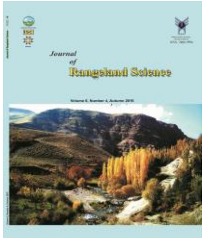
Contents available at ISC and SID

Journal homepage: www.rangeland.ir



Research and Full Length Article:

Impacts of Rangeland Reclamation and Management on Carbon Stock in North East of Iran (Case Study: Kardeh Basin, Mashhad, Iran)

Somayeh Naseri[A], Hossein Tavakoli[B], Mohammad Jafari[C], Hossein Arzani[D]

[A]Ph.D. Student, Department of Range Management, Science and Research Branch, Islamic Azad University, Tehran, Iran
[B]Associate Professor, Agriculture and Natural Resources Research Centre of Khorassan Razavi, Iran (Corresponding Author), Email: tavakoli_res@yahoo.com
[C, D] Professor, College of Natural Resources, University of Tehran, Karaj, Iran

Received on: 28/01/2015
Accepted on: 03/05/2016

Abstract. One of the effective ways for reducing atmospheric CO_2 is carbon sequestration by plants and soils. Rangelands with an expanded area have a great potential for Carbon (C) Stocks. In this study, C stocks in three treatments including natural rangelands (NR), Pit- seeding by *Agropyrum elongatum* (PS) and abandoned dry farming (ADF) were examined in Kardeh basin Mashhad, Iran in 2013. In each treatment, ten transects and in each transect, ten plots were established. Percentages of vegetation cover, litter, rock and soil were recorded in each plot. Aerial and root biomasses of dominant species were sampled by the clipping and weighing method. Litters in each plot were collected and weighed, too. Carbon content of biomass and litter were measured by combustion method using Electric Combustion Furnace. Ten soil samples were taken along each transect at two depths of 0-25 and 25-50 cm. The soil organic carbon percent was determined by the Walkley–Black method. Data analysis was performed by one-way analysis of variance (ANOVA) and means were compared using Duncan test. Results showed significant differences between treatments for total C stocks (soil+biomass+litter). NR and ADF management with the average values of 535.32 and 177.14 ($t.ha^{-1}$) had the highest and lowest C stocks, respectively. Among the components of the ecosystem, soil had a main role in C sequestration followed by above biomass, roots and litters. PS management had the highest C stocks in plant biomass and litter but its soil C stocks were significantly lower than NR. Perennial grasses, bushes and perennial forbs were dominant in PS and NR management that play the most important role in plant C stocks. In conclusion, proper management of natural rangelands and more attention to vegetation and soil conservation may lead to store a considerable amount of C stocks in these lands.

Key words: Abandoned dry farming, Natural rangelands, Pit seeding, Carbon sequestration, Iran

Introduction

Carbon dioxide in the atmosphere since the industrial revolution in 1850 to 2000 is reached from 285 to 370 ppmv[1] which in this duration, the amount of carbon emissions from fossil fuel was 270±30 and then, 136±55 ppmv through land use changes (Lal, 2003). Greenhouse gas emission to the atmosphere, especially CO_2 is one of the main causes of climate change and global warming. Based on forecasts, up to 2100 mean of annual temperature will be increased to 4–6°C that may have a profound impact on the total soil carbon pool and its dynamics (Lal, 2008). Researches have shown that climate phenomenon will cause the changes in air and soil temperature, water stored in the soil and its nutrients, and changes in natural ecosystems such as rangelands through effects on soil, water availability and biodiversity at the regional and global scale particularly in arid and semiarid regions (Lund, 2007; Lal, 2008; Zhang *et al*., 2012).

Approximately 30% of the earth's ice-free land surfaces are classified as rangelands (Booker *et al*., 2012) and there are vast areas of lands in watershed basins of Iran managed as natural rangeland which has been restored biologically or protected from disturbances. Rangeland management can reduce the amount of carbon dioxide in the atmosphere through the process of carbon storage in plant biomass and soil organic matter which is called carbon sequestration (Derner and Schuman, 2007). But despite the considerable area of rangelands in the world, rangeland mismanagement and indiscriminate use of them for providing the human growing needs have encountered them with many threats like land use changes, over utilization, decreased biodiversity, soil erosion and loss of organic carbon. About 20 to 73% of global rangelands are faced with destruction in both soil and vegetation. Degraded rangelands in both soil and vegetation occupy 0.757×10^9 ha of the world's land and 2.576×10^9 ha of these lands may have been destroyed in vegetation only (Lal, 2001; Lund, 2007). It is estimated that approximately 0.5 Petagram[2] carbons is stabilized by these degraded rangelands (Schlesinger, 1997; Scurlock and Hall, 1998). Also, according to the researches which have performed in 11 provinces of Iran, land use change causes 32% of rangeland degradation which is a considerable amount (Ansari *et al*., 2008). Undoubtedly, the carbon sequestration potential of these degraded rangelands will be affected by reclamation and proper management. If managerial decisions are not made timely and precisely, degradation of these resources particularly in arid and semiarid regions such as Iran will be accelerated.

Two main ways for increasing Soil Organic Carbon (SOC) are land use changes and modification of management methods which are often used with each other (Stene, 2007). The amount of carbon sequestration in different areas depends on the plant species, restoration techniques and environmental conditions, especially rainfall, management practices, land use change, physical and biological conditions of soil and previous soil carbon storage (Bagheri, 2011). Size of soil carbon pool in a certain location changes based on specified ratio of input organic carbon (net primary production of aerial and underground) and output (erosion, decomposition of plant material and soil organic matter) for an annual scale or longer periods (Almagro *et al.*, 2009). Also, vegetation life form, clay and vegetation cover are very important factors influencing the carbon sequestration hotspots (Khosravi Moshizi *et al*., 2015). Some researches showed that reclamation measures can reverse the process of soil degradation, cause positive changes in ecosystem, and

[1] parts per million by volume

[2] Petagram= 10^{15} gram = 1 billion ton

sequestration of SOC and increase the economical value of these projects (Ussiri and Lal, 2005). Conservation of natural vegetation or restoration of degraded lands by suitable plants has good potentials for carbon sequestration (Tavakoli, 2016). Total carbon sequestration in biomass, litter and soil increased significantly in rangelands under controlled management systems as compared to uncontrolled and mismanagement systems (Yong-Zhong *et al.,* 2005). Cultivation of short grasses in the steppe areas for 60 years causes 62% reduction in soil organic carbon in the 15 cm of top soil in comparison with natural rangelands (Bowman *et al*., 1990). Soil carbon dynamics in abandoned farmlands were studied from 1927 to 1982 in Minnesota (Knops and Tilman, 2000). Results showed that the projected time for restoration soil carbon without reclamation activities such as before planting is 230 years. After abandoning the cultivated land, carbon sequestration was affected by nutrient status of destroyed soil (Zhang *et al.*, 2012). Other studies showed that higher carbon sequestration occurs in the soil accurse by biological and mechanical activities (Yousefian *et al*., 2011; Naseri *et al.*, 2014).

