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Effects of mechanical erosion control practices on soil and vegetation carbon sequestration (case study: Catchment Basin of Kardeh- Iran)

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Abstract

Climate change and global warming are major problems all over the world that anthropogenic greenhouse gases emission especially Co_2 is one of the main reasons. So it is vital to find methods to reduce Co_2 or increase Carbon sequestration. Carbon sequestration by plants and in soils accounted as an effective way of reducing CO_2 emission to the atmosphere, but considerable amount of soil organic carbon is lost by erosion annually. One way to deal with these losses is mechanical practices that control erosion and stabilizes the soil. This study has been conducted to evaluate the effect of mechanical practices on carbon sequestration in Kardeh watershed of Mashhad, Iran. Rock check dams, gabions and small earth dams were considered as mechanical treatments comparing to natural rangeland. Plant vegetation biomass, litter and soil samples were taken and measured for carbon stocks.Results indicate the most amount of sequestered carbon were occurred in the soil (about 99%). Natural rangelands with 319 and 252 ton. Ha^{-1} in 0-25 and 25-50 cm had highest and rock check dam with 94 and 81 ton. Ha^{-1} in these depthshad the lowest soil carbon sequestration. Small earth dams with 170 and 132 ton. Ha^{-1}intop soil and sub soil has the highest soil carbon stocks among mechanical treatments during 16 years. So soil erosion control measures are potential cases for carbon sequestration projects through soil stabilization.

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Introduction

The projected global warming, with an estimated increase in mean annual temperature of 4–6°C by 2100, may have a profound impact on the total soil carbon pool and its dynamics, one of the main reasons may decrease soil organic carbon (SOC) isincreasing in losses by soil erosion (Lal, 2008a). The accelerated erosion mission of greenhouse gases about 0.8 – 1.2 Pg C to the atmospheric C pool annually (Lal, 2008b). The total amount of SOC displaced by erosion annually is estimated at 4 to 6 Pg, compared to 6.3 Pg C emitted by fossil fuel combustion (Lal, 2003). Therefore, the identification of strategies to minimize the loss of SOC and maximize itsretention in land is globally important and have the potential to reduce the effects of C on global climate change (Van Oost *et al.*, 2007). Soil erosion is a ubiquitous process that redistributes topsoil and associated soil OC within and out of watersheds (Nadeu *et al.,* 2012). Even so, some of the C lost via erosion may end up 'buried' via terrestrial sedimentation (Stockmann *et al.*, 2013). Climate, soil type, vegetation and land management practices influence the addition and decay of organic matter in different lands (Wang *et al.,* 2011).Increasing plant biomass production would likely increase organic soil carbon (Walcott *et al.,* 2009).Maximize photosynthetic capacityby perennial plants provides an ongoing source of soluble carbon in the soil ecosystem, reduces erosion, improves porosity, enhances aggregate stability and water infiltration and etc., (Jones, 2008).Catchments behave as sources or sinks of soil carbon, depending on the magnitude and type of land use changes within their drainage area, on the intensity of erosion processes and on the fate of eroded sediments (Boix-Fayos *et al,*. 2009). The organic soil carbon is usually classified into three 'pools', according to how fast it is broken down and replaced: fast(daily to annual); slow (annual to decadal) and passive (decadal to centennial/millennial) (Walcott *et al.*, 2009; Stockmann *et al,*. 2013). However, the roles that soil erosion can play as a carbon source or sink are still a scientific subject of hot debate (Lal, 2005).In this experiment, the hypothesis tested was that implementation of mechanical erosion control practices such as rock check dams (RCD), gabion dams (GD) and small earth dams (SED) would have different effects on soil and vegetation carbon sequestration and the aim of this research, is comparison of mechanical treatment's efficiency of soil and vegetation carbon sequestration.

Materials and methods

Description of sampling site

The Kardeh Catchment with an area of 557.9 square kilometers is located on the north east of Iran and a distance of 42 kilometers from Mashhad, Khorassan Razavi province. Where is between the 59° 26' 3" to 59° 37' 17" E longitude and 36° 7' 17" to 36° 58' 25" N latitude (Yasouri *et al*, 2012; Ebrahimian, 2009). The range of height is from 1200 (watershed outlet) to 2977 meters (Hezarmasjed peak) above the sea level, with a landscape characterized by a mountain and valley topography. On this site, the average precipitation is 343 mm/year and the mean annual temperature is 8.4 °C. The climate of the area based on Ambergeh classification, is semi-arid and cold (Yasouri *et al*, 2012). Topsoil`s kind in Kardeh catchment is loamy and subsoil is sandy- clay- loamy except in alluvial sediment that have the relatively heavy texture of clay (Ebrahimian *et al*, 2012).Our Study areaswerein a sub basin of this catchment, has been titled Goosh and Bahreh. It has an area about 4917 hectares where is between 59° 31' 04" to 59° 37' 12" E longitude and 36° 37' 17" to 36° 58' 25" N latitude. Theaverage ofthe slope is 31%, withelevation varying from1455m (at Bahreh village) to2200 meters (at the west of the catchment).

Thecatchmentexperiencedhydrological correction worksinthe 1996, consisting of construction RCD, GD and SED (Tabatabai *et al.*, 2006).

