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Assessing potential of farm management practices on Carbon Sequestration capacity in dryland area: case study Razin Watershed

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Abstract

Most scientific findings, confirm global climate change. Land carbon stock is the main carbon sink in carbon cycle and carbon sequestration in the land resource is the main hope to mitigate climate change. This research was conducted to evaluate the carbon sequestration capacity of farmland of Razin watershed as a main watershed target in MENARID program. The background studies and researches on carbon sequestration in neighboring areas were analyzed and while prioritizing reviewed projects, proper projects for every management in Razin were recommended. Results indicated that recommended operation including forage cultivation in dry lands with low productivity, terracing along with dryland gardens, transforming dry lands to almond cultivation and plow and tillage and rotation management can accordingly sequester 72.2, 93.4, 74.7 and 29.3 tons of carbon per hectare. According to the results of this study, total carbon sequestration potential in farmlands of Razin region is 186055tons in about 6490 hectares.

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Introduction

Climate change, at present, is the most important threat against sustainable development, especially for developing countries. This phenomenon is the result of global warming due to aggravated greenhouse emissions from industrial and agricultural activities. Earth lands progress 34 percent of greenhouse gases and cause one third of global warming. While, in 90s this ratio was 15% (FAO 2009). During 80s and 90s, collectively, 18 percent of carbon reservoirs of lands in the world are destroyed or emissioned due to mismanagement (Lal, 2004).

Considering increasing climate change and its effect on agriculture and natural resources, reducing ratio of greenhouse gases in the atmosphere is an unavoidable necessity. Terrestrial carbon sequestration is the only hope for atmospheric carbon sequestration which is practically possible through management and exploiting lands. Terrestrial carbon sequestration requires a mechanism and management, which not only sequesters carbon sources of greenhouse gases in atmosphere but also promotes productivity and quality of the soil and eventually of the crop. Also, it is obvious that the product of such mechanism and management promotes production capacity in agriculture and natural resources and preserves the environment and biodiversity and also improves livelihood situation of users.

Kolahchi (2005) in a study assessed general terrestrial carbon sequestration in various masses of milk vetch in Hamedanm province, west of Iran, under different circumstances and showed that the potential of these masses to sequester carbon is between 71.2 to 233.4 tons per hectare. Moghanni Zadeh Ashkezari (2009) showed that Atriplex species can sequester carbon in the form of biomass from 1.2 to 2.4 ton per hectare and as total carbon from 59.1 to 59.8 tons per hectare. Varamesh (2009) estimated the economic value of carbon sequestration using carbon emission tax estimation method, in Chitgar forest park in Tehran to be accordingly 41.65 million dollars.

Management operation in agriculture application, key controllable factor in organic carbon is the soil. Some of operations in application change of forests and ranges to agriculture, use of tools and serious tillage, fallow, and crop intermittence, management of plant remains, using green fertilizers and livestock fertilizers. In a study conducted in USA indicated that in agriculture, adopting preservative tillage, and 30 to 105 million tons of carbon is added to terrestrial carbon reserves. Also, adopting intermittence preservative agriculture, adds 14 to 29 million tons of organic carbon to soil reserves (Folt, 2001).

Introducing plans which promote soil productivity, in intermittence system (such as yearling and perennial species of Leguminosae) might be effective in improving organic carbon reserves of soil. In a research, the impact of planting three species of legumes in frequent periods of one to three years was studied. They showed that management operation might increase organic carbon reserves of soil by 9 to 19 percent (Kotika et al., 2005).

In a research conducted by Chiochinj et al., (2007) it was shown that preserved tillage and returning the remains to the soil in a period of nine years can promote organic carbon of the soil by 42 to 66 percent.

Management of plant remains, which is one of the principles of nature based agriculture, might well promote organic carbon of the soil. Bierke *et al.*, (2008) in a research indicated that a 16 year program of integrating crop remains in rice cultivation has promoted terrestrial organic carbon by 41 to 45 percent. It has also increased the quality of terrestrial organic carbon.