It is important to evaluate capacity and efficiency of rangeland reclamation practices or other rangeland management systems on carbon sequestration and C stocks for Iranian commitments at the international level. For this purpose, this study was performed to explore these capacities with respect to the impacts of rangeland reclamation and management on C sequestration while comparing three managements of natural rangelands, Pit-seeding and abandoned dry farming for C stocks, vegetation cover and soil properties in order to identify the best method for range management in terms of C sequestration.

Materials and Methods

Study area

This study was carried out in two sub basins of Kardeh catchment (Goosh and Bahreh) in Mashhad, Iran with 4917 ha area which is a mountainous region with relatively steep slopes with the average value of 31% and is located between 36° 7′ 17″ to 36° 58′ 25″ northern latitude and 59° 26′ 3″ to 59° 37′ 17″ longitude (Fig. 1). The elevation is 1200 (watershed outlet) up to 2977 m above sea level (Hezarmasjed peak) (Yasouri *et al.*, 2012; Ebrahimian *et al.*, 2012). The mean long-term rainfall based on the nearest climatology stations (Mareshk and Mashhad) is 353 mm and annual temperature is 9°C; also, its climate classification using Domarten method is semi-arid (Tabatabai *et al*., 2006).

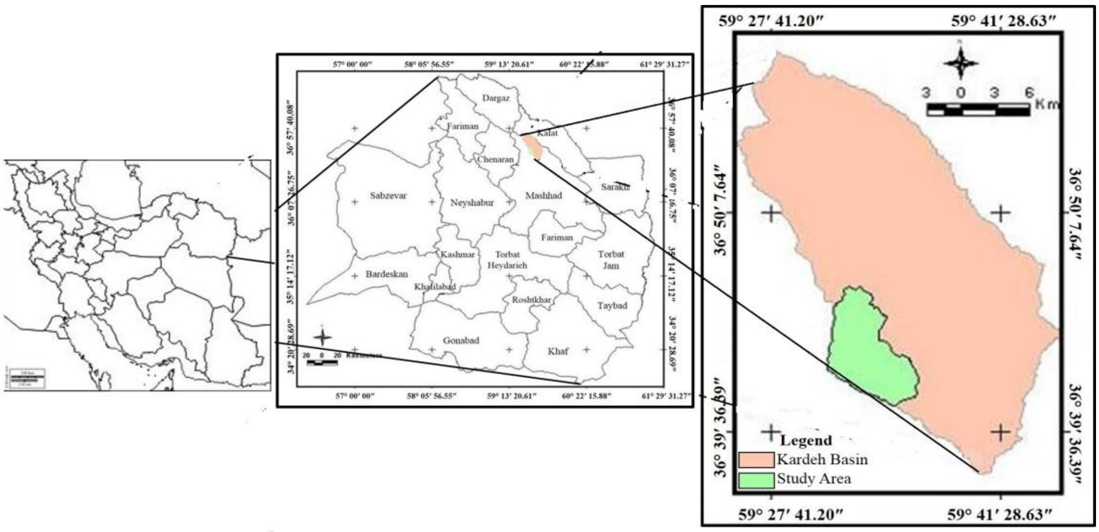


Fig. 1. The location of Kardeh basin in Iran

Dominant plant species in each area are presented in Table 1 based on field observations. Number of livestock in Goosh and Bahreh is 5500 animal units and most of livestock in this area is sheep. The time of animal entrance and existence to rangelands is June and August, respectively.

This watershed experienced different forms of management in 1996 (Tabatabai *et al*., 2006) including natural rangeland (NR), reclamation as Pit-seeding by *Agropyrum elongatum* (PS) and abandoned dry farming (ADF). These areas are utilized as grazing lands by local people according to the government agency program. These three forms of land use were considered as treatments and compared in terms of C stocks. The time of vegetation sampling was coinciding with the maximum growth (flowering stage) and production in 2013. The time of vegetation sampling for annual and perennial spices was June to July and August to September, respectively. Vegetation, litter and soil samples in each treatment were taken along 10 transects that represent the variation of topography, soil and vegetation in the study area (Table 2).

Table 1. Dominant species in different treatments

Natural rangelands (NR)	Pit seeding (PS)	Abandoned dry farming (ADF)
Acantholimon erinaceum	*Acantholimon erinaceum*	*Acantholimon raddeanum*
Acantholimon raddeanum	*Acantholimon raddeanum*	*Acanthophyllum bracteatum*
Agropyrum trichophorum	*Acanthophyllum bracteatum*	*Acroptilon repens*
Artemisia ciniformis	*Agropyrum elongatum*	*Agropyrum trichophorum*
Artemisia kopetdaghensis	*Agropyrum trichophorum*	*Alhagi pseudalhagi*
Artemisia sieberi	*Annual grass*	*Annual grass*
Astragalus brevidens	*Artemisia sieberi*	*Artemisia sieberi*
Astragalus heratensis	*Astragalus heratensis*	*Carthamus oxycantha*
Centaurea virgata	*Centaurea virgata*	*Centaurea virgata*
Eremurus spectabilis	*Dianthus orientalis*	*Cirsium congestum*
Festuca arundinaceae	*Eremurus spectabilis*	*Cousinia spp.*
Phlomis cancellata	*Noaea mucronata*	*Noaea mucronata*
Rosa persica	*Phlomis cancellata*	*Poa bulbosa*
Scariola orientalis	*Rosa persica*	*Rosa persica*
Stipa arabica	*Scariola orientalis*	*Scariola orientalis*
Stipa caragana	*Stipa arabica*	*Stipa arabica*
Verbascum songaricum	*Verbascum songaricum*	*Verbascum songaricum*