Field measurements and methods of experiment

Sampling of vegetation and litter

In this study, mechanical projects which considered were rock check dams (RCD), gabiondams (GD) and small earth dams (SED). In order to measure vegetation biomass, 3 transects were established along3 stream channels at mechanical treatments (as 3 replicated), totally 9 transects for mechanical practices and 9 transects for natural rangelands (NR).

The length of transects was different depending on the length of stream ways at mechanical practices. Finally, vegetation and soil cover wasrandomlyevaluated in 10 plots (2 m^2) for each transects and 30 plots for each treatment. Inside of each plot, percentage of canopy over, litter, rock and bare soil were calculated. Likewise, above-belowbiomassproductionwas estimated through clipping and weighing method. All plant litter was collected from the soil surface in each plot before soil samples (Fig. 1). The dominant species in eachtreatmentare presented in table1.

Table 1. Dominant species in each treatment.

GD	RCD	SD	NR
Annual grasses	*Agropyrum trichophorum*	*Annual grasses*	*Agropyrum trichophorum*
Agropyrum trichophorum	*Annual grasses*	*Xanthium spinosum*	*Stipa arabica*
Peroviskia abrotanoides	*Centurea virgata*	*Cousinia turcomanica*	*Centurea virgate*
Centurea virgata	*Peroviskia abrotanoides*	*Verbascum songaricum*	*Verbascum songaricum*
Verbascum songaricum	*Verbascum songaricum*	*Peroviskia abrotanoides*	*Rosa persica*
Eremurus spectabilis	*Stipa arabica*	*Stipa arabica*	*Poa bulbosa*
Poa bulbosa	*Acanthophyllum sp.*	*Ceratocarpus arenarius*	*Scariola orientalis*
Hordeum bulbosum	*Phlomis cancellata*	*Acanthophyllum spp.*	*Acantholimon erinaceum*
Cichorium intybus	*Marrobium parviflorum*	*Scariola orientalis*	*Artemisia sieberi*
Phlomis cancellata	*Eremurus spectabilis*	*Eremurus spectabilis*	*Annual grasses*

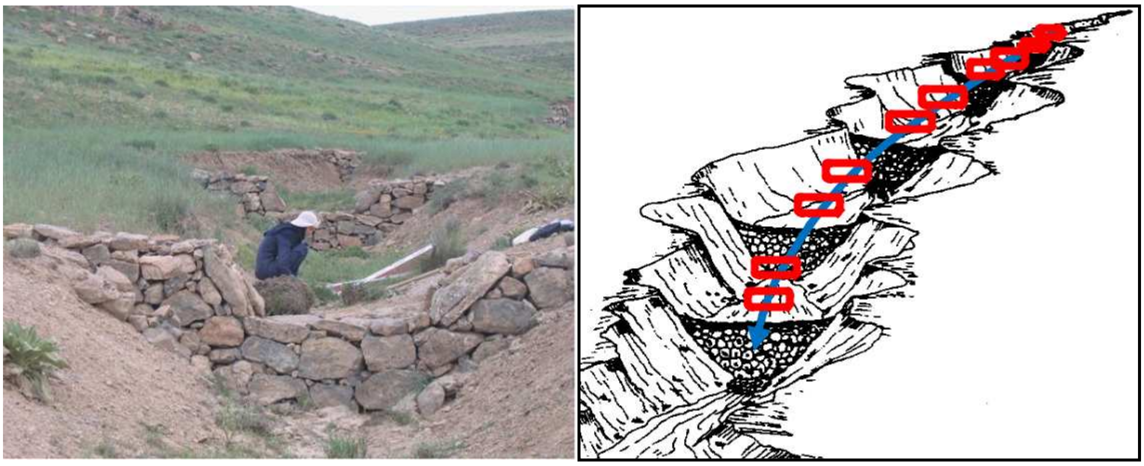

Fig. 1. Sampling method for mechanical treatments.

Laboratory analyses of vegetation and litter

Plant components, especially roots and litters were washedand were dried at 75°C until the weight is constant, and then weighed (Armecin&Gabon; 2008). For organic C content dry combustion method was used (Reeder and Schuman, 2002; Stockmann *et al.,* 2013). Organic matter (%) and organic carbon contents (%) were computed using the following equations:

$$\text{Eq.1:}\quad \%OM = \frac{DW - AW}{DW} \times 100$$

$$\text{Eq.2:}\quad \%OC = \frac{\%OM}{1.724} \times 100$$

Eq.3: Carbon content in biomass ($kg.ha^{-1}$) = Biomass ($kg.ha^{-1}$) ×% OC (Jana, *et al.*, 2009)

Where here OM = organic matter, OC = organic carbon, AW = ash weight of the

Sample, DW = dry weight of the sample, 1.724 = van Bemmelen factor (i.e. Organicmatter contains 58% of OC) (Armecin & Gabon 2008; Mekuria *et al.,* 2009).

Sampling and laboratory analyses of soil
Also soil samples were taken at each transects randomly (3 profiles for each mechanical practice and 9 profiles for natural rangelands (NR) near them as control sites in two depths (0-25 cm and 25-50 cm), Totally 36 soils samples. Electrical conductivity (EC), soil acidity (pH), Saturation percentage (% SP) and the percentage ofsoil organic carbon (SOC), clay, silt, sand, $CaCo_3$, of each sample were measured. One core sample was also taken from each profile for bulk density analysis. The method of Walkly-black was used for soil organic matter analysis (Walkley - Black 1934). Furthermore, Particle Size was determined by hydrometer Method (Mekuria*et al.,* 2009). $CaCo_3$ was measured using the acid digestion and titration method (Bhatti and Bauer, 2002). EC was tested with the saturated paste extract by a conductivity meter (Gartley, 2011).

