and greater than 20% were selected. In each group, three sections of land from each slope group were selected (three replications and overall nine sections or plots). Thus, a total of 18 rainfalls were simulated and soil loss rates were measured. In order to create conditions of equal severity, duration and other characteristics of rainfall, Rainfall simulator (Kamphorst, 1978) with rainfall levels of 25 m × 25 m was used (Figure 3). The results using factorial experiment method in form of randomized complete block design (RCBD) were analyzed. Finally, variation sources (SV) with meaningful "F"and the mean comparison using Duncan method were conducted (Yazdi Samadi, Rezai and Valizadeh, 2003).

For all the tests, rainfall duration and its intensity were 6 min and 6 mm per minute, respectively. Soil structure of land now and past is changed by the land use type, so this research has been trying to select plots of pasture and farmland uses. In the selected agricultural lands, rotation of grains including wheat and barley and fallow during the last ten years has been met. Even though the best standard moisture conditions for testing is when the soil moisture is close to the field moisture capacity condition, but due to not being able to establish these conditions naturally in all plots and also to get more realistic results, tests were conducted under natural moisture conditions during a short time (two days in autumn).

Fig. 3. View of Rainfall Simulator Used in This Study

Results

The results of soil loss rate for the 18 tested plots in this study are presented in Table 2. The study of runoff start time in different slope categories in pasture and farmlands showed that with increasing slope the start time of runoff is decreased and due to water penetration in the agricultural lands, runoff time in comparison with the pasture lands has been delayed (Fig. 4). The runoff start time mean in slopes of 5 to 12%, 12 to 20% and greater than 20 percent has been 198, 154.66 and 81 seconds in agricultural lands and in pasture lands 103.33, 76 and 34.66 seconds, respectively.

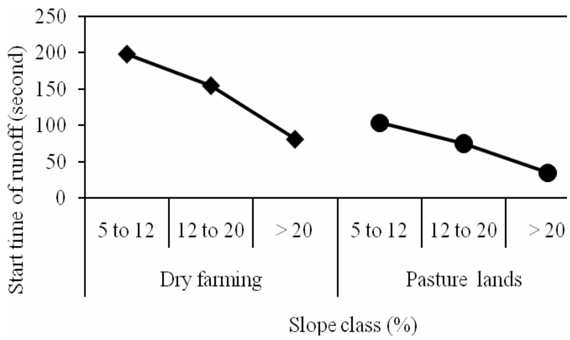


Fig. 4. Runoff Start Time (seconds) of Pasture and Agricultural Soil Based on Slope Classes(%)

Table 2. Runoff start time, runoff and soil loss rates on dry farmlands and rangelands in Dojag Chay sub-watershed

Landuse	Slope gradient (%)	Replication	Runoff start time (second)	Runoff volume (ml)	Soil loss (g/625 cm²)	Sediment concentration (g/l)
Dry farming (a2)	5-12	1	270	480	0.950	1.98
		2	165	460	4.453	9.68
		3	159	490	5.620	11.47
	12-20	1	166	560	1.605	3.21
		2	158	530	9.318	17.92
		3	140	550	8.201	16.08
	>20	1	87	630	29.478	46.79
		2	90	650	27.420	42.19
		3	66	600	21.360	35.60
Pastures (a1)	5-12	1	150	530	0.522	0.99
		2	70	420	0.469	1.12
		3	90	560	1.415	2.53
	12-20	1	72	650	1.080	1.54
		2	80	600	1.031	1.39
		3	76	600	1.292	1.79
	>20	1	25	800	2.355	2.94
		2	47	830	2.307	2.78
		3	32	870	1.857	2.13

With increasing slope, the volume of produced runoff is also increased and this increase is higher in pasture lands than in dry farmlands (Fig. 5).

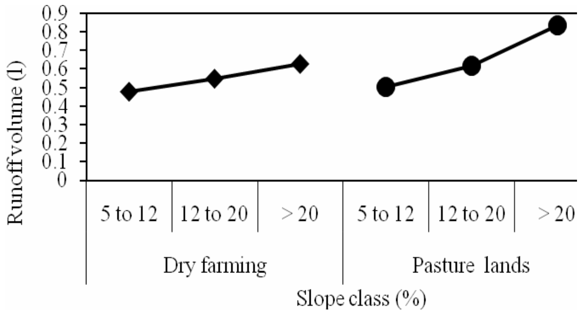


Fig. 5. Volume of Runoff Produced by Simulated Rainfall in Six Minutes in Rangeland and Dry Farmland Soil in Different Slopes

Null hypothesis (H_0), lack of effect of land use type and land slope on the start time and volume of runoff can be rejected based on the analysis of variance (ANOVA) (Table 3). The runoff starts time in agricultural lands increases on average 2.35 times more than the range lands. The results of mean comparison using Duncan method show that the slope percentage of plots in this study has a significant effect on the runoff start time and volume (Table 4).

The results of the interaction effects of land use type and slope gradients on the runoff start time and its volume in experimental treatments indicated that pasture treatments with the slope of more than 12 percent and dry farmlands with more than 20 percent slope are in one subgroup, and in these lands, the start time is minimum. The runoff start time in this sub-group shows a significant difference of dry farms with the ones which are in 12 to 20% and 5 to 12% slopes.

