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Influence of land use on changes of sediment budget components: western Iran case study

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Abstract: Understanding the processes of displacement and redistribution of soil particles caused by different erosion types is considered an efficient sediment management tool in various scales from the field plot to the watershed. The rainfed agriculture practices on high gradient slopes are one of the main sources of accelerated soil erosion due to the disturbance of soil structure by tillage processes. Therefore, the present study aimed to investigate the synergistic effect of rainfed agriculture practices and slope gradient on soil erosion using the activity concentrations of ^{137}Cs fallout in Khamsan experimental watershed, western Iran. The diffusion and migration model was used for undisturbed soils and mass balance equation type II was used for agricultural lands. The distribution map of soil erosion and deposition of the watershed was prepared using ^{137}Cs method and the interactions between rainfed agriculture and slope gradient (as the most effective geomorphological factor) on erosion rate and sediment redistribution were evaluated. The results indicated that the highest rates of soil erosion in rainfed agriculture (11.46 t ha^{-1} year^{-1}) and rangeland (1.27 t ha^{-1} year^{-1}) were recorded in the slope gradient classes of 20%–30% and >60%, respectively. In addition, the maximum sedimentation in rainfed agriculture (5.78 t ha^{-1} year^{-1}) and rangeland (0.89 t ha^{-1} year^{-1}) occurred in the slope classes of 30%–60% and in >60%, respectively.

Key words: Accelerated soil erosion, fingerprinting, cultivated fields, sediment redistribution, sediment source

1. Introduction

World population is increasing at a worrying rate. It has reached 8 billion as of November 2022 (www.worldometers.info/world-population, accessed on November 19, 2022) and according to forecasts will have reached 10 billion by 2056. To improve the human welfare, food consumption per capita per year is expected to increase from 2789 kcal (1999–2001 average) to some 3130 kcal in 2050 globally (Alexandratos et al., 2006). Thus, expanding agricultural land is essential to increase crop production and feed a growing population. This goal can be achieved by changing land use of other land cover to arable land (Spalevic, 2011). It has been estimated that nearly moderate to severe soil erosion (Mabit et al., 2014; Ouallali et al., 2020) affects 80% of agricultural lands.

The type of land use is one of the significant factors in the sediment redistribution of the watershed (Fiener et al., 2011; Zhang et al., 2015; Spalevic et al., 2020).

Iran is also exposed to extreme land use changes. Forest and rangelands have been reduced in the area and/or converted into agricultural, commercial, and residential lands (Mohammadi et al., 2020), which has consequently led to intensifying floods and increased annual sediment production (Zabihi et al., 2020).

Based on data collected by Iranian Forests, Range and Watershed Management Organization (IFRWM), the amount of total soil erosion in Iran is estimated from at least 1 billion to nearly 5 billion t year^{-1}, which extremely differs from less than 1 t ha^{-1} year^{-1} in Hyrcanian forests to more than 50 t ha^{-1} year^{-1} in some semiarid areas with marl geological formations in various parts of the country. In addition, the estimated soil erosion rate for 125 million hectares of the watersheds of Iran ranges from 25 to 30 t ha^{-1} year^{-1} (Khajavi et al, 2015).

Soil erosion intensity on agricultural land is at least 1-2 times higher compared to natural undisturbed lands (Pimentel and Kounang, 1998). The estimated erosion sensitivity of agricultural lands was estimated in the range of 2.4 and 2 times of magnitude compared to forest and rangeland land use, respectively (Celik, 2005). According to some of the researchers, the greatest values of soil erosion and sediment yield occurred in agricultural land

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uses (Collins et al., 2001; Pardini et al., 2003; García-Ruiz, 2010; Nunes et al., 2010; Meliho et al., 2019; Aneseyee et al., 2020). Liu et al. (2008) stated that the alterations of steep slopes in cropland along with rangeland degradation are the key reasons for erosion occurrence on agricultural lands.

Although the impact of land use change on soil erosion rate has been extensively documented, the effect of land use changes on the river sediment loads is less clear (Walling, 1999).

Hence, understanding the relationship between land use changes and effectiveness of the consequences is necessary for correct management strategies of the watersheds. Many environmental problems such as soil erosion, desertification, resource degradation, and environmental pollutions are the result of land use changes (Bai et al., 2017).

Impacts of land use on global soil erosion have been evaluated by using different methods in many studies (e.g., Kosmas et al., 2002; Wei et al., 2007; García-Ruiz, 2010; Yoshimura et al., 2015; Borrelli et al., 2017; Ouyang et al., 2018; de Hipt et al., 2019; Zabihi et al., 2020).

Many researchers have estimated the erosion rate and sediment yield affected by land use using different erosion models such as erosion potential model (EPM) (Solaimani et al., 2009), IntErO model based on EPM (Spalevic, 2019), universal soil loss equation (USLE) (Wijitkosum, 2012; Paroissien et al., 2015), revised universal soil loss equation (RUSLE) (Zhang et al., 2006; Zhou et al., 2008), water and tillage erosion model/ sediment delivery model (WaTEM/SEDEM) (Szilassi et al., 2006), and geo-spatial interface for water erosion prediction project (GeoWEPP) (Zhang et al., 2015). In some other studies, ^{137}Cs technique has been utilized for the same targets (Walling, 1999; Meliho et al., 2019) because of some advantages especially measuring not only soil erosion but also soil deposition at the soil-sampling site, which makes it possible to prepare a distribution map of erosion and sediment.

The ^{137}Cs technique has also been applied to modelling the influence of the land use on soil erosion at various scales (Santos et al., 2017) associated with specific situations of agricultural use, for example, no-tillage (Didoné et al., 2019). The probability of determining the amount of sediment redistribution caused by displacement of soil particles under different land uses is one of the most vital benefits of applying fallout radionuclides in soil-erosion and sedimentation investigations (Zapata, 2002).