Soil Carbon Stock (SCS) estimates
The total SCS content was calculated using the following equation:

Eq.4: $$CS = 100 \times OC\,(\%) \times BD \times d$$

WhereCS is soil carbon sequestration (ton. ha^{-1}), OC is organic carbon, BD is thesoil bulk density (gr. Cm^{-3}) and d is depth in meters (Akala and Lal; 2001; Zhang*et al.,* 2012). Finally, carbon sequestration indicators in soil, vegetation and the amount of total sequestered carbon in each treatment were determined and compared with NR.

Statistical analysis
The normality of data was tested using Kolmogorov – Smirnov (k-s) test. To test significant differences between all mean to each other, Duncan tests were done. Also, Pearson correlation tests were conducted to examine the relationships between carbon stocks in plant and other site characters. All data were analyzed by SPSS software.

Results

-Site Characters Vegetation properties and carbon sequestration in above and belowground biomass and litter
Results indicate that canopy cover in RCD is significantly more than other treatments (40%) and SEDhas the least cover with 24% ($p \leq 0.05$). There is no significant difference between RCD and NR for this factor. GD and NR doesn't have significant differences in terms of canopy cover percent too (33% and35%respectively). Also, significant differences in bare soil percentwere found betweentreatments ($p \leq 0.05$). Bare soil wassignificant higherinSED (46%) and less inRCD (21 %,)but there is not any significant difference between GD with NR and NR with RCD.In terms of rock percent, there is no significantdifference between treatments, buton average, the rock percentwas in the order: NR>RCD>GD and SED (respectively: 36%, 34%, 23% and 23%). Additionally, about litter, there is no difference in various treatments, but the percentage of litter is greater in SED with 7% and then NR, RCDandGD were with 6%, 5% and 4% respectively (Fig2).

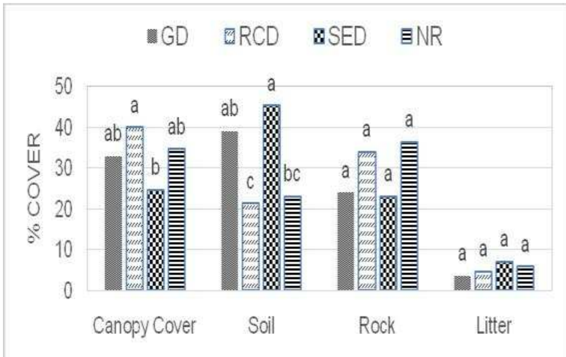

Fig. 2. The percentage of canopy cover, soil, rock and litter in various treatments. Different letters shows significant difference ($p > 0.01$ but ≤ 0.05).

Above and below ground biomass and litter weight
Fig.3 shows the above ground biomass (AGB) of the four treatments doesn't have any significant difference and it was ranging from 471 kg.ha^{-1}in GDto569 kg.ha^{-1}in NR. The amount of AGB in RCD and SED was 565 and 509 (kg.ha^{-1}) respectively. Likewise the below ground biomass (BGB) showed significant difference among the various treatments

($p \leq 0.05$). RCD has the highest andGD has the lowest BGB with an amount of 255 and146 kg.ha^{-1} respectively. SED with 156 kg.ha^{-1} has no significant difference with NR (209kg.ha^{-1}) and both of them don't have significant difference with RCD and GD. Totally the amount of whole plants biomasses (Above-below ground biomass= ABGB) were not significant in different treatments.But on average, the ABGB was in the order: RCD>NR>SED and GD (820, 778, 665 and 617kg.ha^{-1} respectively). Comparison between various measures shows that the weight of the litter was significantly different ($p \leq 0.05$). SED had the highest and NR had the lowest weight of litter (respectively with 360 and 152 kg.ha^{-1}) but there are no significant differences between SED and GD (264 kg.ha^{-1}). Also, it was observed that litters' weight of RCD (190kg.ha^{-1}) was significantly lower than SED ($p \leq 0.05$). Furthermore NR, RCD and GD have no significantdifferences with each other.