Table 2. Characteristics of sampling areas

Treatment	Transect No.	Vegetation type	Altitude (m)	Slope (%)	Aspect	longitude	Latitude
Natural rangelands	1	*Ag.tr-Ro. pe-Ar.si*	1903	12-25	SE	59° 32′ 38.5″	36° 46′ 5.87″
	2	*Ag.tr-Ro. pe-Ar.si*	1811	12-25	W	59° 32′ 7.47″	36° 44′ 33.32″
	3	*Ag.tr-Ro. pe-Ar.si*	1801	5-12	E	59° 33′ 10.82″	36° 45′ 21.45″
	4	*Ag.tr-Ro. pe-Ar.si*	1893	12-25	W	59° 34′ 6.72″	36° 44′ 59.96″
	5	*Ag.tr-Ph.ca -Ar.si*	1875	5-12	NW	59° 34′ 4.15″	36° 44′ 27.80″
	6	*Ag.tr-Ph.ca -Ar.si*	1766	5-12	SE	59° 31′ 54.05″	36° 44′ 27.48″
	7	*Ag.tr-Ph.ca -Ar.si*	1604	12-25	NW	59° 32′ 53.48″	36° 44′ 3.40″
	8	*Ag.tr-Ar.si-Ac.ra*	1811	12-25	W	59° 32′ 7.47″	36° 44′ 33.32″
	9	*Ag.tr-Ar.si-Ac.ra*	1769	5-12	SW	59° 31′ 57.67″	36° 44′ 27.17″
	10	*Ag.tr-Ar.si-Ac.ra*	1704	12-25	NW	59° 32′ 7.30″	36° 44′ 34.20″
Pit seeding	1	*Ag.tr-Ro. pe-Ar.si*	1881	12-25	SE	59° 34′ 4.20″	36° 45′ 6.80″
	2	*Ag.tr-Ro. pe-Ar.si*	1838	12-25	W	59° 32′ 23.43″	36° 45′ 23.47″
	3	*Ag.tr-Ro. pe-Ar.si*	1924	12-25	SE	59° 32′ 49.83″	36° 46′ 28.86″
	4	*Ag.tr-Ro. pe-Ar.si*	1843	12-25	W	59° 32′ 9.05″	36° 44′ 53.31″
	5	*Ag.tr-Ph.ca -Ar.si*	1758	12-25	SW	59° 33′ 54.96″	36° 41′ 58.86″
	6	*Ag.tr-Ph.ca -Ar.si*	1795	12-25	NW	59° 32′ 2.55″	36° 44′ 35.86″
	7	*Ag.tr-Ph.ca -Ar.si*	1820	12-25	SE	59° 31′ 51.50″	36° 44′ 32.07″
	8	*Ag.tr-Ar.si-Ac.ra*	1875	5-12	NW	59° 32′ 8.31″	36° 45′ 9.97″
	9	*Ag.tr-Ar.si-Ac.ra*	1789	5-12	SW	59° 32′ 2.77″	36° 44′ 35.01″
	10	*Ag.tr-Ar.si-Ac.ra*	1811	12-25	W	59° 32′ 7.47″	36° 44′ 33.32″
Abandoned dry farming	1	*Ag.tr-Ro. pe-Ar.si*	1908	12-25	SE	59° 32′ 30.44″	36° 45′ 31.62″
	2	*Ag.tr-Ro. pe-Ar.si*	1857	5-12	W	59° 32′ 54.16″	36° 45′ 53.49″
	3	*Ag.tr-Ro. pe-Ar.si*	1608	12-25	E	59° 32′ 49.93″	36° 43′ 19.32″
	4	*Ag.tr-Ro. pe-Ar.si*	1885	12-25	W	59° 33′ 50.34″	36° 45′ 20.43″
	5	*Ag.tr-Ph.ca -Ar.si*	1951	5-12	SE	59° 34′ 7.79″	36° 44′ 13.55″
	6	*Ag.tr-Ph.ca -Ar.si*	1927	5-12	NW	59° 34′ 3.47″	36° 44′ 22.92″
	7	*Ag.tr-Ph.ca -Ar.si*	1890	5-12	SW	59° 33′ 13.83″	36° 44′ 55.33″
	8	*Ag.tr-Ar.si-Ac.ra*	1763	12-25	SW	59° 31′ 57.64″	36° 44′ 31.00″
	9	*Ag.tr-Ar.si-Ac.ra*	1620	12-25	W	59° 32′ 6.62″	36° 45′ 6.21″
	10	*Ag.tr-Ar.si-Ac.ra*	1780	12-25	NW	59° 32′ 2.86″	36° 44′ 50.00″

Vegetation type= *Ag.tr: Agropyrum trichophorum- Ro. pe: Rosa persica, Ar.si: Artemisia sieberi, Ph.ca: Phlomis cancellata, Ac.ra: Acantholimon raddeanum,* Aspect= N: North, S: South, E: East, W: West

Vegetation sampling methods

In each treatment, vegetation was measured by sampling plots of 2 m^2 with 10 m intervals along ten transects with 100 m length (100 rectangular plots for each treatment). To remove the slope effect in hills and mountainous area, sampling transects were located diagonal to slope direction. Aerial and underground biomasses of plants were estimated through clipping and weighing. Litters were also collected from soil surface. In addition, the growth form (i.e. grass, forbs, shrub and bush) and life longevity (annual and perennial) of species were recorded. All plants and litters were washed and dried at 75°C (Armecin & Gabon; 2008) and then, weighed for dry matter production. Samples of each material were milled to a fine powder and combusted for the determination of organic carbon content using Electric Combustion Furnace at 450°C for three hours (Reeder and Schuman, 2002). Organic matter (%) and organic carbon content (%) were calculated using following equations (Equations 1, 2 & 3):

$$OM\% = \frac{D_W - A_W}{D_W} \times 100 \qquad (1)$$

$$OC\% = OM\% \times 0.5 \qquad (E\ 2)$$

Biomass C (kg. ha^{-1}) =Biomass (kg. ha^{-1}) × OC% (3)

Where:

OM = Organic matter,

OC = Organic carbon,

A_W = ash weight of sample,

D_W = dry weight of sample (Jana *et al*., 2009).

Soil sampling and analysis

Ten soil profiles were dug systematic-randomly for each treatment along each transect and 20 samples were taken from two depths of 0-25 cm and 25-50 cm. The soil organic carbon percent was determined by Walkley- Black method (1934). Furthermore, particle size (ratio of clay, silt and sand) and bulk density were determined by hydrometer methods and core samples (Mekuria *et al*., 2009), respectively. $CaCo_3$ was measured using the acid digestion and titration method (Bhatti and Bauer, 2002). Soil acidity (pH) and electrical conductivity (EC) were measured by conventional methods. Soil C stocks were calculated by Equation 4.

$$SCS = OC\% \times 100 \times BD \times d \quad (4)$$

Where:

SCS =Soil Carbon Stock ($t.ha^{-1}$),

OC=Organic carbon (%),

BD =soil bulk density ($g.cm^{-3}$)

d=Soil depth in meters (Zhang *et al*., 2012).

Carbon storage in the soil profile was calculated for the determined depths. Before subjecting the data to a statistical analysis, the uniformity of data was checked using Kolmogorov–Smirnov. Statistical analyses were conducted by one-way ANOVA and significant differences between means were tested using the Duncan test.