In addition, the great capabilities of ^{137}Cs technique such as the distribution map of soil erosion/deposition and calculation of sediment budget components has been demonstrated by numerous researchers (e.g., Li et al., 2009; Abbaszadeh Afshar et al., 2010; Benmansour et al., 2010, 2013; Gharibreza et al., 2013; Nosrati et al., 2015; Rabesiranana et al., 2016; Porto et al., 2016; Lizaga et al., 2018; Hancock et al., 2020; Sedighi et al., 2021; Ayoubi et al. 2021).

One consequence of climate change and population growth is more changes in land-use and therefore severe soil erosion in some areas of the world, such as Yemen (Pietsch and Mabit, 2012). Iran also suffers from similar concerns in terms of pressure on water and soil resources, because most regions of Iran have arid and semiarid climates (Modares and da Silva, 2007), as well as having experienced rapid population growth and increase in the area of agricultural lands especially through rainfed agriculture in recent decades. Two most dramatic aspects of the rainfed agriculture are: 1) the higher slope gradient of these lands compared to the irrigated agriculture and 2) the soil ploughing parallel to the slope direction. Because of the low precipitation and more than 5–6 months without precipitation during spring and summer in this area, the production capacity of rainfed agricultural lands especially in higher slope gradients are very low and also soil ploughing parallel with the slope direction causes more runoff, erosion, and sediment transport in these lands. Therefore, the main aim and novelty of the present study is to highlight the effects of land use especially changing from rangeland to rainfed agriculture in western Iran.

The current investigation is section of a series projects for the quantification of soil erosion and deposition rates in one of the 15 representative watersheds selected and gauged by Forest, Range and Watershed Management Organization of Iran. Each of these 15 watersheds signifies a greater area with similar conditions where the chief aim of evaluating and conducting the researches in these watersheds is a possibility to expand and utilize the findings to those larger regions of the country. The goals of the current investigation were as follows:

(i) To quantify soil erosion and deposition rates for different types of land use (rainfed and irrigated farming, orchard, and rangeland with and without contour trenching soil conservation practice) in Khamsan representative watershed, west Iran.

(ii) To identify the major effective factors on sediment redistribution using ^{137}Cs method in mentioned watershed.

2. Materials and methods

2.1. Study area

The Khamsan Watershed with an area of 4336 ha is located between 47°04′06″ to 47°10′44″ E longitude and 34°57′ 41″ to 35°01′29″ N latitude in Kurdistan Province in western part of Iran (Figure 1). The mean elevation and slope of the watershed are 1840 m and 25.11%, respectively. Although the slopes in the watershed upstream branches and subwatersheds have high gradient (up to 115%), 48% of watershed is hilly plain with slope gradient <20%. This

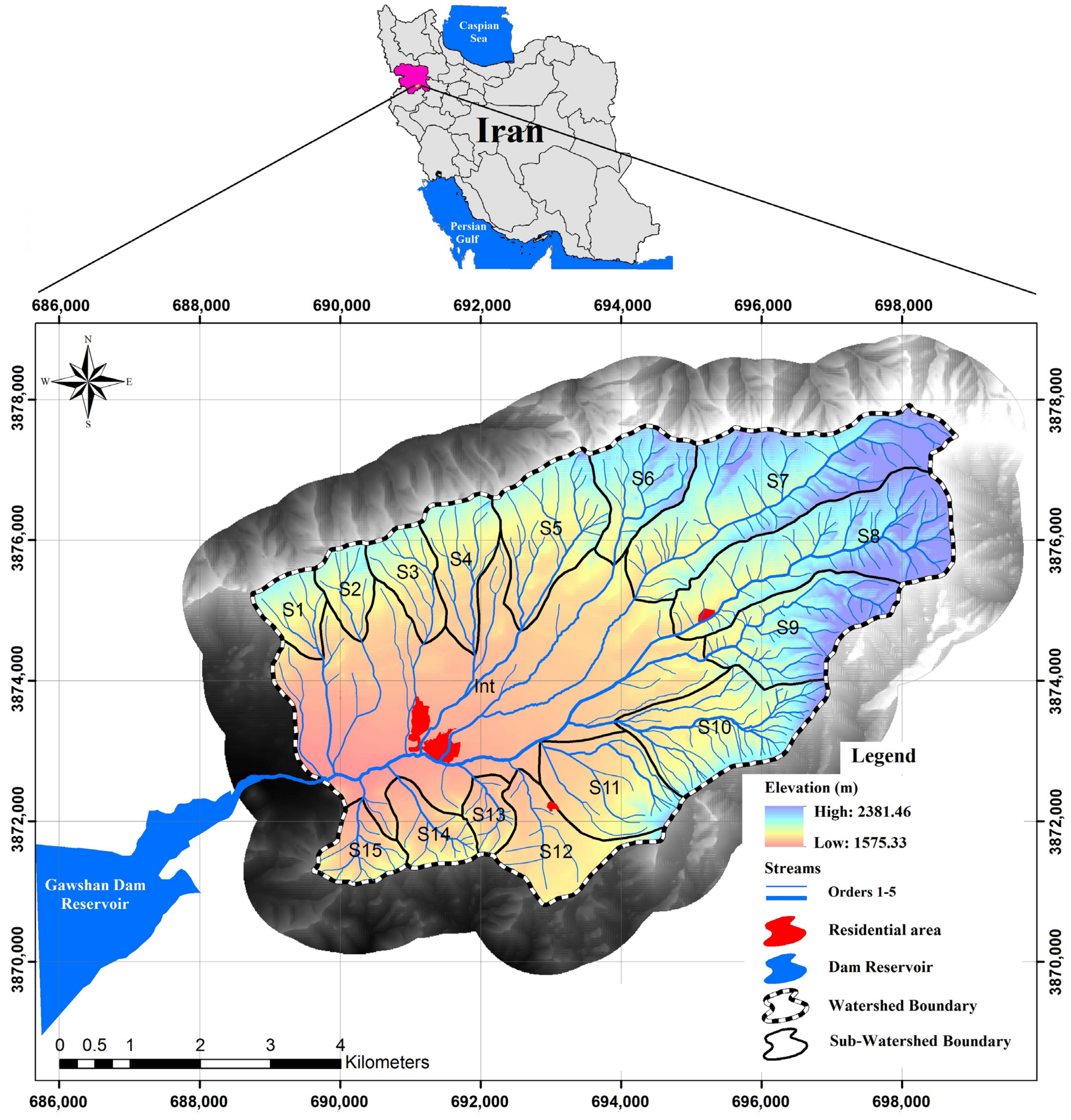

Figure 1. Location of the study watershed in Kurdistan Province in western Iran.

area of 1323 ha occupies the middle part of the watershed (Figure 1) and the area of 1000 ha occupies the high slope parts of the watershed.