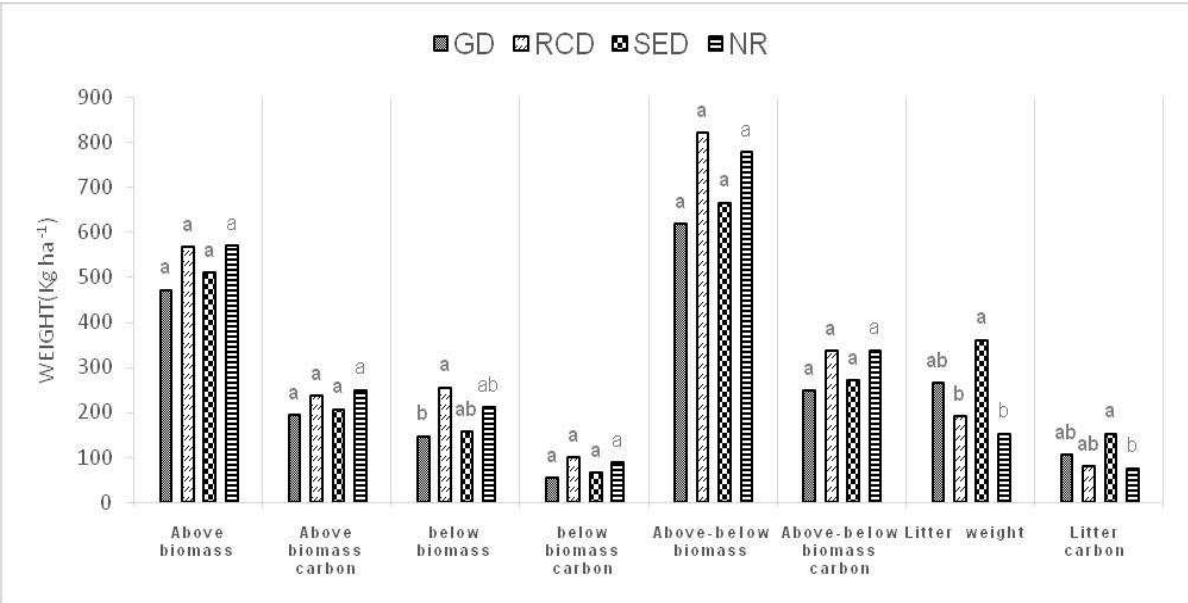

Fig. 3. Above ground biomass, below ground biomass, the weight of litter and their carbon content in the different treatments. Means with various letters are significantly different.

Carbon stocks in vegetation and litter

The carbon content of above and belowground biomass and litterCarbon (kg.ha^{-1}) is shown in Fig.3. According to the results, there was no significant difference among treatments in terms ofabove ground carbon stocks (AGCS). Despite this, AGCS were various between the treatments in this order:NR>RCD>SED and GD with 249, 236, 206 and 193kg.ha^{-1}). Furthermore, below ground biomass carbon (BGBC) varied between 99 kg.ha^{-1}(RCD) and 54 kg.ha^{-1}(GD) across the different measures. Nonetheless the differences between the treatments were not significant ($p \leq 0.05$). BGBC of NRand SED were respectively 88 and 65kg.ha^{-1}. Also, the carbon content of total plant biomass (Above-below ground biomass carbon = ABGBC) showed no significant differences among the treatments. It's ranged from 337 to 247 kg.ha^{-1}(NR and GD respectively). Also the amounts of carbon in RCDand SED were 335 and 271 kg.ha^{-1}respectively. The amounts of litters' carbon differed significantly among the treatments ($p \leq 0.05$). SED with 152kg.ha^{-1}had the highest litters' carbon comparison with other measures and was significantly different from the NR with 75kg.ha^{-1}. In additionGD and RCD with 105kg.ha^{-1}and 78kg.ha^{-1}didn't have significant differences with SED or NR.

Relationships between vegetation cover percent, biomass, litter and Site Characteristics with carbon stocks in them

Above ground biomass carbon stocks

Correlation analyses were done to determine the relationships between the Site Characteristics with carbon stocks (table 2). The results showed there is a correlation between vegetation cover percent and total plant biomass with above ground carbon stocks in all treatments ($p \leq 0.05$) except SED. There was a positive and strong relationship in the whole practices betweenabove biomass and its carbon stocks. Only in NR there are a correlation betweenabove ground carbon stocks with below biomass. Also in GD, RCD and NR the relation between rock percent and above biomass carbon is negative although it is not significant. At SED as it has shown in Fig. 2, most of soil surface is covered by sediment and bare soil, not by rock and vegetation cover. There is not a correlation between litter percent and its weigh with the above ground carbon stocks.

Table 2. Correlation coefficient of the relationships between site characters, vegetation properties and carbon sequestration in above and below ground biomass and litter.