Results

Plant biomass and C stocks

Results demonstrated that PS and ADF management with the average values of 35.98% and 23.2% had higher and lower vegetation cover, respectively. There was no significant difference between PS and NR in terms of vegetation cover. In addition, the litter percent in PS was significantly higher than that for NR and ADF (Table 3).

Table 3. Means comparison between three treatments by Duncan test in terms of land cover

Parameters	Natural Rangelands	Pit Seeding	Abandoned Dry Farming
Vegetation cover (%)	31.86 ^{a} ±1.2	35.98 ^{a} ± 1.8	23.2 ^{b} ±2.33
Bare Soil (%)	29.41 ^{b} ± 4.04	16.87 ^{c} ±1.83	51.87 ^{a} ±5.37
Rock (%)	32.4^a ±3.65	37.65 ^{a} ± 3.1	20.08 ^{b} ±4.96
Litter (%)	6.33^b ±0.56	9.48 ^{a} ±0.69	4.85 ^{c} ±0.33

Means ±Standard error, means of rows with various letters are significantly different ($p < 0.05$)

Data indicated that there were significant differences between treatments for aerial, root and total biomasses, and aerial and biomass C stocks (Table 4). Higher values of these traits were obtained in PS management. There were no differences between treatments, C stocks of root biomass and litters (Table 4).

Table 4. Means comparisons of aerial and root biomass and their C stocks in various treatments by Duncan test

Parameters	Natural rangelands	Pit seeding	Abandoned dry farming
Aerial biomass (kg/ ha)	572.9 ^{b} ±43.31	1226.51^a ±78.04	429.00 ^{b} ±34.36
Root biomass (kg/ ha)	208.54^b ±14.75	297.7^a ± 18.78	198.00 ^{b} ± 45.42
Total biomass (kg/ ha)	781.44^b ±56.6	1524.21^a ± 92.96	627.04 ^{b} ± 71.72
Litters (kg/ ha)	135.34^a ±9.78	354.52^a ±96.65	124.01^a ±18.19
Aerial biomass C stock (kg/ ha)	249.27^b ± 19.68	557.85^a ± 36.48	179.89^b ±13.88
Root biomass C stock (kg/ ha)	88.31^a ±6.69	121.51^a ± 7.74	84.04^a ±19.32
Total biomass C stock (kg/ ha)	337.58^b ±25.78	679.36^a ±42.33	263.92^b ± 29.79
litter C stock (kg/ ha)	64.45^a ±4.60	142.38^a ± 40.69	48.05^a ± 6.80

Means ±Standard error, means of rows with various letters are significantly different ($p < 0.05$)

Mean vegetation cover of various plant growth forms in different treatments is presented in Table 5. Results indicated that the PS and ADF managements with the average values of 422.02 and 17.60 kg/ha had higher and lower perennial grass production in vegetation composition (Table 5). Perennial forbs, annual forbs and annual grasses in ADF were significantly higher than those for PS and NR. The biomasses of bush and shrubs were the same in PS and NR but higher than ADF.

Table 5. Means comparisons between three treatments for vegetation cover of plant growth forms by Duncan test

Parameters	Natural Rangelands	Pit Seeding	Abandoned Dry Farming
Perennial Grasses	36.85 ^{b} ± 4.64	48.76 ^{a} ±3.42	9.23 ^{c}± 3.17
Perennial Forbs	29. 18^{b} ± 3.26	20.36 ^{b}±1.49	53.89 ^{a} ± 4.93
Bushes	25.91 ^{a}± 3.34	23.61 ^{ab}±3.93	14.13 ^{b} ± 2.00
Annual Grasses	3. 59 ^{b} ±1.06	5.47 ^{b}±1.96	12.60 ^{a}±2.47
Annual Forbs	2.71 ^{b} ± 0.79	1.40 ^{b} ±0.42	10.15 ^{a}± 2.10
Shrubs	1.76 ^{a} ± 0.85	0.40 ^{a}±0.40	0.00 ^{a}
Sum	100	100	100

Means ±Standard error, means of rows with various letters are significantly different ($p< 0.05$)

Likewise, perennial grasses in PS have the highest C stock among other plant growth forms. In NR perennial forbs, bushes and perennial grasses play an important role in carbon biomass stocks. But in ADF, perennial grasses have a negligible role in C stocks versus perennial forbs (Table 6).

Table 6. Means comparisons of three treatments in terms of C stocks in various growth forms by Duncan test

Parameters	Natural rangelands (kg/ ha)	Pit seeding (kg/ ha)	Abandoned dry farming (kg/ ha)
Perennial Grasses	90.65^{b} ± 9.80	422.02^{a} ± 46.2	17.60^{c} ± 6.90
Perennial Forbs	116.04^{b} ± 20.25	113.61^{b} ±9.95	183.33^{a} ±23.5
Bushes	110.26^{a} ± 16.3	127.23^{b} ± 24.11	43.50^{b} ± 8.88
Annual Grasses	10.51^{a} ± 3.30	15.21^{a} ± 4.90	12.91^{a} ± 3.40
Annual Forbs	2.31^{b} ±0.93	1.01 ^{b}± 0.31	6.59^{a} ± 1.80
Shrubs	7.82^{a} ± 3.80	0.28^{b} ± 0.28	0.00^{b}

Means ±Standard error, means of rows with various letters are significantly different ($p< 0.05$)

Soil characters and soil carbon

Table 7 shows the physical and chemical properties of soil and also the amount of soil C in different management treatments in two measured soil depths. EC and pH, sand, silt and clay percent and fine particles (Silt + Clay) were the same between treatments and in depths but a significant difference was observed between treatments in the topsoil layer in terms of CaCo3. Organic carbon percent and consequently, soil C were significantly higher in NR than two management treatments and in both depths. Surface Soil C of NR and PS was higher than sub surface soil, but it was observed the same or inversely in ADF treatment.