The lithological data showed that the main lithology units of the watershed is grey to red conglomerates, alluvial deposits, and also limestone which covers about 49%, 30%, and 6%, respectively. The mean and standard deviation of the soil properties for the top 25 cm of the soil in various land uses are shown in Table 1.

As can be seen in Table 1, factors of >2 mm fragments, mean and median particle sizes, organic matter content, and bulk density are significantly different in the soils of various land uses. The average annual air temperature and the average annual precipitation are 12.5 °C and 428 mm, respectively, based on the 16 years of data from the Khamsan meteorological station which is located inside the subwatershed 14 (S14) close to the Khamsan village. The distribution of the precipitation along the year cause

Table 1. Mean and standard deviation of the soil properties for the top 25 cm of the soil in various land uses.

Land use	Depths (cm)	>2 mm fragments (%)	Sand (%)	Silt (%)	Clay (%)	pH	EC (mS m^{-1})	Organic matter (%)	Bulk density (g cm^{-3})
Rainfed agriculture	Mean	26.03	65.71	30.75	3.54	7.54	165.88	0.77	1.18
	Standard deviation	12.78	2.24	3.12	1.69	0.1	18.25	0.31	0.24
Orchard	Mean	58.11	72.66	23.8	3.54	7.31	389.67	1.86	0.96
	Standard deviation	9.35	3.76	4.13	0.79	0.16	273.8	0.42	0.15
Rangeland	Mean	39.29	67.17	25.42	7.41	7.35	213.47	0.99	1.05
	Standard deviation	9.24	2	3.52	4.04	0.23	203.78	0.33	0.06
Irrigated agriculture	Mean	45.73	64.55	31.43	4.03	7.38	319.67	2.01	0.91
	Standard deviation	21.52	2.05	2.55	0.73	0.15	21.56	0.18	0.13

more droughts during late spring and summer. The maximum rainfall intensity observed during the last 16 years in the study area is about 140 mm h^{-1}, which mostly occurred during spring and autumn.

Khamsan watershed has seven types of land use/land cover including rainfed and irrigated agriculture (mostly wheat and barley), orchard, rangeland (various species of the families Poaceae and Leguminosae, especially Hordeum, Aegilops, and Astragalus), rangeland with contour trenching, residential land, and rock outcrops. The rangelands of the study area faced the intense effect of droughts, overgrazing, and land use change to rainfed agriculture in recent decades. The rangeland and residential land use represent about 48% and 1% of the total area, respectively (Figure 2).

2.2. Measuring soil erosion/deposition using ^{137}Cs method

Two cemeteries were selected as the reference areas at the distance of 4 and 3 km in the north and northwest from the watershed of Khamsan, respectively (Figure 2). Cultivating and grazing in these old parts of the cemeteries are completely prevented. In addition, the old parts of the cemeteries have not been used for burial for at least 60 years. Both reference areas are located at a distance of 4 and 3 km in the north and northwest away from the watershed, respectively (Figure 2). A rectangular scraper plate sampler with dimensions of 40 × 20 × 30 cm was used for incremental sampling (Sedighi et al., 2021). Incremental soil sampling in the reference areas was undertaken in July 2017 at 10 points allocated in a random grid strategy and at different horizons as 0–3, 3–6, 6–10, 10–15, 15–20, and 20–25 cm.

Both bulk and incremental samples were collected in the studied watershed following a systematic strategy considering the homogenous units based on land use/land cover and slope gradient map. In the present study, due to the diversity of land use and in view of the purpose of the study, which was to investigate the effect of internal low slope area on the transfer and delivery of sediment to the watershed outlet, it was attempted to spread the sampling points in such a way that in each land use and slope level, there would be several sampling points proportional to the area. In other words, considering the effect of slope for precise measurements of erosion and sedimentation, systematic-random sampling was carried out. Accordingly, 46 bulk samples and 10 incremental samples were taken on different slopes and elevation levels. The distribution of soil samples on land use map of the study area is shown in Figure 2.

All incremental and bulk soil samples were oven dried at 105 °C for 24 h, disaggregated and passed through a 2-mm sieve. A representative subsample of <2-mm fraction was packed into Perspex plastic pots for determining the ^{137}Cs activity (Bq kg^{-1}) by gamma spectroscopy in the radiometry laboratory of the Department of Nuclear Physics at the University of Isfahan, Iran. Concentrations were measured via gamma spectrometry at 662 keV, using a high-resolution coaxial HPGe p-type detector coupled to a PC-based data collection system. Count times were typically approximately 86,400 s, providing results with an analytical precision of approximately 10% at the 95% level of confidence. The grain size analysis of soil and sediment was done through sieving and hydrometer method (Sedighi et al., 2021).

For the use of ^{137}Cs in erosion and sediment studies, the coefficient of variation of ^{137}Cs in reference area's sampling points should be less than 20% (Zapata, 2002). After measuring ^{137}Cs inventory for reference and other sampling points, erosion and sediment yields were calculated using appropriate conversion models. The different conversion models were used for calculation of soil loss/gain for cultivated and non-cultivated soils (Walling et al., 2007).