TRT	Parameters	AGCS (kg.ha^{-1})	BGBC (kg.ha^{-1})	ABGBC (kg.ha^{-1})	LC (kg.ha^{-1})
GD	Cover (%)	0.99*	$-0.04^{n.s}$	0.992^{ns}	$0.18^{n.s}$
	Litter (%)	$0.6^{n.s}$	$-0.85^{n.s}$	$0.46^{n.s}$	$-0.71^{n.s}$
	Rock (%)	$-0.97^{n.s}$	$-0.16^{n.s}$	-0.99*	$-0.37^{n.s}$
	Soil (%)	$-0.86^{n.s}$	$0.58^{n.s}$	$-0.76^{n.s}$	$-0.38^{n.s}$
	Above biomass (kg.ha^{-1})	1**	$-0.73^{n.s}$	$0.98^{n.s}$	$0.15^{n.s}$
	below biomass (kg.ha^{-1})	$0.34^{n.s}$	$0.91^{n.s}$	$0.49^{n.s}$	$0.98^{n.s}$
	Above-below biomass(kg.ha^{-1})	0.99*	$0.03^{n.s}$	1*	$0.25^{n.s}$
	Litter weight (kg.ha^{-1})	$0.24^{n.s}$	$0.95^{n.s}$	$0.39^{n.s}$	0.99*
RCD	Cover (%)	0.99*	$0.89^{n.s}$	$0.98^{n.s}$	$-0.8^{n.s}$
	Litter (%)	$0.88^{n.s}$	0.99*	$0.94^{n.s}$	$-0.39^{n.s}$
	Rock (%)	$-0.96^{n.s}$	$-0.99^{n.s}$	$-0.98^{n.s}$	$0.58^{n.s}$
	Soil (%)	$0.76^{n.s}$	$0.96^{n.s}$	$0.84^{n.s}$	$0.184^{n.s}$
	Above biomass (kg.ha^{-1})	1*	$0.91^{n.s}$	$0.99^{n.s}$	$-0.79^{n.s}$
	below biomass (kg.ha^{-1})	$0.90^{n.s}$	1*	$0.95^{n.s}$	$-0.43^{n.s}$
	Above-below biomass(kg.ha^{-1})	0.99*	$0.96^{n.s}$	1**	$-0.69^{n.s}$
	Litter weight (kg.ha^{-1})	$-0.76^{n.s}$	$-0.45^{n.s}$	$-0.69^{n.s}$	1**
SED	Cover (%)	$0.79^{n.s}$	$0.98^{n.s}$	$0.91^{n.s}$	$-0.35^{n.s}$
	Litter (%)	$-0.32^{n.s}$	$0.53^{n.s}$	$-1^{n.s}$	-1*
	Rock (%)	$0.85^{n.s}$	$0.13^{n.s}$	$0.71^{n.s}$	$0.76^{n.s}$
	Soil (%)	$0.98^{n.s}$	$-0.49^{n.s}$	$-0.92^{n.s}$	$-0.46^{n.s}$
	Above biomass (kg.ha^{-1})	0.99*	$0.71^{n.s}$	$0.99^{n.s}$	$0.21^{n.s}$
	below biomass (kg.ha^{-1})	$0.68^{n.s}$	0.99*	$0.83^{n.s}$	$-0.49^{n.s}$
	Above-below biomass(kg.ha^{-1})	$0.96^{n.s}$	$0.82^{n.s}$	0.99*	$0.033^{n.s}$
	Litter weight (kg.ha^{-1})	$0.36^{n.s}$	$-0.48^{n.s}$	$0.14^{n.s}$	0.99*
NR	Cover (%)	0.55*	$0.43^{n.s}$	$0.53^{n.s}$	$0.02^{n.s}$
	Litter (%)	$0.31^{n.s}$	$0.16^{n.s}$	$0.28^{n.s}$	-0.87**
	Rock (%)	-0.73*	$-0.37^{n.s}$	-0.65*	0.85**
	Soil (%)	$0.64^{n.s}$	$0.28^{n.s}$	$0.56^{n.s}$	-0.84**
	Above biomass (kg.ha^{-1})	0.99**	0.91**	0.99**	$-0.65^{n.s}$
	below biomass (kg.ha^{-1})	0.88**	0.99**	0.92**	$-0.39^{n.s}$
	Above-below biomass(kg.ha^{-1})	0.98**	0.95**	0.98**	$0.6^{n.s}$
	Litter weight (kg.ha^{-1})	$-0.38^{n.s}$	$-0.47^{n.s}$	$-0.41^{n.s}$	$0.43^{n.s}$

AGCS= above ground carbon stocks, BGBC= below ground biomass carbon, ABGBC= Above-below ground biomass carbon. * Significant ($p \leq 0.05$); ** highly significant ($p \leq 0.01$) and "ns": not significant. GD: gabion dams, RCD: rock check dams, SED: small earth dams and NR: natural rangelands.

Below ground biomass carbon stocks

In the RCD, SED, NR there is positive relationship between below ground biomass and its carbon too, respectively, with 95%, 95% and 99% confidence.

Only in the NR observed a correlation among the above biomass and total biomass with its carbon.

Above-below ground biomass carbon stocks

As it's shown in table 2, there is a positive and direct relation between Above-below ground biomass and its carbon in all treatments. In NR, RCD and GD, the relation between rock percent and above-below biomass carbon is negative as mentioned previously about above biomass carbon and rock%.

Litter carbon stocks

In mechanical treatments, a large volume of litter transformed by runoff and erosion so in these measures, there is a positive and strong relation between litter weight and its carbon, But after reducing the water flow rate or encountering to an obstacle, this litter usually are accumulated on the surface instead of being spread so there is not a significant or positive relation between the litter percentof the surface and litter carbon.

Soil Characters and Carbon Stocks

Table 3 shows the mean soil carbon sequestration (SCS) and other characters of soil in two depths and various treatments. Soil carbon sequestration in 0-25 cm of mechanical practices ranged from 94 to 170 tons.ha $^{-1}$ in RCD and SED respectively, and in GD it was 117 tons.ha $^{-1}$. Also in NR the amount of SCS is 319 tons.ha^{-1} that is significantly higher than mechanical measures ($p \leq 0.05$). But there is no significant difference in SCS between mechanical practices with each other. In the second depth, the amount of SCS in all treatments is lower than top soil, but there is not any significant difference between these two depths in various treatments in this respect (Fig.4). Also a significant variety of SCS content was observed between the three mechanical treatments compare with NR (252tons.ha^{-1}) in the second layer ($p \leq 0.05$). In subsoil GD, RCD and SED have 76, 81 and 132 tons.ha^{-1} SCS respectively. In the first soil layer, the organic carbon (OC) varied between 0.48% and 0.57% across the GD and SED (mechanical treatments) and 1.34%in NR. Also the OC (%) in subsurface soil was between 0.33 to 0.53 in GD and SED respectively and it was 1.08% in NR.