Table 7. Means comparisons of different treatments by Duncan test in terms of soil physical, chemical and soil carbon in two soil layers

Variables	Depth1 (0-25 cm)			Depth2 (25-50cm)		
	Natural rangelands	Pit seeding	Abandoned dry farming	Natural rangelands	Pit seeding	Abandoned dry farming
pH	7.82 ^{a} ±0.05	8.00 ^{a} ±0.10	7.87 ^{a} ± 0.05	7.94 ^{a} ±0.04	7.97 ^{a}± 0.03	7.98^{a} ± 0.06
Ec	0.92 ^{a} ± 0.15	0.50 ^{a} ±0.07	0.65 ^{a} ± 0.09	0.59 ^{a} ±0.09	0.36 ^{a} ±0.05	0.48^{a} ± 0.06
$CaCo_3$ (%)	32.62 ^{ab} ±3.29	41.26^{a} ± 4.19	25.03 ^{b} ± 1.11	36.11^{ab} ±3.46	49.07^{a} ±6.34	29.8 ^{a} ±2.61
Sand (%)	29.81 ^{a} ±1.85	30.67^{a}±5.46	31.33 ^{a} ±3.61	27.6 ^{a} ± 2.36	29.0^{a} ±4.36	34.17^{a} ±3.75
Silt (%)	47.76 ^{a} ±1.7	43.67^{a} ±3.18	48.77 ^{a} ± 2.74	46.35 ^{a} ±2.3	45.33^{a} ±3.28	41.93^{a} ±2.96
Clay (%)	22.42 ^{a} ±1.73	25.67^{a}±2.33	19.90 ^{a} ±1.92	26.05 ^{a} ±2.27	25.67 ^{a} ±3.48	23.9^{a} ±2.91
Silt+Clay (%)	70.19 ^{a} ±1.85	69.33^{a} ± 5.46	68.67 ^{a} ±3.61	72.4 ^{a} ± 2.36	71.0 ^{a} ±4.36	65.83^{a} ± 3.75
OC (%)	1.20 ^{a} ± 0.12	0.45 ^{b} ±0.09	0.49 ^{b} ±0.08	0.97 ^{a} ± 0.01	0.41 ^{b} ±0.08	0.50 ^{b}± 0.07
Soil C ($t.ha^{-1}$)	293.59^{a} ±52.76	100.5^{b} ±18.4	86.97^{b} ±16.59	241.3^{a} ±40.2	93.45^{b}±18.99	89.87^{b}±16.45

Means ±Standard error, means of rows with various letters are significantly different ($p< 0.05$)

Total amount of C stocks in plant biomass and litter was summarized in Table 8. According to the obtained results, less than 1% of total C stocks might be observed in plant skeleton and litter. Amount of Soil C in NR was 2.75 times higher than PS and 3.02 times higher than ADF over 0-50 cm of soil.

Table 8. Means comparisons of three treatments for C stocks in plant biomass, litter and soil depth layers

Parameters Treatments	biomass C (kg/ha)	litter C (kg/ha)	0-25 cm Soil C (kg/ha)	25-50 cm Soil C (kg/ha)	Total C (ton/ha)
Natural rangelands	338 [b]	64[a]	293596 [a]	241319 [a]	535.32 [a]
Pit seeding	679 [a]	142 [a]	10049 [b]	93451 [b]	194.77 [b]
Abandoned dry farming	237 [b]	48 [a]	86956 [b]	89874 [b]	177.14 [b]

Means with various letters are significantly different ($p< 0.05$).

Discussion

The results revealed that natural rangelands had the highest C stocks that were 3 times more than ADF area with the lowest C stocks; accordingly, other treatments need more time to achieve carbon stored as much as NR. This is due to the preservation of natural vegetation and soil in natural rangelands. In NR, soil is intact and sustainable over many years and because of proper utilization in this region, these lands have greater amounts of stored organic carbon. Also, an initial C stock in the NR soil is higher than other treatments. Hence, as other researches had shown, carbon sequestration is a process affected by management methods, reclamation practices, physical and biological conditions of soil and initial C stocks (Derner and Schuman, 2007). Therefore, any changes in each factor might have positive or negative influences on ecosystem carbon accumulation. Earlier reports demonstrated that there was a positive relationship between organic carbon with vegetation cover and plant biomass percent (Abdi *et al*., 2008; Gheytouri, 2012). This clearly indicates the necessity of proper utilization and protection of NR management as the most stable and economical method of carbon sequestration. In this regard, some researchers stated that instead of focusing on the annual flux of carbon, policies and management plans should be shifted to long-term protection of rangeland species and their soil for carbon maintenance with a wider range of environmental and social benefits (Booker *et al.,* 2012). Our finding confirms these results.

PS treatment had the second rank for C stock followed NR. It seems that planting *Agropyrum elongatum* in the degraded lands resulted in faster restoration of carbon as compared with ADF management. Other studies about the restoration of rangelands confirm an increase in soil organic carbon sequestration as a result of the implementation of these projects (Akala and Lal, 2001; Derner and Schuman, 2007). From the viewpoint of USDA (2000), the main protection methods that have affected the carbon sequestration process are the modification of marginal lands to the compatible land use systems, reclamation of degraded soil and application of best management practices. Although PS management had higher C stocks in biomass in present study, its soil C was lower than that for NR management; it seems that soil needs more time for restoration. These findings are in accordance with other researches. Studying soil carbon dynamics in the abandoned farmlands from 1927 to 1982 in Minnesota showed that the projected time for restoration soil carbon without reclamation activities such as before planting is 230 years (Knops and Tilman, 2000) whereas efforts to restore the plains with long grasses will require 158 years to modify carbon reservoirs such as natural rangelands (Potter *et al*., 1999). It seems t5hat after abandoning the cultivated land, carbon sequestration will be affected by nutrient status of destroyed soil (Zhang *et al*., 2012). A meta-analysis on data from 74 international land use changes and their soil carbon storage showed that there was a decline in soil C after land use conversion from grassland to cropland (−59%) and there was a significant increase in soil C after land use changes from cropland to grassland (+19%) (Guo and Gifford, 2002). The results of this research are consistent with those studies. Also, their research indicated that if a given land uses conversion, it is responsible for wasting soil carbon; then, an inverse change could potentially increase soil carbon storage. But it is important to understand that long time is required for recovering soil C such as its original level after disturbance because of land use changes (maybe decades or centuries).

According to Stene (2007), if carbon sequestration is the main objective of restoring vegetation, using woody species can be a strategy to store more organic matter in the soil. Therefore, the enhanced land cover by cultivation of perennial plants with deeper roots is one of the management methods that may increase the soil C sequestration, improve soil fertility, remove biological, physical and chemical restrictions of soil and modify it (Chang *et al*., 2014). In our research, NR management had higher root biomass and it had plants with deeper roots such as bushes including *Artemisia spp.* (*Ar. ciniformis, Ar. kopetgaghensis, Ar. Sieberi*), *Acantholimon spp.* (*Ac. raddeanum, Ac. erinaceum*), *Rosa persica* and perennial forbs like *Phlomis cancellata* and *Verbascum songaricum* and also, perennial grasses with denser roots such as *Agropyrum trichophorum, Stipa spp.* (*S. arabica, S. caragana*) and *Festuca arundinaceae.* In PS management, cultivation of *Agropyrum elongatum* alongside other perennial plants had remarkable effects on biomass C because this plant has a considerable biomass with very dense root. Plants with deeper and bushy root ecosystems could simultaneously improve both of soil structure and its steady-state carbon, water and nutrient retention as well as sustainable plant yields (Kell, 2011). Although biomass C in PS management was the highest, it was ranked as the second treatment in terms of total C stock due to the lowest initial organic carbon in the soil of PS. In ADF management, perennial forbs in vegetation composition were the highest. Therefore, this plant form had the greatest biomass C in this treatment. These findings support earlier reports on soil carbon (Almagro *et al*., 2009).