In this study, for rangelands, because of the lack of initial evaluation and signs of material displacement in

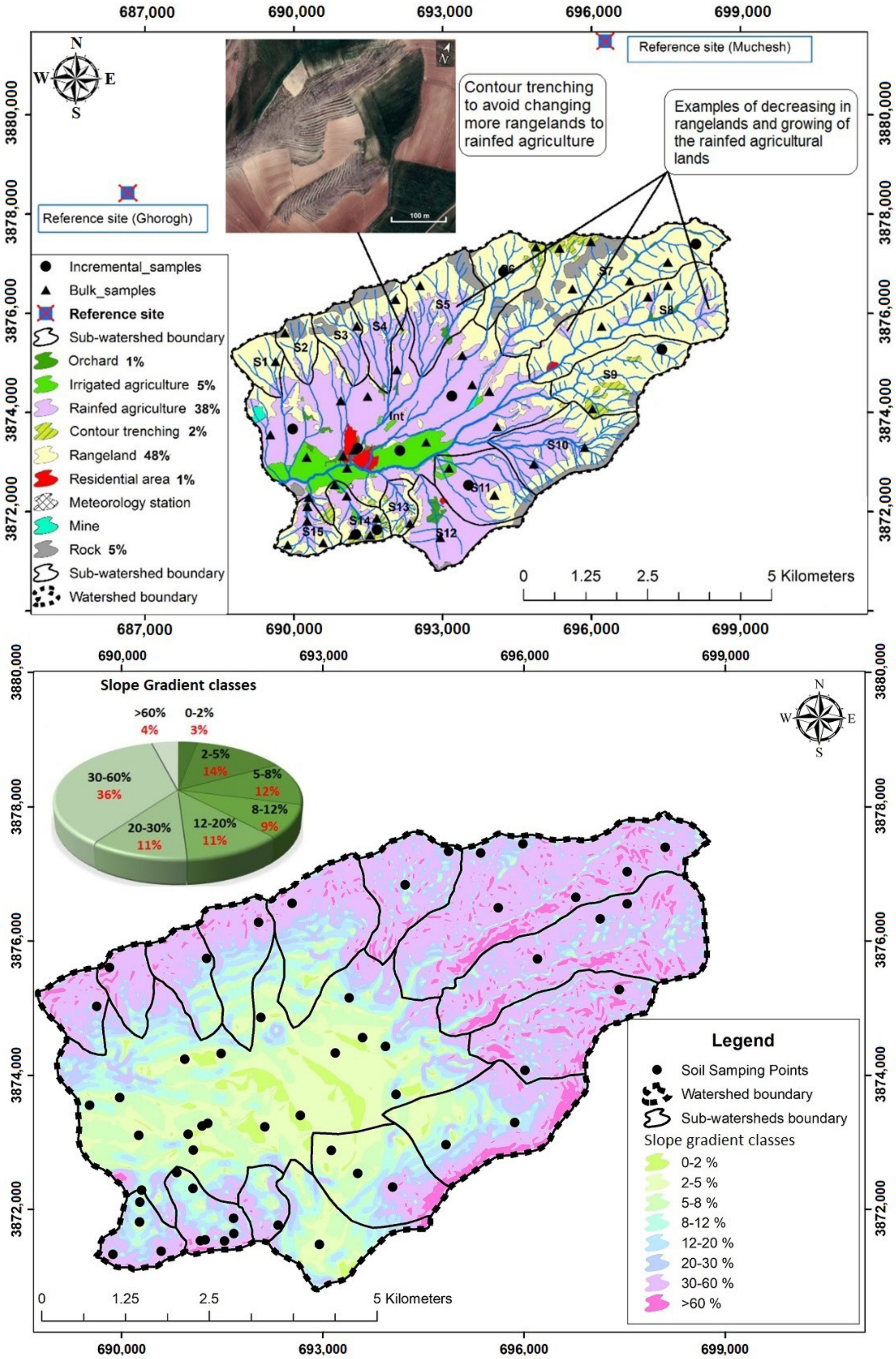

Figure 2. The distribution of soil sampling points on land use map (up) and slope gradient classes (down) in the study area.

the soil profile, diffusion and migration model was used, and for agricultural lands, because there was no initial evaluation, and the regime of rainfall and time of tillage was clear and there was no evidence of soil displacement (agricultural areas are mainly in inland low slopes of the watershed), the mass balance equation type II was used. Because of the large number and complexity of the models, standardization and facilitating the use of models, a software package Excel, presented by He and Walling (2000), has been used in the present study.

In order to prepare the distribution map of soil erosion/deposition, the homogenous units method was used. Based on this method, two maps of the land use/land cover and the slope were overlapped. Next, in the obtained polygons as a homogenous unit, where the soil sampling point was located, the erosion/sedimentation value of the sample was generalized to the adjacent homogenous unit and all similar units (in term of slope direction). It should be noted that soil sampling was conducted in all northern and southern parts of the watershed, so the effect of slope direction in soil sampling was covered. Valuation of the few remaining homogenous units (without soil sampling) was performed according to the average results of the sampling points in the same land use/land cover but in the lower and higher slope gradient classes, finally, the map of the distribution of erosion and sediment was prepared using the inverse distance weighting interpolation method in ArcGIS software. In addition, in the process of mapping, the identified points as stable conditions were considered with a numerical value of zero for the calculation, generalization of results, and mapping. Afterward, the components of the sediment budget consist of total erosion, sedimentation, net erosion, and sediment delivery ratio were calculated for land uses and different slope gradient classes.

3. Results and discussion

3.1. Erosion and sediment estimation by ^{137}Cs

In the studied watershed, the coefficient of variation of ^{137}Cs initial fallout in the reference area is 15.05% and the mean value of ^{137}Cs inventory in the reference area was 2542.81 Bq m^{-2}. Depth profile of activity concentration of ^{137}Cs in the reference area is shown in Figure 3. The reference value of the ^{137}Cs inventory for the study area has been discussed with the results of previous studies in Iran and other countries with the same arid and/or semiarid climates and reported by Sedighi et al. (2020). According to the previous studies, the reference value is in agreement with previous studies in western Iran.