Based on the volume of produced runoff, the treatments can be placed in three sub-groups in which the rangelands with a slope of greater than 12% and the agricultural lands with a slope of greater than 20% have the highest runoff volume. The agricultural lands with a slope of less than 20% and the rangelands with a slope of 5 to 12% have the lowest runoff volume and are placed in the same subgroup and show a significant difference with the above-mentioned subgroups (Table 5).

Table 3. Results of two way ANOVA and main and reciprocal effects of slope groups and land use type based on runoff onset, runoff volume and penetrating water volume (F: ratio of variance of the means to mean of the variance of the samples)

Sources of variation		Start time of runoff (second)		Runoff volume (ml)	
		F	Sig.	F	Sig.
Main effect	Landuse	24.022	0.000	28.208	0.000
	Slope classes (%)	13.116	0.001	14.74	0.002
Interaction effects (landuse and slope gradient)		0.891	0.436	9.236	0.004

Table 4. Duncan method comparison show that the runoff start time, runoff volume and slope classes were affected by the slope levels and in three subgroups with 0.01 level are significant

Slope classes (%)	Runoff start time (second)		Runoff volume (ml)		
	Subset for alpha=0.01		Subset for alpha=0.01		
	1	2	1	2	3
>20	57.83 (a)		0.73 (a)		
12 to 20		115.33 (b)		0.58 (b)	
5 to 12		150.66 (b)			0.49 (c)

Table 5. The results of mean comparison of unoff start time and volume in six treatments using Duncan method in three repeated tests (a2: rain-fed farming, a1: pasture, b1: slope of 5 to 12%, b2: slope of 12 to 20%, b3: slope of greater than 20%).

Runoff start time (second)					Runoff volume (ml)				
Treatments	Subset for alpha=0.01			Ranked order	Treatments	Subset for alpha=0.01			Ranked order
	1	2	3			1	2	3	
a1b3	34.66			a	a2b1	0.476			a
a1b2	76.00	76.00		ab	a1b1	0.503			a
a2b3	81.00	81.00		ab	a2b2	0.546	0.546		ab
a1b1	103.33	103.33		ab	a1b2		0.616		b
a2b2		154.66	154.66	bc	a2b3		0.626		b
a2b1			198.00	c	a1b3			0.833	c
Sig.	0.030	0.016	0.122		Sig.	0.051	0.029	1.00	

Note: The phrases which are in the same sub-group do not have a significant difference; whereas the phrases which are in different sub-groups (due to not being redundant) have a significant difference with one another.

With increasing the slope of domains, soil loss rate (sediment) increases and the increase in agricultural land is much more than the pasture sediment production rate of converted agricultural lands compared to the pasture lands in which slopes of 5-12%, 12-20% and greater than 20 percent increase 4.5, 5.6 and 12 times,respectively (Fig. 6).

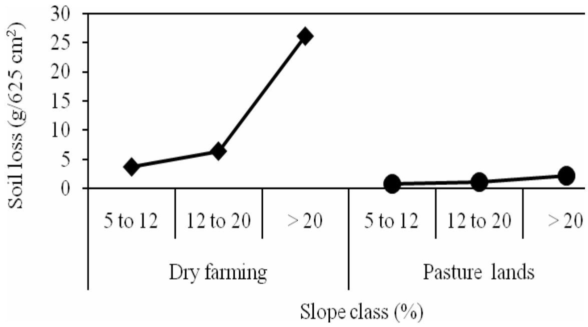


Fig. 6. Average soil loss (grams per 625 cm square) in rangeland and dry farmlands with different slopes

Test results also show that the land use type and slope of tested plots are the causes of significant difference in the produced sediment amount (Tables 6 and 7). 93 percent scattered condition of sediment produced (R2 = 0.93) can be explained by the landuse type and slope category of lands.

Table 6. Variance analysis using two way variance analysis (ANOVA) with main and interaction effect based on sediments of pasture and rain-fed agriculture lands, Alpha = 0.01

Sources of variation		Soil loss (g/625 cm^2) F	Sig.
Main effect	Landuse	14.91	0.002
	Slope classes (%)	7.31	0.007
Interaction effects (landuse and slope gradient)		28.82	0.000

Table 7. Comparison of soil loss means (sediment) using Duncan method in dry farmlands and pasture lands in three slope classes

Slope classes (%)	Soil loss (g/625 cm^2) Subset for alpha=0.01: 1	2
5 to 12	2.238 (a)	
12 to 20	3.754 (a)	
>20		14.129 (b)

Based on the comparison results of sediment deposition means in the treated agricultural lands, the treated lands could be divided into two groups of treated agricultural rangeland or pasture lands and proves that the sediment rate for the treated agricultural lands is more than the treated pastures. Sediment produced in the treatments with rain-fed agriculture use and slope of more than 12 percent has a significant difference with all treatments including all the treated pastures and agricultural lands with a slope of lower than 12% (Table 8).