Various stages of soil degradation are different in carbon sequestration. In areas with high degradation sash as ADF managements, ecosystem functions are highly inefficient and the amount of carbon sequestration is lower than the sites with better conditions. It has been shown that there were ecological thresholds in the system which emphasized the importance of maintaining vegetation and soil functions (Thorsson and Svavarsdottir, 2013). Recovery of vegetation can affect the direction and rate of succession differently. By restoring the vegetation cover, ecosystem functions can be developed. It seems that in ADF management because of cultivating plant in past, soil surface that had higher root biomass and soil C sequestration capacity (Povirk *et al*., 2001) is disturbed and a lot of soil organic C is lost from this layer.

According to present research, between three components of the ecosystem (soil, plants and litter), the litter had the lowest C stock. According to pervious research, most of the carbon added to the top soil by litter returns to the atmosphere by decomposition and only a very small part of it is converted into humus (Meentemeyer, 1978; Melillo *et al*., 1982).

In our research, most of total C was stored in the soil. This finding supports the earlier reports about the contribution of soil in the land carbon sequestration (e.g. Azarnivand *et al*., 2010; Dianati Tilaki *et al*., 2010; Naghipour Borj *et al*., 2012; Lal, 2004). Due to higher humus and microbial activity in the soil up surface layer, the carbon sequestration was more than subsurface layer. Also, with the increased soil depths and enhanced concentrations of organo-minerals compounds by depth, the average remaining of these matters has increased showing that microbial activity and turnover of soil C are reduced by depth (Patil *et al.*, 2012). In current study, soil C in soil surface layer of NR and PS managements was higher than subsurface layer that confirms their findings. Results of our study showed that deeper soil layers of ADF had higher C stock. However, its content was decreased with the increased soil depth in both PS and NR managements. This can be due to soil degradation in ADF management because of ploughing and cultivating in previous years. This causes mechanical disturbance in soil aggregates which plays an important role in physical protection of soil organic matter. Cultivating plant in previous years has led to soil surface disturbance. Therefore, more soil organic carbon is lost from 0-25 cm layer. Deeper soil layers of ADF were less encountered with human activity so that it had more soil C. Cultivating short grasses in the steppe areas for 60 years may cause 62% soil C decrease in the 15 cm of top soil as compared to natural rangelands (Bowman *et al*., 1990). Although there was no significant difference between fine particles in our research, the amount of silt+clay was higher in NR and PS than that for ADF; this may be the result of erosion and losing fine aggregates in ADF. Fine aggregates cause to facilitate the chemical resistance of organo-mineral materials with relatively high durability. Soil organic carbon increased with the clay and silt contents. Clay particles have participated in soil carbon sequestration through the absorption of organic C to clay surfaces by polyvalent cation bridges or being trapped between expanding layers of clays or physical protection from decomposers. Soil OM is placed in very small pores that is reduced the microbial accessibility to SOM for decomposition. Both of these mechanisms prevent from the breakdown of organic matter (Post *et al*., 2004; Ussiri and Lal, 2005; Patil *et al.*, 2012). Physical protection (e.g. occlusion within soil structures or entrapment within clay and mineral aggregates) is one of the important factors that prevent C stocks from decomposition for 100 to 1000 years in the passive pool and they are the most stable carbon reservoirs (Breuer, 2012; Starr *et al.*, 2000).

In general, proper management of vegetation and soil in order to stabilize carbon in rangeland ecosystems can significantly reduce atmospheric carbon dioxide and store it as organic carbon reservoir. The best strategy is the protection of natural rangeland with proper usage which is sustainable, inexpensive and multipurpose prevention of plowing and abandoning them. Then, the rehabilitation of degraded rangelands and abandoned dry land farms uses the adapted perennial plants with high biomass content and preferably dense roots. Because of a vast area of watershed basin used as rangelands [approximately 30% of the ice-free land surface and 52.28% of Iranian lands], protection and reclamation have great potentials for increasing C stocks and other benefits for local people and global commitment.

Literature Cited

Abdi, N., Maddah Arefi, H., Zahedi Amiri, Gh., 2008. Estimation of carbon sequestration in *Astragalus* rangelands of Markazi province (Case study: Malmir rangeland in Shazand region). *Iranian Jour. Range Desert Research*, 15(2): 269- 282. (In Persian).

Akala, VA., Lal, R., 2001. Soil organic carbon pools and sequestration rates in reclaimed mine soils in Ohio, *Jour. Environmental Quality*, 30(6): 2098-104.

Almagro, M., López, J., Boix-Fayos, C., Albaladejo, J., Martínez-Mena, M., 2009. Carbon sequestration capacity in a semiarid ecosystem. *Proceeding of International conference on Desertification*, Advances in studies on desertification, Murcia, Spain, 16-18 September 507-510.

Ansari, N., Seyed Akhlaghi Shal, S. and Ghasemi, M., 2008. Determination of socio-economic factors on natural resources degradation of Iran, *Iranian Jour. Range Desert Research*, 15(4): 508-524. (In Persian).

Armecin, R.B. and Gabon, F.M., 2008. Biomass, organic carbon and mineral matter contents of abaca (*Musa textilis* Nee) at different stages of growth. *Jour. Industrial Crops and Products* 28: 340-345.

Azarnivand, H., Joneydi Jafari, H., Zare Chahouki, M. A., Jafari, M., Nikou, Sh., 2010. Effect of grazing on carbon sequestration and nitrogen storage of ecosystem on *Artemisia sieberi* rangeland in Semnan, Iran *Iranian Jour. Range and Desert Research*, 3(4): 590-610. (In Persian).

Bagheri, R., 2011. Analysis of rangeland ecosystem. First edition. Islamic Azad university of Baft press. (In Persian).

Bhatti, J. S., Bauer, I. E., 2002. Comparing loss-on-ignition with dry combustion as a method for determining carbon content in upland and lowland forest ecosystems Communications in soil science and plant analysis, *Canadian Forest Service Publications*, 33: 3419–3430.