After applying the appropriate models to convert ^{137}Cs inventories into erosion and sedimentation in each user, the rate of erosion and deposition in the sampled areas is calculated and shown in Figure 4. In addition, the map of the distribution of erosion and deposition was exhibited in Figure 4.

The distribution of erosion and deposition map prepared by ^{137}Cs technique in Khamsan watershed (Figure 4) indicated that the highest rates of erosion and deposition in this watershed were 21.20 and 53.23 t ha^{-1} year^{-1}, respectively. Besides, average erosion of studied watershed was 3.37 t ha^{-1} year^{-1}. The erosion dominant area and sedimentation and/or steady state (ha) according to slope gradient classes in Khamsan watershed can be seen in Table 2.

Moreover, the depth profile of ^{137}Cs activity concentration in various land uses in Khamsan representative watershed is revealed in Figure 5, which also schematically shows the slope gradient of the sampling points on a line from upslope (rangeland sampling points) to downslope (agricultural sampling points).

The components of sediment budget including total erosion, sedimentation, net erosion, and sediment delivery ratio are shown for different slope gradient classes in Figure 6 and each of land uses in Figure 7. In other words, erosion and sediment transport and deposition processes change based on the interactions between erosion/deposition and slope gradient and land use/land cover (Figures 6 and 7). The maximum amounts of erosion occurred in the slope gradient classes of 12%–20%, 2%–5%, and 8%–12%, which is the result of rainfed agriculture as the most erodible land

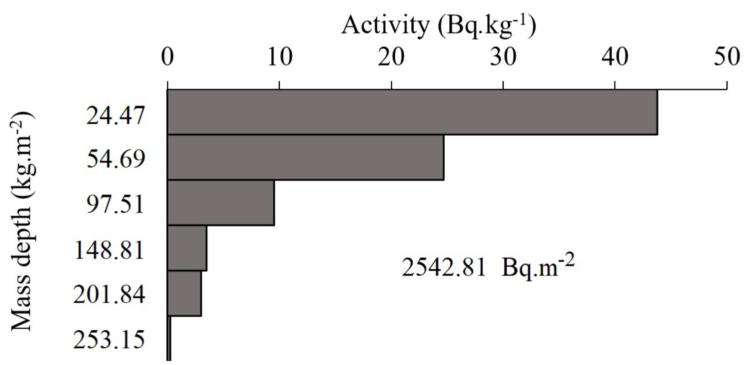

Figure 3. Mean depth profile of ^{137}Cs in the reference site.

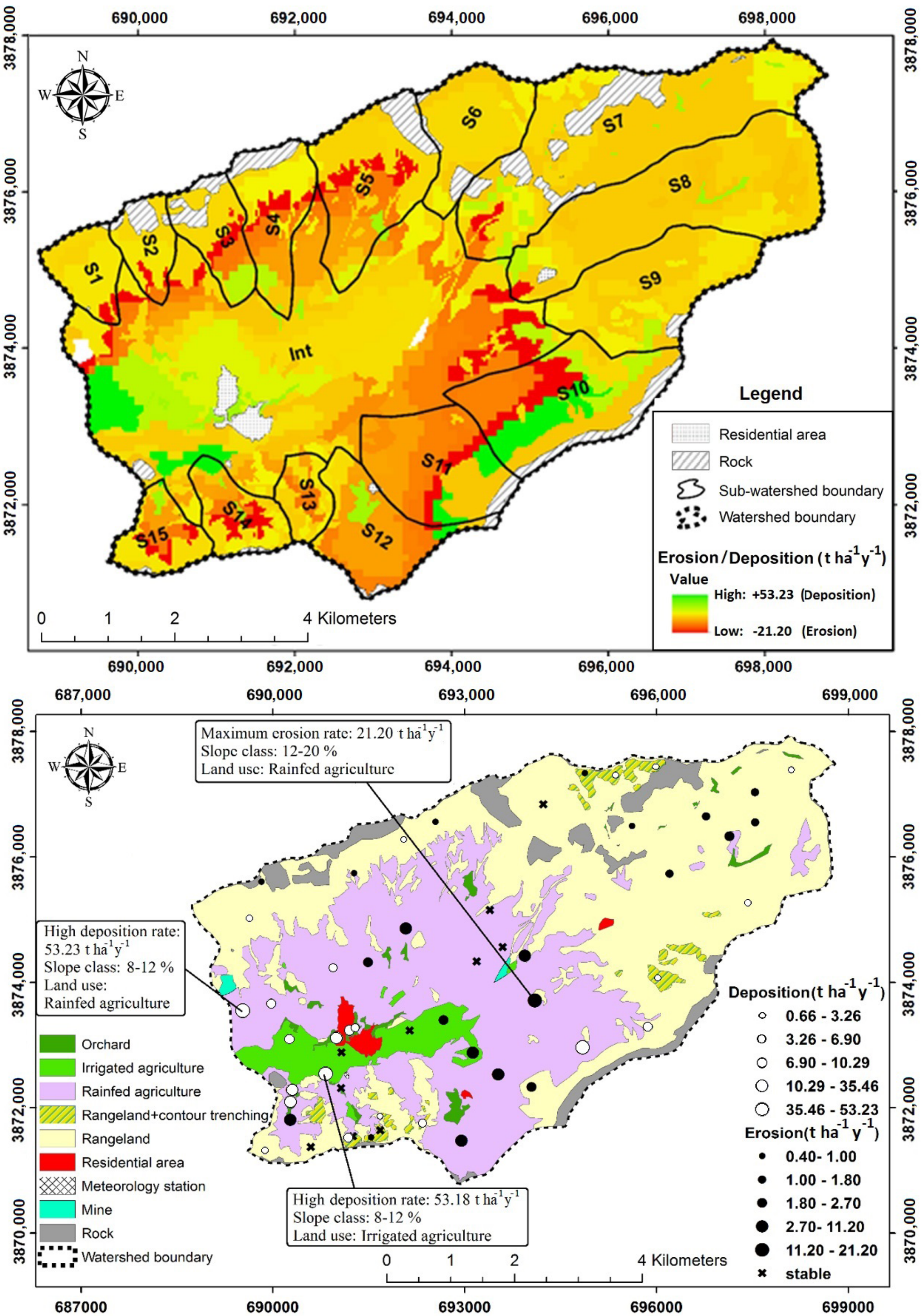

Figure 4. Erosion/deposition map of the study watershed (up) and the spatial distribution of the soil redistribution rates (down).