Table 3. Comparison of different treatments in terms of soil parameters and soil carbon sequestration

Trt	Depth1 (0-25 cm)				Depth2 (25-50 cm)			
Variable	GD	RCD	SED	NR	GD	RCD	SED	NR
Ph	7.80^{a}	7.83 ^{a}	7.80 ^{a}	7.68 ^{a}	8.03 ^{a}	7.93 ^{a}	7.90 ^{a}	7.89 ^{a}
Ec	1.81^{a}	1.04 ^{a}	1.25 ^{a}	0.95 ^{a}	0.83 ^{a}	0.71 ^{a}	0.95 ^{a}	0.59 ^{a}
Sp (%)	37.93 ^{a}	28.80 ^{a}	39.90 ^{a}	41.8 ^{a}	35.27^{a}	32.80^{a}	39.07^{a}	38.90^{a}
CaCo3(%)	31.87 ^{a}	34.38^{a}	38.43 ^{a}	31.11 ^{a}	33.87^{a}	42.25^{a}	40.13^{a}	32.78^{a}
OC (%)	0.51^{b}	0.48 ^{b}	0.57 ^{b}	1.34 ^{a}	0.33 ^{b}	0.40 ^{b}	0.53 ^{b}	1.08 ^{a}
Sand (%)	32.67 ^{a}	50.50 ^{a}	39.33 ^{a}	34.67 ^{a}	38.67^{a}	40.50^{a}	28.00^{a}	33.33^{a}
Silt (%)	52.33 ^{a}	31.83 ^{a}	36.00 ^{a}	48.00 ^{a}	46.00^{a}	35.33^{a}	50.33^{a}	46.56^{a}
Clay (%)	15.00 ^{a}	17.67 ^{a}	24.67 ^{a}	17.33 ^{a}	15.33^{b}	24.2^{a}	21.67^{ab}	20.11^{ab}
Silt+ Clay(%)	67.33 ^{a}	49.5 ^{a}	60.67 ^{a}	65.33 ^{a}	61.33 ^{a}	59.5 ^{a}	72 ^{a}	66.67 ^{a}
SCS (ton.ha^{-1})	117.19^{b}	94.37 ^{b}	170.33 ^{b}	319.31 ^{a}	76.25^{b}	81.10^{b}	131.75^{b}	252.39^{a}

Different letters shows significant difference ($p \leq 0.05$)

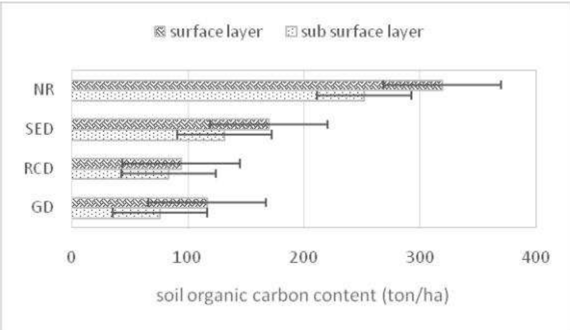

Fig. 4. Soil organic carbon content in the four treatments in topsoil and subsoil.

In terms of pH, all treatments have alkaline soil. And as it is clear there is no significant difference between them in the view of pH and EC but both of them are low in NR. In addition, there are no significant differences in terms of Sp (%) and CaCo3 (%) among thetreatments, too. But CaCo3 in mechanical practices is more than NR.

Statistics show that the highest clay was found in SED at the first depth (25%) but it was no significant differences between treatments. Also GD has the most silt at the topsoil (52%) that is not significant compare with others, too. In the sub soil layer highest clay belongs to the RCD although there is a not significant difference between it and SED and NR. SED has the greatest silt in sub depth of soil. Additionally sum of clay and silt content was more in SED and it is similar to NR and RCD. Fig.5 is showing a comparison of organic carbon storage in different components of the ecosystem in the four treatments. According to the results, soil has the greatest role in carbon sequestration, especially surface layer of soil. Then there are above- below biomass and litter. In other words, in all treatments, less than 1% of total carbon sequestration is belong to above- below biomass and litter altogether.

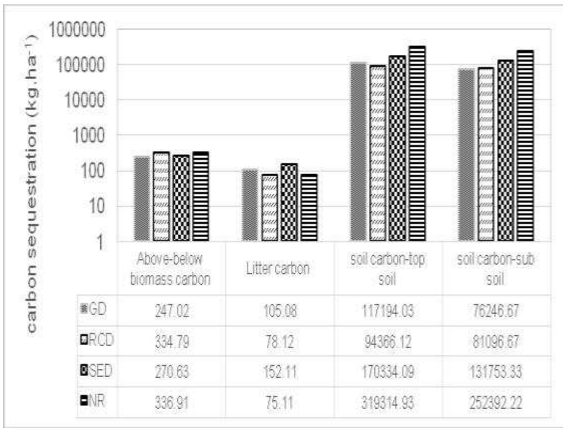

Fig. 5. A comparison of organic carbon storage indifferent components of ecosystem in the four treatments (vertical axis is based on logarithmic scale).