Booker, K., Huntsinger, L., Bartolome, J., Sayre, N., Stewart, W., 2012. What can ecological science tell us about opportunities for carbon sequestration on arid rangelands in the United States? *Jour. Global Environmental Change*, 23 (1): 240–251.

Bowman, R.A., Reeder, J. D., Lober, R.W., 1990. Changes in soil properties in a central plains rangeland soil after 3, 20, and 60 years of cultivation. *Jour. Soil Science*, 150: 851- 857.

Breuer, B., 2012. Effect of vegetation type and composition on carbon stocks in semi- arid Ethiopian savannahs. Master thesis. University of Hohenheim. Pp 75.

Chang, X. F., Wang, S. P., Zhu, X. X., Cui, S. J., Luo, C. Y., Zhang, Z. H., Wilkes, A., 2014. Impacts of management practices on soil organic carbon in degraded alpine meadows on the Tibetan Plateau. *Jour. Biogeosciences Discuss*, 11: 417–440.

Derner, JD., Schuman, GE., 2007. Carbon sequestration and rangelands: A synthesis of land management and precipitation effects. *Jour. Soil Water Conservation*, 62(2): 77-85.

Dianati Tilaki, GH. A., Naghipour Borj, A.A., Tavakoli, H., Haidarian, M., Aghakhani, M., Afkham Shoara, M., 2010. Influence of Exclosure on Carbon Sequestration of soil and Plant Biomass in semiarid rangelands of North Khorasan Province, Iran *Jour. Rangeland*, 3(4): 668-679. (In Persian).

Ebrahimian, M., Nuruddin, A.B., MohdSoom, M.A.B., Neng, L.J., 2012. Runoff Estimation in Steep Slope Watershed with Standard and slop-adjusted curve number method. *Polish Jour. Environmental Studies*, 21(5): 1191-1202.

Gheitury, M., 2012. Assessment of management practices efficiency on carbon sequestration in the rangeland of Kermanshah province, Iran. Ph.D. thesis of rangeland science. Islamic Azad university of Tehran. Branch: science and researches. 138pp. (In Persian).

Guo, L.B., Gifford, R.M., 2002. Soil carbon stocks and land use change. *Jour. Global Change Biology*. 8: 345–360.

Jana, BK., Biswas, S., Majumder, M., Roy, PK., Mazumdar, A., 2009. Comparative Assessment of Carbon Sequestration Rate and Biomass Carbon Potential of Young *Shorea robusta* and *Albizzia lebbek*. *International Jour. Hydro-Climatic Engineering*. 1-15.

Kell, D.B., 2011. Breeding crop plants with deep roots: their role in sustainable carbon, nutrient and water sequestration.. *Annals of Botany*. 1-12.

Khosravi Moshizi, A., Heshmati, G.A., Salman Mahini, A.R., 2015. Identifying Carbon Sequestration Hotspots in Semi-arid Rangelands (Case Study: Baghbazm Region of Bardsir City, Kerman Province). *Jour. Rangeland Science* 5(4): 325-335.

Knops, J.M.H. and Tilman, D., 2000. Dynamics of soil nitrogen and carbon accumulation for 61 years after agricultural abandonment. *Jour. Ecology*, 81: 88-98.

Lal, R., 2001. Potential of desertification control to sequester Carbon and mitigate the greenhouse effect, *Jour. Climatic Change*, 51: 35–72.

Lal, R., 2003. Offsetting global CO_2 emissions by restoration of degraded soils and intensification of world agriculture and forestry. *Jour. Land Degradation & Development*, 14(3): 309–322.

Lal, R., 2004. Soil carbon sequestration to mitigate climate change. *Jour. Geoderma*, 123: 1-22.

Lal, R., 2008. Soil carbon stocks under present and future climate with specific reference to European eco regions. *Jour. Nutrient Cycling in Agro ecosystems*, 81(2): 113-127.

Lund, H.G., 2007. Accounting for the world's rangelands. *Jour. Rangelands*, 29: 3–10.

Meentemeyer, V., 1978. Macroclimate the lignin control of litter decomposition rates. *Jour. Ecology*, 59: 465–472.

Mekuria, W., Veldkamp, E., Haile, M., 2009. Carbon stock changes with relation to land use conversion in the lowlands of Tigray, Ethiopia, Conference on International Research on Food Security, Natural Resource Management and Rural Development. University of Hamburg. Pp 6.

Melillo, J.M., Aber, J.D. and Muratore, J.F., 1982. Nitrogen and lignin control of hardwood leaf litter decomposition dynamics. *Jour. Ecology*, 63: 621–626.

Naghipour Borj, A.A., Haidarian Aghakhani, M., Nasri, M., 2012. An investigation of carbon sequestration and plant biomass in modified rangeland communities (Case study: Sisab rangelands of Bojnord). *Jour. Watershed Management Research*, 94: 19-26. (In Persian).

Naseri, S., Jafari, M., Tavakoli, H. and Arzani, H., 2014. Effect of mechanical control practices on soil and vegetation carbon sequestration (Case study: Catchment Basin of Kardeh- Iran). *Jour. Biodiversity and Environmental Sciences*, 5(2): 122 -135.

Patil, V.P., Vaghela, B.N., Soni, D.B., Patel, P.N., Jasrai, Y.T., 2012. Carbon Sequestration Potential of the Soil of Jambughoda Wildlife Sanctuary. *International Jour. Scientific Research Publications*, 2(12): Pp6.

Post, W.M., Izaurralde, R.C., Jastrow, J.D., McCarl, B.A., Amonette, J.E., Bailey, V.L., Jardine, P.M., West, T.O., Zhou, J., 2004. Enhancement of Carbon Sequestration in U.S. Soils. *Jour. Bioscience*, 54 (10): 895- 908.

Potter, K.N., Torbert, H.A., Johnson, H.B., Tischler, C.R., 1999. Carbon storage after long-term grass establishment on degraded soils. *Jour. Soil Science*, 164: 718- 725.

Povirk, K.L., Welker, J.M., Vance, G.F., 2001. Carbon sequestration in Arctic and alpline tundra and mountain meadow ecosystems. In Follett, R.F., Kimble, J.M., Lal., R. (Eds.), The Potential of US Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect. Lewis Publishers, Boca Raton, FL, 189–228

Reeder, J.D. and Schuman, G.E., 2002. Influence of livestock grazing on C sequestration in semi-arid mixed-grass and short-grass rangelands. *Jour. Environmental Pollution*, 116: 457–463.

Schlesinger, W.H., 1997. Biogeochemistry: An Analysis of Global Change, North Carolina, Gulf Professional Publishing. 588 pages.