Table 2. The erosion dominant area and sedimentation and/or steady state (ha) according to slope gradient classes in Khamsan watershed.

Land use/land covers	Condition	Slope gradient class (%)							
		0–2	2–5	5–8	8–12	12–20	20–30	30–60	>60
Orchard	Erosion	0	0	0	0	0	0	0	0
	Deposition	0.64	10.29	18.64	12.28	5.26	4.28	2.59	0.00
	Stable	0	0	0	0	0	0	0	0
Irrigated agriculture	Erosion	14.80	58.30	9.90	2.08	1.30	0.11	0.00	0.00
	Deposition	0.21	13.24	16.57	6.18	2.42	1.15	0.28	0.00
	Stable	3.40	37.06	27.53	9.10	3.23	0.39	0.00	0.00
Rainfed agriculture	Erosion	14.45	252.62	247.37	234.50	210.12	93.36	30.51	0.74
	Deposition	4.19	68.78	113.05	44.93	41.57	21.12	3.62	0.00
	Stable	14.89	176.62	46.64	18.30	7.36	0.77	0.12	0.00
Rangeland	Erosion	4.58	22.59	23.88	34.63	96.45	211.80	972.17	103.35
	Deposition	0.96	6.06	7.98	17.09	44.23	91.10	276.04	16.69
	Stable	0.08	1.71	3.54	4.51	11.12	33.06	77.79	2.35
Contour trenching	Erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Deposition	0.01	0.12	0.28	1.11	7.79	24.46	49.80	1.10
	Stable	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

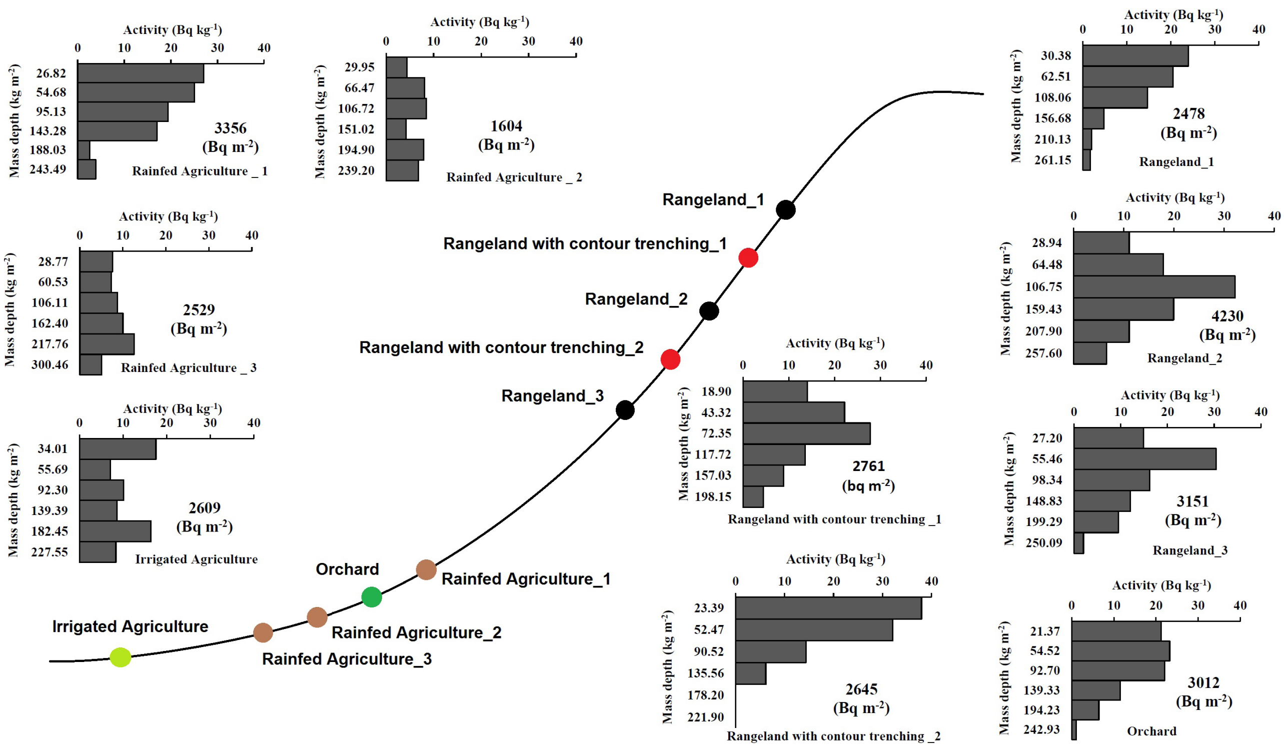

Figure 5. Depth profile of ^{137}Cs in various land use/land covers in different parts of the schematic slope based on their actual locations and the slope gradient of each sampling point decreasing from rangeland to agricultural lands (Sedighi et al., 2021).

use in the study area. On the other hand, the maximum SDR also occurred in rainfed agriculture, which is directly located on the marginal higher parts of the internal plain of the study watershed. The maximum SDR occurred in the slope gradient class of 0%–2%, which is even higher than that of the slope gradient class >60%. It is because of