Agroforesrtry are another turning point to achieve carbon sequestration. Production of one square meter of wood, sequesters 900 kilograms of carbon and using it instead of other elements which require energy consumption and produce carbon dioxide, hampers emission of 1100 kilogram of carbon. Hence, every square meter of wood, refrains 2 tons of carbon dioxide (Lal 2008).

This research was conducted to evaluate the potential of carbon sequestration of arable land specially drylands of Razin watershed as a main watershed target in MENARID program.

Materials and methods

Site study

Razin watershed region with an extent of 14688 hectares is located in the north of Kermanshah province. Average annual temperature is 11.4 degree centigrade, the maximum average reaches 19.3 and the minimum average reaches 3.5 degree centigrade. Annual rainfall on average is 588.5 millimeters. Regional climate based on Ambregere, is semi-wet and cold. Current land use of Razin watershed upon determination include agriculture lands, gardens, forests, ranges and rocky protrusions and combination of forests and rocky protrusions. In this region, an area equal to 6154.5 hectares (43 percent of the region) is covered by farmlands and usually grains such as wheat and barley and also pea is cultivated.

Humidity regime of the soil in the area is xeric humidity regime and temperature regime of the soil is Mesic regime type. Soil context in the area is heavy and contains clay, clay loam and silt clay. The ratio of lime in lower horizon in most of the area is between 14 to 41 percent. According to geology studies of the area, surface soil is steep and has extreme highs and lows and contains debris deposits and the soil in the area of river sedimentation is of entisol category and other soil in the area are inseptisol with lime accumulation horizon.

Assessment of Carbon Sequestration Potential of the Region

In this assessment, applicable corrective and reclamation measures and also management methods for croplands in Razin region are assessed. In order to fulfill the task, background studies and researches on carbon sequestration in neighboring areas, which will be discussed on next sectors, were analyzed and while prioritizing reviewed projects, from carbon sequestration point of view, proper projects for every management in Razin were recommended. Eventually, level of carbon sequestration for every unit will be provisioned based on the impact of implementing these projects. In the final section and next chapters, optimum capacity for carbon sequestration through implementation of correction actions recommended in Razin region will be determined.

Carbon Sequestration Potential

In this section, in order to study natural capacity of carbon sequestration in farmlands in Razin region, background studies and researches on carbon sequestration in neighboring regions will be reviewed. In order to fulfill this task, research background on assessing reclamation in Kermanshah provinces, sharing similar natural, physical and climate conditions with the target region will be analyzed. In these studies, different reclamation action alternatives in carbon sequestration are researched and studied. Also, the results of a comprehensive research study in the form of a doctrine and two Masters' degree thesis on assessing the impact of different management methods on carbon reserves of the lands in Kermanshah will be used and analyzed for extrapolation of management measures' impact.

Results and discussion

In order to assess the impact of reclamation actions in atmosphere carbon sequestration a research was conducted in summer pastures of Kermanshah province. In order to assess biological reclamation actions' impact on carbon sequestration in Kermanshah province, 8 areas of summer pastures with similar ecologic situation were selected. Biologic action adopted to assess carbon sequestration in this province included protection management action along with transforming drylands to preserve farming and forage planting.

Total carbon reserve in 0-20 centimeters of the protection management soil is approximately 72.05 tons per hectare. Whereas the level of carbon reserved in control ranges is 26.60 tons per hectare. Also, total carbon reserves in vegetation, leaf litter and soil in ranges under biologic action indicates that there is 96 percent carbon reserve in the soil and merely 4 percent of carbon of plant and leaf litter is sequestered.

Final results of carbon sequestration, segregated by different regions covered in Kermanshah province under biologic reclamation actions are presented in table 1. It is worth mentioning that all regions studied, as indicated in this table, have similar climate and geographic features as Razin region.