Scurlock, J.M. and Hall, D.O., 1998. The global carbon sink: A grassland perspective. *Jour. Global Change Biology*, 4: 229-233.

Starr, G. C., Lal., R., Malone, R., Hothem, D., Owens, L. Kimble, J., 2000. Modelling soil carbon transported by water erosion processes. *Jour. Land degradation & development*, 11: 83-91.

Stene, R., 2007. Potential for soil carbon sequestration through rehabilitation of degraded lands in the baringo district, Kenya, Master thesis, Norwegian University of Life Sciences, The Department of International Environment and Development Studies. Norway. 40 Pp.

Tabatabai, SM., Ghoddousi, J., Mohamadi Golrang, B., Abbasi, A.A., Seddigh, R., 2006. Final Report of Research Plan: Investigation and assessment on the technical efficiency of implemented watershed management project in Kardeh basin. Soil Conservation and Watershed Management Institute, Pp. 136, Tehran, Iran. (In Persian).

Tavakoli, H. 2016. Potential of Carbon Sequestration of *Hammada salicornica* Vegetation type in Desert Areas (Case Study: South Khorasan, Iran). *Jour. Rangeland Science* 6(1): 24- 32.

Thorsson, J. and Svavarsdottir, K., 2013. Soil carbon sequestration: A component of ecological restoration. Soil Carbon Sequestration, for climate, food security and ecosystem services. International conference. Reykjavík, Iceland. Book of Abstracts. 186 Pp.

USDA., 2000. Growing Carbon: A New Crop that Helps Agricultural Producers and the Climate too. Natural Resources Conservation Service. United States Department of Agriculture Washington DC. 8 Pp.

Ussiri, D. and Lal, R., 2005. Carbon Sequestration in Reclaimed Mine soils. *Jour. Plant Sciences*, 24: 151–165.

Walkley, A. and Black, I.A., 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Jour. Soil Science*, 37: 29–38.

Yasouri, M., Sulaiman, W. B., Saeidian, F. 2012. Conversion trends of rangelands to dry farming and its effects on erosion and sediment yield in Kardeh drainage basin. *Caspian Jour. Environmental Sciences,* 10 (2): 257-272.

Yong-Zhong, S., Yu-Lin, L., Jian-Yuan, C., Wen-Zhi, Z., 2005. Influences of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China. *Jour. Catena* 59: 267–27.

Yousefian, M., Mahdavi, K.H., Mahdavi, M., Tamartash, R., 2011. Evaluation of Enclosure Effects on Soil Carbon Storage (Case Study: Rangeland of Shahtappeh-Chah Mahmood and Chiro in Semnan Province). *Jour. Rangeland Science*, 2 (1): 439-448.

Zhang, L., Xie, Z.h., Zhao, R., Wang, Y., 2012. The impact of land use change on soil organic carbon and labile organic carbon stocks in the Long zhong region of Loess Plateau. *Jour. Arid Land*, 4(3): 241−250.

بررسی اثرات احیاء و مدیریت مراتع بر ذخیره کربن در شمال شرق ایران (مطالعه موردی: حوضه آبخیز کارده، مشهد، ایران)

سمیه ناصری[الف]، حسین توکلی[ب]، محمد جعفری[ج]، حسین ارزانی[د]

[الف]گروه مرتع‌داری، واحد علوم و تحقیقات، دانشگاه آزاد اسلامی، تهران، ایران
[ب]بخش جنگل و مرتع، مرکز تحقیقات کشاورزی و منابع طبیعی استان خراسان رضوی، سازمان تحقیقات، آموزش و ترویج کشاورزی، مشهد، ایران
(نگارنده مسئول) پست الکترونیک: tavakoli_res@yahoo.co
[ج و د] استاد دانشکده منابع طبیعی، دانشگاه تهران

تاریخ دریافت: ۱۳۹۳/۱۱/۰۸
تاریخ پذیرش: ۱۳۹۵/۰۲/۱۴

چکیده. ترسیب کربن در گیاه و خاک از راه‌های مهم مقابله با تغییرات اقلیمی است. با توجه به وسعت مراتع این اراضی ظرفیت زیادی برای ذخیره کربن دارند. در پژوهش حاضر ذخیره کربن (CS) در سه تیمار مراتع طبیعی (NR)، کپه‌کاری (PS) و دیمزار رها شده (ADF) در حوضه کارده در سال ۱۳۹۲ مقایسه شد. در هر تیمار ده ترانسکت و در طول هر ترانسکت ده پلات مستقر گردید. درصد پوشش گیاهی، لاشبرگ، سنگ و سنگریزه و خاک لخت در پلات‌ها ثبت شد. همچنین زی‌توده هوایی و ریشه گیاهان غالب با روش قطع و توزین نمونه‌برداری شد. کربن اندام‌های گیاهی و لاشبرگ با روش احتراق در کوره الکتریکی محاسبه شد. در هر تیمار ده نمونه خاک در دو عمق ۲۵-۰ و ۵۰-۲۵ سانتی‌متر برداشت و کربن آلی خاک با روش والکلی-بلاک اندازه‌گیری شد. تجزیه و تحلیل داده‌ها با آنالیز واریانس یکطرفه و مقایسه میانگین دانکن انجام شد. نتایج نشان داد تیمارهای مختلف از نظر ذخیره کربن کل (خاک+ بیوماس گیاهی+ لاشبرگ) اختلاف معنی‌دار داشتند. مراتع طبیعی و دیمزار رها شده به ترتیب با ۵۳۵/۳۲ و ۱۷۷/۱۴ تن در هکتار بیشترین و کمترین ذخیره کربن را داشتند. بین اجزای اکوسیستم، خاک مهمترین سهم را در ذخیره کربن داشته و بیوماس هوایی، ریشه و لاشبرگ پس از آن قرار گرفتند. در مقایسه بین تیمارها، کپه کاری بیشترین ذخیره کربن بیوماس گیاهی و لاشبرگ را داشته اما مقدار ذخیره کربن خاک آن در مقایسه با مراتع طبیعی به مراتب کمتر بود. در کپه کاری و مراتع طبیعی گندمیان چندساله، بوته‌ای‌ها و پهن برگان دائمی غالب بودند و بیشترین نقش را در ذخیره کربن گیاهی ایفا کردند. بطور کلی مدیریت صحیح مراتع طبیعی و توجه به حفاظت از پوشش گیاهی و خاک در این اراضی توانسته است مقدار قابل توجهی کربن آلی را ذخیره سازد.

کلمات کلیدی: دیمزارهای رها شده، مراتع طبیعی، کپه کاری، ترسیب کربن، ایران