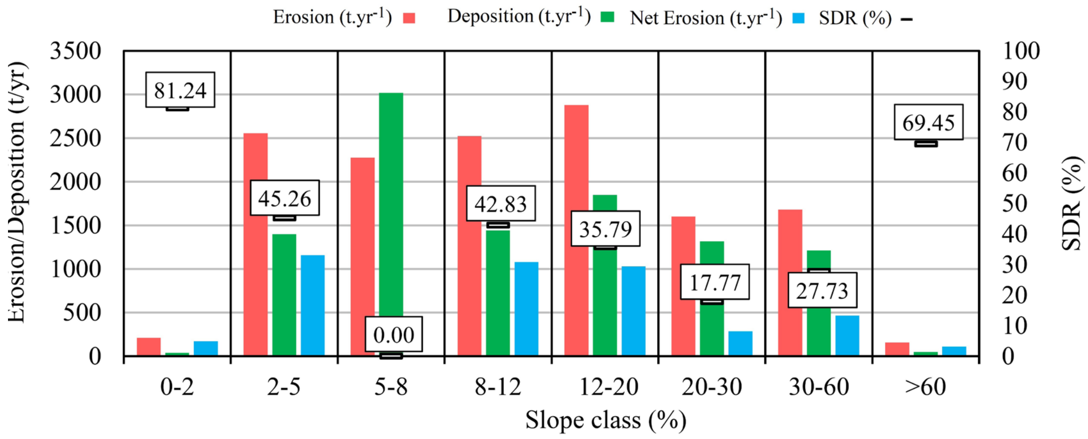

Figure 6. Values of sediment budget components based on slope gradient classes in Khamsan watershed.

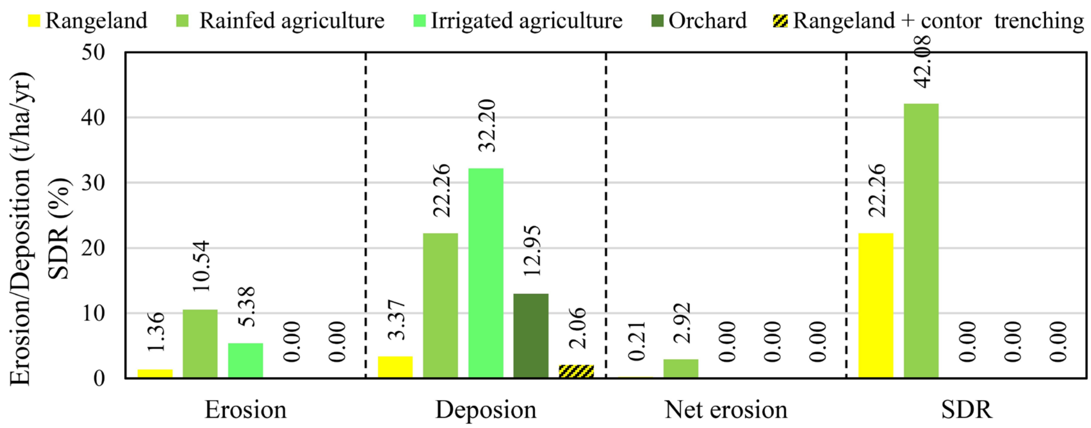

Figure 7. Components of sediment budget for land uses/land covers in Khamsan watershed.

the lower amount of erosion (as the denominator of SDR) in a small part of the plain with slope gradient class of 0%–2%. The sediment budget diagram according to land use is depicted in Figure 8.

3.2. Depth profile of ^{137}Cs in various land use/land covers

Comparison of the depth profile of ^{137}Cs changes in the reference area with the depth profile in land uses/ land cover indicates that soil movement in rangelands, rangelands with contour trenching, and orchard is not appropriate, while in agricultural lands soil movement is clearly visible because of ploughing.

In general, the depth distribution profiles of ^{137}Cs in rangeland soils indicated low rates of erosion within this type of land use.

For all sectioned cores collected from the cultivated fields, the ^{137}Cs concentrations were expectedly relatively uniform within the plough layer, as also emphasized by many studies (Walling and Quine, 1991; Xinbao et al., 1990; Collins et al., 2001; Poręba et al., 2003).

3.3. Sediment budget components in different land use/ land covers and slope gradients

Sources of sediment production in Khamsan watershed, involved land use of rainfed agriculture and to a lesser extent rangeland. According to Table 2 and Figure 6, rate of erosion at the level of 1083.67 ha of rainfed land with slope gradient classes of 2%–5%, 5%–8%, 12%–8%, and 12%–20% was 11426 t year^{-1}, and from the level of 1469.44 ha of rangeland use with slope gradient classes of 30%–60% and >60% was 1992 t year^{-1}. The highest erosion in the slope gradient classes of 12%–20%, 2%–5%, and 8%–12% was 2877.80, 2556.85, and 2521.99 t year^{-1}, respectively. The largest area of land use in mentioned slope categories was related to rainfed agriculture with cover levels of 58.18%, 73.95%, and 76.23 %, respectively. Thus, it can be concluded that in Khamsan watershed, rainfed agriculture and rangeland are situated as the first and second priorities, respectively, in view of levels with predominance of soil erosion processes over sedimentation