Table 1. Carbon Sequestration Level in protected rangelend.

No	Site	Period	Biomass & leaf litter carbon sequestration (hectare)	Terrestrial carbon sequestration (hectare)	Total project carbon sequestration (hectare)
1	Khanghah	15	1.28	78.45	79.73
2	Varmanjeh	18	0.55	76.8	77.35
3	Siah Kamar	10	0	44.4	44.4
4	Javanmard	13	0.89	69.85	70.74
5	Einalkesh	16	1.15	57.7	58.85
6	Kouh Sefid	15	1.71	61.03	62.8

Table 2. Biomass carbon reserves and soil of dry lands upon change of application in ranges compared to preserved ranges as evidence.

Type of Cultivation	Total biomass & leaf litter organic carbon (ton/ha)	Terrestrial organic carbon (ton/ha)	Total carbon reserve (ton/ha)
Peas	0.98	50.96	51.94
Wheat	1.41	46.34	47.75
Barley	1.58	39.67	41.25
Average	1.32	45.66	46.97
Evidence range (preserved)	4.15	113.2	117.3

Lal study (2008) indicates that carbon value in soil productivity and crop, regardless of its environmental impact is equal to 200 dollars per ton of carbon. Now, if minimum economic value of carbon sequestration in ranges of Kermanshah province is considered to be equal to 200 dollars, then economic value of carbon sequestration in biologic projects is approximately 23822 dollars per hectare. In an assessment on the impacts of application change of dry farming to ranges, a comparative research was conducted where carbon reserves of these lands were compared to the neighboring preserved ranges with similar physical features and modified application. Inputs from dry farming, where pea, wheat and barley cultivation is prevailing were collected and compared to neighboring ranges as evidence. The results of comparing carbon reserves and vegetation are reflected in table 2. The results of this assessment indicated that in case of application change of dry lands to ranges in a mid-term period of time, approximately 15 years, carbon stock of the lands in question shall increase by two and a half fold and it is possible to increase carbon stock by 72.2 tons per hectare. Analysis of these results is also applicable in a reversed process meaning that change of application in these lands causes 61 percent of carbon reserves to be wasted.

In order to assess the impact of biomechanical reclamation actions in carbon sequestration, the process of cultivating species of fruit trees in the form of dry gardens of almonds and grapes over mechanical tradition structures of platforms and constructing rigid walls on steeps were selected. This action was assessed and studied in sample areas of Paveh, Javanmard, Ravansar and Siah Kamar in Kermanshah. The soil in the areas under biomechanical action to the depth of 20 centimeters, in a normal condition, is capable to reserve carbon to a minimum 72.05 tons per hectare. The final result of carbon sequestration in biomechanical action in Kermanshah province is reflected in table 3. Climate and geographic conditions of areas studied were similar to Razin region. According to the result table, biomechanical actions of cultivating vineyards in traditional platform areas, sequestration 112 ton of carbon per hectare, had highest sequestration capacity. It is worth mentioning that approximately 98 percent of sequestered carbon was in soil and the rest in biomass and leaf litter. Dry cultivation of almonds also helps to sequester 75 tons of carbon per hectare and in other words carbon reserves increase by 2 to 3 folds with cultivation of almonds and vine.

Table 3. Carbon sequestration capacity in biomechanical reclamation actions in biomass, leaf litter and soil.