Discussion and conclusions

According to the Results, NR as a control site has the most plant biomass, Above-below biomass carbon stocks, carbon sequestration of top soil and sub soil and total carbon sequestration (plants+ litter+ soil). NR in comparing with other eroded area and mechanical treatments has a better condition because it was intact. As other researchers have emphasized, there is a positive relation between organic carbon and vegetation (Abdi *et al.*, 2008; Gheitury, 2012). As

Andrade-Limas *et al.,* (2011) stated that innatural vegetation cover; organic carbon capture was higher owing to higher organic content in the soil compare with dams which control gully erosion. As well as Pearson correlation results indicated there is a strong positive correlation between vegetation cover(%) with aboveground carbon stocks in all treatments ($p \leq 0.05$) except SED. It shows that the biomass carbon in NR, RCD, and GD can be predicted by vegetation cover with high confidence. Also carbon storage of above biomass can be calculated by weight of above biomass (in all treatment) and with using oftotal biomass (except in SED)via reasonable accuracy. Lal (2008, a) Stated that SOC pool may increase due to increase in biomass production and accretion into the soil, which may also enhance production of the root. In addition, carbon content of total biomass can be estimated in all treatments based on above -below ground biomass.These findings show that the greater amount of plant cover (%) and biomass production leads to higher carbon sequestration in above-below biomass. And also in places like NR and RCD which perennial plants are dominant (compare with SED that has invasive and annual plants) estimating carbon content stored in the plant by vegetation cover percent as a non-destructive method is preferred. Only in NR there is a correlation between above biomass via below ground biomass carbon stocks and with above-below ground biomass carbon storage. This indicates in an intact environment such as NR which has not accelerated soil erosion we can predict carbon sequestration inbelow ground biomass using the indirect methodof measuring above biomass weight. Dinakaran and krishnayya(2008) and Kirby (2007), also confirms that there is a positive relationship between organic carbon and weight and cover of biomass. Also in GD, RCD and NR the relation between rock percent with above biomass carbon and with above-below biomass carbon is negative although it is not significant. Schumacher *et al* (2002) mentioned that large inorganic particles, such as gravel, pebbles and rocks, have lack of contribution to total organic carbon and the percentage of large inorganic particles can be determined visually or gravimetrically and is recorded for completeness of sample characterization. In Akala and Lal, (2001) research, the layers below 0.25 m primarily had consisted of rock over burden that had limited root presence. Also about the erosion control practices, according to the classification of streams by Strahler (1952), RCD in this catchmentusuallyhave been made in order 1 stream, with no upstream tributaries and with primary stage of erosion, so in comparison with SED or GD in terms of vegetation cover (%), above- blow biomass, and total biomass carbon storage has better condition and have no significant difference with the NR but in terms of soil carbon sequestration, it is vice versa. BoixFayos *et al.,* (2009) said that in catchment scale from the 4 % of the soil C stock mobilized by water erosion, 77 % is buried in the sediment wedges behind dams, but in the current study, sedimentation volume is less behind RCD compared with SED and GD so it has lower SCS. Likewise In present study rock (%) at the soil surface is higher in RCD and NR. In this basin, SED and GD have been built in 2nd or 3rd order streams with high risk of erosion. Due to erosion rates, more sediment will accumulate behind these dams. Runoff flows left rocks and pebbles in the upper land and transfers finer sediments to the GD and SED. Starr *et al.*, 2000 said smaller aggregates are transferred a greater distance by erosion. Upon entering the depositional area a slight sorting effect could be observed with gradual enrichment of sediment deposits in clay-sized particles and particularly SOC (Hemelryck *et al.,*2010). Moreover, in GD and SED, water flow carries more litter, thus the weight of litter and its carbon amount is higher than RCD and NR. Meentemeyer (1978) and Melillo *et al.,* (1982) expressed most of litters' carbon, which added to the surface of soil, returns to the atmosphere by decomposition and only a small amount of litter be converted to humus. Besides, runoff and sediment which annually come in to the GD and SED, cause difficult conditions for the establishment of permanent plant species unless at the margins of streams, and in their stream beds only annual, invasive and spiny species have been dominated (such as annual grasses and *Xanthium spinosum*). However, in a few cases, some species that are more resistant to flooding and sedimentation such as *Peroviskia abrotanoides* may grow in the stream bed. Smith (2013) stated that an overall decrease in vegetation cover was observed in the two years' post gulley blocking and there was a clear shift in the dominant vegetation groups, hydrophytes such as Sphagna and Sedges and decrease in herbs and grasses.Also the present study indicated that below biomass weight and carbon in SED and GD is less than RCD and NR, this result is in agreement with Lal (1998 and 2003) who said erosion reduce the amount of root and its effective depth. This study indicated in two depths, soil carbon sequestration of NR is considerably greater than mechanical practices due to the soil in NR is undisturbed and stable over many years. Gheitury (2012), suggests the proper management of rangeland vegetation can increase the potential for carbon sequestration, additionally other objectives such as protecting the environment, preventing soil erosion and sustainable productivity of the land resources can be found. During process of water erosion, soil clay is preferentially removed by runoff, thus disrupting soil aggregates (Xiaojun *et al.*, 2013).This research findings show SED has highest clay amounts, GD is in the second places and RCD is the last one among mechanical treatments, Also average of silt + clay in two depths have similar trend this treatment. Soils have a finite capacity to sequester organic carbon that is determined by soil texture and aggregation. Soil organic carbon levels increase with silt + clay content (Patil*et al.,* 2012). Soil carbon is related linearly to soil texture, increasing as clay content, increases that soil carbon stores(Schimel *et al.,*1994; Bauer *et al.,* 1987).Ussiri and Lal (2005) said runoff from eroding landscapes is enriched in clay sized particles.Therefore, in all of mechanical treatments SED has the most potential for carbon sequestrating and followed by GD and RCD. As Ussiri and Lal (2005) and Walcott *et al.*, (2009) are mentioned, clay contributes in SCS through two mechanisms, one of them is organic C absorbed to clay surfaces by polyvalent cation bridges or trapped between expanding layers of clays and physical protection where organic material is chemically bonded to soil minerals or is located in spaces too small for microbial access. That both of these methods will prevent the decomposition of organic matter. Moreover, soil texture can also affect the amount of carbon in the different pools. In soils with a high level of clays and silts, about 30% of organic soil carbon tends to be found in the passive pool (in the form of charcoal and physically protected carbon), whereas in soils with a low level of fine particles is about 4%. Breuer (2012) said that one of the most important parameters to prevent C from decomposition for 100 to 1000 years in the passive pool is because SOC is bound due to physical (e.g. Occlusion within soil structures or clay particles attachment) pore size distribution of clay soils limits decompose organism to reach potential organic substrates. Starr *et al.,* (2000); Reeder and Schuman (2002); Zhang *et al.*, (2012); Patil *et al.*, (2012); Xiaojun *et al.*, (2013); and Stockmann *et al.*, (2013) also confirms that. Our findings demonstrate that in all treatments the rate of carbon sequestration in topsoil is higher than sub surface layer. This result is in accordance with these researcherAkala and Lal (2001); Bhatti and Bauer (2002); Ussiri and Lal (2005); Walcott *et al.*, (2009); Zhang *et al.*, (2012); Stockmann *et al.*, (2013) said SOC is most in the top of the soil, the zone that inhabits the majority of roots, plant inputs and microbial activity. Derner and Schuman (2007) stated that in deeper soil, C turnover is influenced by decomposition rates of roots which decrease with increasing soil depth. Jobbágy and Jackson (2000) said that plant production and patterns of biomass allocation strongly influence relative distributions of C with soil depth, patterns of root biomass and relative root density that also decline with soil depth.