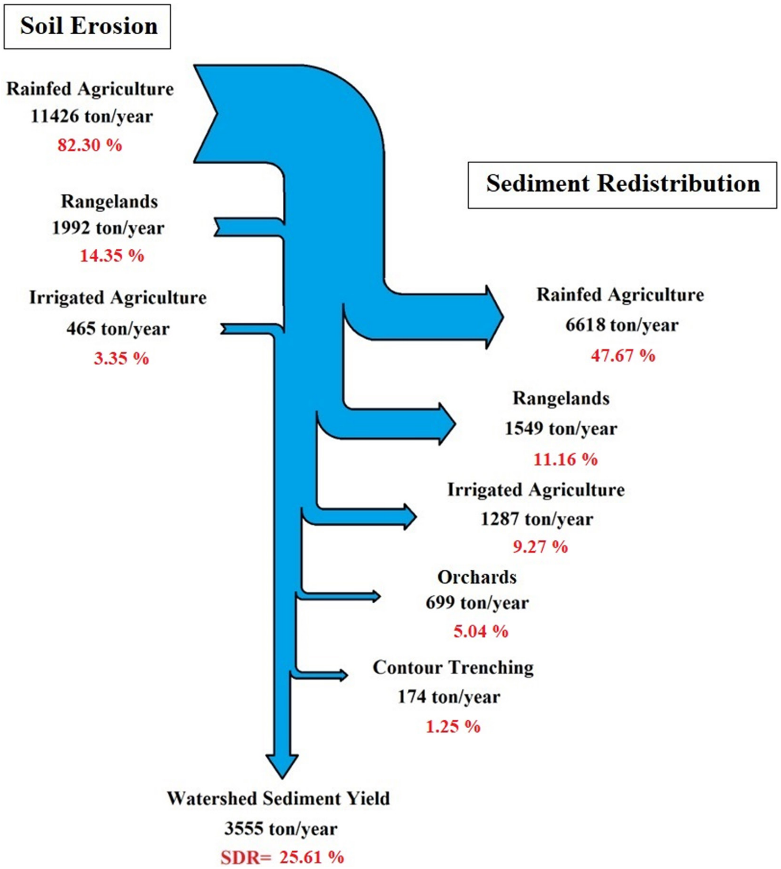

Figure 8. Watershed sediment budget considering the contribution of various land uses in soil erosion and redistribution in the study watershed.

in the watershed. The findings of the present investigation are in line with the many studies which have known land use/land cover and vegetation as an effective factor in intensity of runoff and soil erosion (e.g., Tejwani, 1980; Swanwerakamton, 1994; Kosmas et al., 1997; López et al., 1998; Martínez-Casasnovas and Sánchez-Bosch, 2000; Celik, 2005; Szilassi et al., 2006; Cebecauer and Hofierka, 2008; Zhou et al., 2008; García-Ruiz, 2010; Mohammad and Adam, 2010; Aneseyee et al., 2020). Pacheco et al. (2014) and Garcia-Ruiz (2010) also emphasized the strong correlation between soil erosion rate with land use and land use/land cover.

Another key point is the location of irrigated and rainfed agriculture relative to each other. Not only in Khamsan watershed, but also in many watersheds of country with similar conditions, irrigated agriculture is located in downstream slope, where access to water is high. This special arrangement in land-use has caused the transfer of sediments resulting from erosion and particularly intensified sediments due to plough on slope direction in rainfed agricultural to downstream and therefore has increased the possibility of sedimentation in the downstream parts of rainfed agricultural lands and even irrigated agricultural lands (Figure 7). Occurrence of such events in Khamsan watershed due to special topographic conditions and arrangement of land uses/land covers has been inevitable. The results of measurement of ^{137}Cs activity at soil sampling points in land uses/land cover also revealed that the higher sedimentation in the studied watershed occurred in rainfed agriculture, rangeland, and then irrigated agriculture (Figure 8).

In rainfed agriculture, increase in slope was associated with a promoted rate of erosion, and in slopes of more than 12%, the maximum rate of erosion has been observed. In the studied watershed, rainfed cultivation in most slopes based on the potential and suitability of lands is not correct and conversion of rangelands into cultivated land, especially in many slopes, and ploughing of soil in the slope direction has exacerbated the erosion of these lands. In rangelands in regions where erosion is predominant, the average erosion intensity in various slope gradient classes was 1.36 t ha^{-1} year^{-1}, while in rainfed agriculture in areas where erosion is predominant, the average intensity of erosion in different slope degrees was obtained as 10.54 t ha^{-1} year^{-1}. In the slope gradient classes of 12%–20% and 20%–30%, erosion in land use of rainfed agricultural compared to pasture increases about 1200%, which, in turn, is a key outcome for the rainfed agricultural management.

According to Figure 8, about 82.30% of the sediment produced in Khamsan watershed occurred in rainfed agricultural lands mainly because of ploughing of soil in the slope direction. In these lands, mostly due to the ease of movement of the tractor in sloping lands and especially in lands with great elongation in the slope direction, ploughing operations are performed in the direction of up to down slope, which increases runoff and more sediment transfer to downstream lands. Our findings are in close conformity with the results reported by Martínez Murillo et al. (2011), Esfandiari et al. (2014), Moradi et al. (2016), and Da Silva et al. (2016), who identified agricultural and pasture land uses with the highest and lowest potential of erosion, respectively. In fact, the sediment delivery ratio (SDR) by 42.08% of rainfed agricultural in Khamsan watershed (Figure 7) indicates that a large proportion of the eroded soil belongs to rainfed agriculture. These results are consistent with the studies of Walling (1999), Gellis (2010), and Nosrati et al. (2015).

4. Conclusion

Understanding the processes of displacement and redistribution of soil particles caused by various erosion types is a great management tool for erosion and sediment management. Therefore, in the present study, the distribution map of erosion and deposition was prepared using ^{137}Cs method, and sediment budget components were extracted in Khamsan watershed, western Iran, to investigate the interaction effect of slope gradient and land use/land cover on erosion and sediment redistribution.

The results showed that the main sources of sediment in this watershed include rainfed agricultural lands (82.30%), rangelands (14.35%), and irrigated agricultural lands (3.35%). Meanwhile, the participation of rainfed agricultural, rangeland, irrigated agriculture, orchard, and rangeland with contour trenching in sediment redistribution were 47.67%, 11.15%, 9.27%, 5.03%, and 1.25%, respectively.

The highest erosion occurred in the slope gradient class of 12%–20% at the rate of 2877.80 t year^{-1}, which relates to erosion in 210.21 ha of rainfed agricultural lands, 96.45 ha of rangelands, and a very small area (1.30 ha) of irrigated agricultural lands. In fact, cultivating in rangelands, especially on steep slopes, and ploughing in the direction of the main slope gradient is the main factor of accelerated soil erosion rates in these landscapes.

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