No	Operation	Site	Project Description	Term	Species	Biomass carbon sequestration (ton)	Biomass & leaf litter carbon sequestration (ton per hectare)	Terrestrial carbon sequestration (ton per hectare)	Total project carbon sequestration (ton per hectare)
4	Biomechanical traditional	Kermanshah	Terracing & dry walls	15 12	Grape Almond	1.19 2.49	1.3 2.6	110.8 72.1	112.1 74.7
	Average biomechanical operation					1.84	1.95	91.45	93.4

Potential of crop management on carbon sequestration

In order to review the impact of crop management on destruction or sequestration of organic carbon in arable lands a research was conducted in watershed area of Mereg in Kermanshah. In this research, components of crop management were classified into three groups and their impact over carbon reserves of the lands were reviewed. One of the components was crop residues managemnet. Other component, was tillage management which was determined by integration of three variable index of machine energy

(MJ per hectare per year), index of species and sequence of tillage instruments and plowing direction. Crop rotation pattern, was the third component of management which was determined by integrating three variable of legume and grain sequences (ratio of the number of years of legume cultivation and grain to sequence period) and traditional fallow system. Accordingly, for crop rotation management, tillage and management of plant residue, respectively 8, 7 and 9 different patterns were designed and their dispersion was determined based on geostatistics.

Through geostatistical interpolation, distribution of terrestrial carbon stock were designed. Figure 1 shows the dispersion of terrestrial organic carbon reserves of the region. As indicated in the map, the more we move from northern and eastern areas to the center of the region and especially west, terrestrial organic carbon reserves grow dry and soil grows weaker. Whereas, most arable savanna and integrated lands are located in center, west and south of the region, where intensive agriculture with focused management takes place and other areas of the region are inconsistent drylands, where tillage, crop rotation and sequence in managed traditionally.

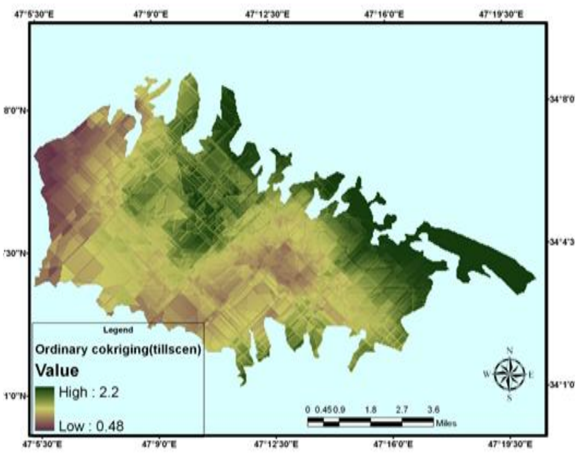

Fig. 1. Dispersion map of organic carbon stock in arable lands.

In this research, artificial neural networks were used to foresee changes in carbon reserves. In order to prioritize the impact of variables on terrestrial organic components, sensitivity analysis was done over primary compound of the network. Input analysis indicates that variability of terrestrial organic carbon in dry lands is affected by tillage.

The results of sensitivity analysis of the network indicated that manure, index of tillage , harvest of crop residues, stubble burning, slope direction, winter fallow and legume frequency in rotation are most vital elements in terrestrial organic carbon variety (figure 2). Also, traditional winter fallow system and use of animal fertilizers have a positive impact on terrestrial organic matters. Also, in this application, only 7 percent of the changes in terrestrial organic matters had physical origin. Modification of tillage system, sequencing and remains' management, on average, increase terrestrial organic carbon reserves by 1.06 percent (1.86 percent organic matters). It is estimated to be equal to 29.3 tons per hectare in depth of plow of 410 thousand tons of terrestrial carbon in 14 thousand hectares. Annually, on average 1.32 ton carbon in produced in dry lands and 3 tons in watersheds in the form of biomass which shall be added to the above figure.

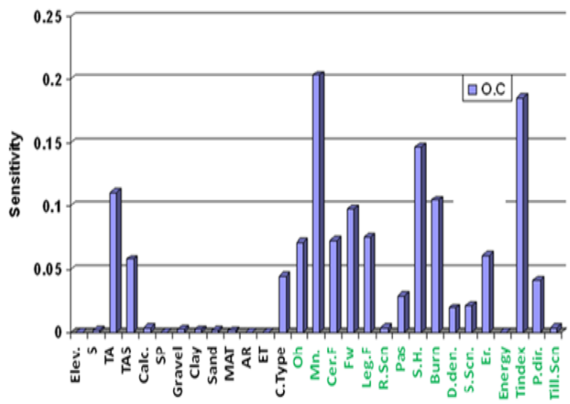

Fig. 2. Sensitivity analysis diagram of effective factors in carbon stock sequestering or destruction.