Also, other researches show inorganic carbon forms are present in soils and sediments typically as carbonates and one of the most common carbonate minerals is $CaCO_3$ (Schumacher, 2002). High $CaCO_3$ may lead to higher SOCS through carbonate coating of fresh organic matter the decomposition is reduced. Clay rich soils also contain a high level of multivariate cations. Especially Ca^{2+} is stabilizing soil C and protects it from decomposition (Breuer, 2012). In present research a trend to increased $CaCo_3$ content was observed with increasing soil depth among all treatments and in mechanical practices $CaCo_3$ is more than NR, although it was not statistically significant. In this study EC was more in top soil and also in mechanical treatments too, particularly in GD and SED. EC is an important indicator of soil health that one of its roles is affecting on the activity of soil microorganisms which influence key soil processes including the emission of greenhouse gases such as carbon dioxide. Because salts move with water; low areas, depressions or other wet areas where water accumulates tend to be higher in EC than surrounding higher-lying. Soils with restrictive layers, such as clay pans, typically have higher EC because salts cannot be leached from the root zone and accumulate on the surface. High clay or organic matter content soils have a higher CEC than low organic matter or sandy soils (Anonymous, 2014). Zhang *et al.* (2006) suggested that soil erosion can result in net losses of SOC from the soil carbon pool and can modify the effects of SOC sequestration significantly in semi-arid, Also Wang *et al.,* (2011) stated SOC inventories increases with decreasing soil erosion at the watershed scale.Therefore, the implementation such constructs that reduce soil erosion resulted in increased carbon sequestration. Final result shows that mechanical control erosion practices, especially small earth dams are efficient methods to prevent soil erosion and increase soil carbon sequestration.Although NR as an intact environment have the most amount of carbon sequestration, but if these mechanical practices were not performed, large amount of organic matter was wasted and part of it was re-released to the atmosphere due to erosion. Also based on this research, between three components of soil, vegetation and litter, litter has the lowest amount of carbon and soil have the most carbon sequestration capacity(about 99% of total carbon sequestration capacity) that is in accordance with Stockmann *et al.*, (2013) that stated Soil contains approximately 2344 Gt (1gigaton=1billiontonnes) of organic carbon globally and is the largest terrestrial pool of organic carbon. Small changes in the soil organic carbon stock could result in significant impacts on the atmospheric carbon concentration. Also Jobbagy and Jackson (2000) have been emphasized on the role of soil carbon sequestration as a major component in terrestrial ecosystems.So during 1996- 2012, SED with more volume of sediment, higher amount of fine soil particles and CaCo3 is the best among mechanical treatments althoughit has lowest vegetation cover. And as mentioned before, in SED and NR due to the better physical and chemical protection of organic material because of higher amount of fine particles and CaCo3, more organic carbon is stabilized in the passive pool and will prevent the decomposition.In general the total organic carbon are considerable in all treatments thereforesoil conservation measures are potential cases for carbon sequestration projects through soil stabilization.

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