Table 8. Comparison of average produced sediment in treatment 6 using Duncan method

Soil loss (g/ 625 cm^2)

Treatments			Subset for alpha=0.05			Ranked order
Landuse	Slope gradient	Abbreviations	1	2	3	
Pasture	5 to 12%	a1b1	0.802			a
	12 to 20%	a1b2	1.134			a
	>20%	a1b3	2.173	2.173		ab
Dry farms	5 to 12%	a2b1	3.674	3.674		ab
	12 to 20%	a2b2		6.374		b
	>20%	a2b3			26.085	c
Sig.			0.238	0.086	1.00	

Discussion

With the aim to evaluate the land use role in the runoff generation and sediment yield, replicated experimental microplots (625 m^2) were installed in two environments, pasture lands and dry farms. The results of soil loss measurement due to the artificial rain with an intensity of 6 mm/min in 18 experimental plots under natural moisture conditions in the wet season and different slopes using two types of management practices showed that between the volume of runoff and soil loss both in crop and pasture lands, a significant correlation exists (correlation of agricultural land with a coefficient of 0.874 and pasture land with a coefficient of 0.894 is significant at 0.01 level. But the soil loss average in rain-fed lands is always more than pasture lands with moderate conditions and constant trends. Although, according to some literature, a direct relationship between rainfall, runoff and soil loss is proved. Moreover, runoff and eroded soil are also highly positive correlated (Dunjó *et al.*, 2004) but in study area, it can be said that the lowest rates of runoff volume and highest soil loss are related to the cultivated or recently abandoned environments and the highest runoff volume and lowest soil loss to the pasture lands with good condition.Runoff start time in agricultural lands compared to pasture has been reduced.The reduction of runoff start time in dry farm lands compared to pasture has been proven by another researcher (Raeisian, 2004 and Sadeghi *et al.*, 2004). Comparing the amount of runoff shows that after runoff gets started in rain-fed agriculture lands, the flowing speed and amount of water become more than those of pasture lands. Many factors play an important role in hydrological and erosion processes of which soil type, vegetation cover type and percentage, land use and rainfall erosivity are expected to be important (Wischmeier *et al.*, 1971; Luk, 1979; Lal, 1988; Bajaracharya and Lal, 1992; Romero-Díaz *et al.*, 1999). In this research, such a reduction in the runoff onset is believed to be caused by a decrease in vegetation cover and apparent porosity of soil and increased grazing in pasture land and in agricultural lands, the roughness of soil is caused by plowing. Vegetation cover of pasture lands can affect the runoff volume and sediment yield in the study area and several studies in a variety of environments have demonstrated the positive effect of vegetation cover on the reduction of water erosion (Elwell and Stocking, 1976; Dunne *et al.*, 1978; Francis and Thornes, 1990; Boix-Fayos *et al.*, 1998). Although in the agricultural lands, the soil permeability is increased by plowing thus delaying the runoff start time in comparison with the pasture lands, the sediment production rate in dry farmlands are more than that of the pasture lands under the same conditions with regard to moisture. The overall soil loss is, on average, in rain-fed farmlands is 1.369 grams and in agricultural lands is 12.04 grams per 625 square centimeters. This result represents the increase of soil loss eight times more than that of pastures with moderate conditions. The results of this study are in line with findings of walt (1983), Jasa and Dickey (1991), Agha Razi and Ghodoosi (2000), Ahmadi Ilkhchy (2001), Ghodoosi *et al.* (2004), Vanyompaey *et al.* (2002) and Yousefi Fard *et al.* (2005). The results showed that the cultivation of the pastures degraded the soil physical properties leaving soils more susceptible to the erosion. Comparison of the erosion degree in sloped lands, especially in agricultural lands with a slope of higher than 20% with the less sloped lands showed a highly significant value has been proven by Valmis *et al.* (2005) and Celik (2006). They showed that increase in slope is directly associated with the increased rate of runoff and erosion.

Conclusions and Recommendations

Considering the results of this study, it can be concluded that on the whole, the soil loss rate in pasture lands of this region is lower that the rain-fed agricultural lands. Therefore, if the pastures have good plant coverage, the soil loss rate and the produced sediment in them will be fairly lower than those of degraded lands which are converted and are used as rain-fed agricultural lands, especially in the high-sloped domains. The results of this study are like a warning bell reminding us that if the pastures are degraded, misused, converted and used improperly as agricultural lands, in time they will lose their plant coverage. Moreover, if the trend of using the pasture lands for agricultural purposes is to be continued unmethodically, the amount of produced sediment in them will be much more than the pasture lands with good degree of plant coverage. As the result, the erosion and sedimentation rates will greatly increase. This would lead to irreversible and irreplaceable direct and indirect damages to the soil and land. Thus, it is vital to prevent the unmethodical conversion of pastures and reduce the soil erosion and sedimentation in these lands. It is also vital to make it a priority to manage the lands which are currently used for agricultural purposes and use appropriate mid-term quarantine methods in pasture lands. It is also vital to start planting seeds which would strengthen the plant coverage of degraded pastures. This suggests that land disturbances should be strictly avoided in the pastures with the limited soil depth in the Qara-su basin highlands.

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