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Effects of Soil Compaction on Soil Carbon and Nitrogen Sequestration and Some Physico-Chemical Features (Case Study: NorthofAqQala)

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ABSTRACT Soil compaction has become a widespread problem in the world and it is considered as one of the main factors affecting land degradation in arid and semi-arid agricultural land. The aim of this study was to investigate the effects of soil compaction on soil carbon and nitrogen sequestration, physical (aggregate stability, saturated soil moisture content, bulk density, and porosity) and chemical (EC, pH, organic carbon and nitrogen) features. The treatments were applied in the form of the completely randomized block design with four independent variables and three replicates. The study treatments included: control treatment (no artificial compaction), T_2 (2 times passing heavy tractor), T_3 (4 times passing heavy tractor) and T_4 (6 times passing heavy tractor). Toward this attempt, data was analyzed by means of the SPSS 16.0. Software package. The type of mean comparison method applied is the LSD test (at significant level of 5%). The results showed that different levels of soil compaction caused a significant effect on soil physical and chemical features. Based on the results, 6 times passing heavy tractor significantly reduced soil porosity and aggregate stability (respectively from 0.45% and 5.32 mm in control treatment to 0.255% and 3.88 mm) while this treatment (4) significantly increased soil bulk density as compared to other treatments(from 1.45 g cm^{-3} in the control to 1.97 g cm^{-3}). Four and six times to-and-fro passing heavy tractor caused a significant reduction in soil carbon and nitrogen sequestration respectively from 3.26 t ha^{-1} and 149.62 kg ha^{-1} (in control) to 1.70 ton ha^{-1} and 48.16 kg $ha^{-1}$for T_3 and T_4 treatments, but significantly increased EC in comparison with other treatments (changed from 0.58dS m^{-1} in control treatment to 0.83dS m^{-1} in T_4). Also, all soil compaction treatments significantly increased soil pH. For example pH increased from 7.93 in control to 8.09 inT_4. While soil compaction treatments resulted in significant decrease in organic carbon, total nitrogen and saturated soil moisture values.

Key words: *Artificial compaction, Land degradation, Soil feature*

1 INTRODUCTION

Soil compaction is a global problem and is considered an important form of physical degradation of land occurring in a wide range of soil types and climate conditions. This phenomenon causes a lot of changes in soil properties (Van Ouwerkerk, and Soane, 1994). Degradation caused by soil compaction is

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approximated as around 68 million hectares of land worldwide. The vast majority of modern agriculture soil compaction is caused by the passages of machineries (Flowers and Lal, 1996).

Soil is regarded as a sluggish renewable natural resource which conservation or degradation depends to a large extend on the way it is managed (Haj Abbasi *et al.,* 1998). Selection of the type of device used in the tillage has effects on physical, chemical and biological soil attributes and thus crop yield (Tripathi *et al.,* 2007).

Increased soil compaction arises from soil bulk density and penetration resistance growth. Reduction of the size of large pores, blockage of pores, soil surface crust formation and reduced aggregate stability, soil structure degradation, reduced soil porosity and permeability was considered as negative consequences of soil compaction (Al- Adawi and Reader, 1996). These negative consequences required additional fertilizer consumption and escalation of the cost of production. This create other consequences such as reduced plant growth resulting from less input of fresh organic matter to the soil, reduction of the recycling of organic matter and the mineralization process, reduced microorganisms activity, and depreciation of machineries. Compaction in dry conditions induces soil aridity stress and in high humidity conditions imposes less soil aeration, reduced availability of nutrients, decreased roots metabolic activity and finally reduction of plant growth and yield. Soil compaction was also reduced available potassium and nitrogen. This could increase the incidence of pests, resulting in added stress to crops and reduction of performance (Ahmad *et al.,* 2006). For germination and growth of plants, a favorable level of water and nutrient should be available. Besides, for root penetration and germination soil should also be porous enough (Mosadeqhi *et al.,* 2000).