The results indicate that various management systems including agroforestry management promoted terrestrial organic carbon reserves by 32.8 tons per hectare and biomass carbon reserves increased by 3.5 tons per hectare.

Recommended Measures in farmlands of Razin Region

Based on estimated potential of carbon sequestration in various applications in Razin region, recommendations were made in the study report. Also, to estimate carbon sequestration quantity in corrective measures as stated, the results presented in section 4 of the report were generalized. Table 7, the extended of the corrective measure recommended, segregated by sub regions and application is presented. What follows are operation recommendations in study report segregated by application.

Farmlands consist of an area of 6477.88 hectares of the region. Based on the study report, approximately 6350.24 hectares are under low-slope farming.

i. Transforming low performing dry lands to forage

Almost 94 hectare of low performing dry lands is located above a slope of 12 percent which are recommended for forage cultivation.

ii. Transforming low performing dry lands to contour faro and dry almond cultivation

Approximately 36 hectares of the area is identified for this program.

iii. Terracing of irrigated lands and slope gardens

Irrigated arable lands with low productivity and a slope of above 20 percent, including 6 hectares of the area, are dedicated to this program.

iv. Reform plow, remain management (farm management)

Plow reform and tillage is applicable to 6300 hectares of the arable lands.

Table 4 shows the transmittal of operations recommended in all applications.

Table 4. Extent of recommended reform programs in Razin region (hectare).

Arable land reform program			
Terracing and gardens	Plow reform and remains management*	Transforming dry lands To range	Transforming dry lands to contour faro and dry almond cultivation
5.76	6350	60.96	35.84

Estimating carbon sequestration capacity in Razin Region

In this section, carbon sequestration potential in farmlands of Razin region will be estimated based on reform programs are stated in section 3-3 of this study. The bases of estimation of carbon sequestration will the results of field studies indicated in section 3-1. Then we will review and estimate carbon sequestration potential of every application based on the above principle.

Carbon Sequestration Potential in Razin farmlands

In agriculture application, reform operations stated in section 5 include grassland cultivation or forage cultivation in dry lands with low productivity, terracing along with gardens, transforming dry lands to almond cultivation and plow and tillage and rotation management. Based on the conclusions in the study reports of neighboring regions, indicated in section 3-1, these operations can accordingly sequester 72.2, 93.4, 74.7 and 29.3 tons of carbon per hectare. In table 5, area of each operation recommended, segregated by final provision and level of carbon sequestration is shown. It is worth mentioning that considering lack of any principle restriction for remaining arable lands, the area of 6350 hectares of arable lands including arable lands minus the areas selected for other three management operation, are suitable for tillage and remains management. Hence, data on management operation to promote tillage and remains are not delivered segregated by region.

The results of estimates under ideal circumstances are demonstrated in table 5. As the figures show, agriculture, range and forest, on average, have the potential to sequester carbon by 28.8, 29.9 and 27 tons per hectare. The studies show that carbon sequestration potential in all three applications, with the priority of ranges, exists almost homogeneously in all areas. Spatial transmittal of optimum carbon sequestration potential is demonstrated in figure 3.

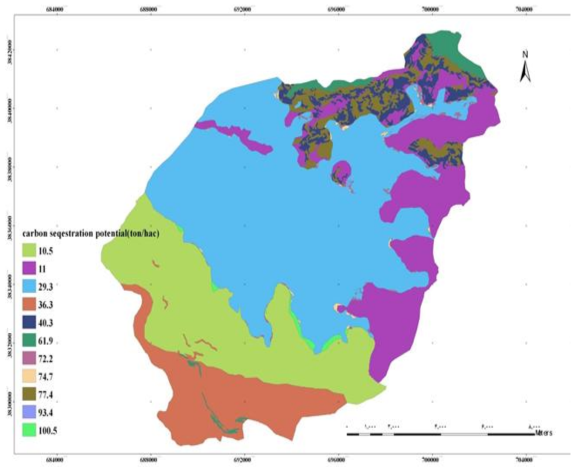

Fig. 3. Optimum Carbon Sequestration Potential in Different Areas of the Region, tons per hectare.

Table 5. Recommended Reform Programs in Arable lands (hectare).

Recommended measures for farmlands (hectare)								Total carbon sequestration (ton)
Terracing & Gardens	Carbon sequestration Potential (ton per hectare)	Transforming dry lands - ranges	Carbon sequestration Potential (ton per hectare(	Plow reform & remains management	Carbon sequestration Potential (ton per hectare)	Transforming dry lands to counter faroe and almond dry cultivation	Carbon sequestration Potential (ton per hectare)	
5.76	537.984	60.96	4401.312	6350	242570	35.84	2677.248	250186

Table 5. Optimum Carbon Sequestration Potential of Recommended Operations.

Programs	Arable land Reform Program			
Area	Terracing and gardens	Tillage reform and remains management*	Transforming dry lands to ranges	Transforming dry lands, contour faro and dry almond cultivation
Area	6	6350	94	36
Carbon sequestration potential (ton per hectare)	93.4	29.3	72.2	74.7
Total carbon sequestration (ton)	560.2	242570	6786.8	2689.2
Total carbon sequestration in every application (ton)	186055			

* Annual biomass production is not included in the estimation of these figures. Carbon sequestration figures should be added.

According to the inputs of this study, total carbon sequestration potential in farmlands of Razin region is 186055tons in about 6490 hectares. The interesting point is that of the recommended management agriculture management operations in arable lands, due to their extensive impact, with 79 percent potential in carbon sequestration, have a crucial role in the region. Also, such management operations are cost effective and have physical facilities and provide the opportunity of capacity building to promote living standard of the local people. Implementation of such management operations is possible through participation of beneficiaries and their training on different techniques to realize the operation.

The following management operations segregated in farmland.

A. The interesting point in agriculture is the high potential of low productive dry lands with slope in carbon sequestration, in case they are allocated to cultivation of trees and shrubs through biomechanical reclamation methods. The other important point about arable lands is the potential of agriculture management for atmosphere carbon sequestration. The important point to realize this potential is the very fact that it might be possible through low costs and merely reform of simple management methods consistent with sustainable agriculture principles and preserving the environment. The following are proof of efficiency of this management method.

B. Reform of tillage system: tillage system is consistent with the climate and physical condition of the land. Required techniques for tillage system reform include change of plow equipment, moving from moldboard plow to cultivator and goose plow, and adopting preservative plow methods including minimal plow, reducing number and sequence of plow operation and equipment application and eventually correct plowing in the right time.

C. Other agriculture management methods are efficient management of crop residue. The following are recommended in this method:

1- Including the remains of livestock fertilizers and green fertilizers to the soil

2- Preventing burning stubble

3- Planning for pasture of the arable lands

4- Development of altering industries to use plants remains such as paper and carton industries and eventually creating an added value for plant remains. This will result in increased production and alteration of these remains and carbon sequestration.

5- Production of biofuels: This method creates an added value for some crop the remains of which have the potential to produce biofuels and this is significantly effective in carbon sequestration.

6- New methods such as biochar production: This material is made by pyrolysis from plant remains in lack of oxygen, pressure and high temperature in furnaces. The final product is gas production as energy resource for domestic and industrial use and the remainder is used as active charcoal known as biochar, which might be a super absorber of high sustainability, and has a crucial role in physical reform and eventually promotes productivity. Also, adding it to the soil promotes carbon reserves and their life expectancy in the soil.

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