Changes in soil organic carbon is also an important indicator for estimating soil fertility and quality (Pathack *et al.,* 2004). Carbon is stored in soil organic matter, but these reserves can be influence by different types of land uses. Agricultural operations, increases mineralization of organic material that leads to the withdrawal of soil carbon (to the atmosphere). Soil carbon due to the decisive role in determining the physical, chemical and biological soil attributes had a positive effect on soil quality and stability, crop production and environmental qualities. Transfiguration of pristine arable lands to agricultural fields, converts an important part of soil stable organic carbon to unstable form and hence increases soil organic material loss, excessive carbon oxidation and emission of carbon dioxide to the atmosphere (Jung, 2001). Conservative management systems can improve soil organic matter reserves and contribute to the reduction of atmospheric carbon (Zanatta, 2006).

Carbon sequestration using long-term operation of plant management not only increased carbon storage in soils but also reduced carbon exchange and CO_2 emissions. It also improved soil quality and production. Similarly, nitrogen fixation was able to reduce the rates and amounts of fertilizer applications (nitrogen fertilizer) and release of N_2O (another harmful greenhouse gases that causes global warming) (Upendra *et al.,* 2008). Motavalli *et al.* (2003) also stated that the level of soil surface compaction reduces soil mineral nitrogen. Ventilation of poorly compacted soils reduced mineralization of organic matter which in turn reduced nitrogen and other elements biologic fixation. In addition, intensive de-nitrification in compacted with soil and nitrogen loss to the groundwater and the atmosphere was much more noticeable than the soil not compacted (Khalilian *et al.,* 1991).

Soil organic matter, as one of the most important factor in soil quality, play important role in the stabilization of the soil structure and improve the soil physical and chemical properties (Martel and Mackenzie, 1980). The improvement of soil aggregation was attributed to the increase in the organic matter. Organic matter is an important factor in soil aggregate stability since its size and various forms on soil be controllable through the optimal agriculture management (Bardgett and Shine, 1999), thus it could have an influence on the effective processes in the soil aggregation (Abiven *et al.*, 2007).

Unsuitable and indiscriminate agricultural operations break the coarse aggregate sand put the soil organic matter at risk of destruction (Steiner *et al.*,2007).So soil aggregates dispersion leads to a crust forming on the soil surface that this caused reduced permeability and increased runoff (Karimi *et al.*, 2008).

The effect of salinity and alkalinity which is caused by the presence of high exchangeable sodium can lead to the destruction of soil structure (Barzegar, 2001). Soil degradation in the first place is affected by natural factors, lurking weakly in the background, which is intensified by improper agricultural activities and manifest itself through soil salinity (Jafari, 2000). Problem of soil salinization in agricultural activities is a major problem facing mankind throughout the history. Agricultural operations can directly cause soil salinity. Anything that increases soil salinity can lead to land degradation and push the land towards desertification. Therefore, one must consider factors and the manner they alternate.

Currently, environment protection and achieving sustainable development is one of the pressing issues being highly appreciated through comprehensive economic, social and cultural evaluation plans in different countries of the world including our country.

Soils of the study area (north of the Aqqala city) could be classified as arid and semi-arid soils. The use of heavy machinery for agriculture and plowing at a constant depth in this area for many years has increased the density of surface or subsurface layers (in the root growth zone). The study on the impact of environmental stresses can reveal ways to increase product performance and ensure stable production (Asgari, 2008). So, this study is aimed at quantifying the effects of soil compaction on carbon and nitrogen sequestration in wheat along with physical and chemical properties of soil as significant parameters in sustainable production.

2 MATERIALS AND METHODS

The study area is located in the northwest of Golestan Province. A part of the northern fields of Aq qala town ship was selected as the case study. The farms expanded from 37^o 04′ 36″ northern latitude to 54^o 27′ 24″ eastern longitudes. The relief of the area ranges between 46 to 21 meters above the sea level.

In the first experiment, artificially subsurface compaction was performed by means of a tractor of the SAME LASER 150 model, weighing 5,700 kg with 26 in 52 meters in diameters (the land was completely flat with no gradient). Next, the 0.1m of topsoil was prepared by soft disking for seeding. The experiment with 4 treatments and 3 replications was conducted as follows:

i) $T_{1:}$ Control treatment (without artificial compaction): chiseling + shallow disking to a depth of 10 cm ii) T_2: two passings heavy tractor + shallow disking to a depth of 10 cm iii) T_3: four passings heavy tractor + shallow disking to a depth of 10 cm and iv) T_4: six passings of a heavy tractor + shallow disking to a depth of 10 cm (Figure 1).

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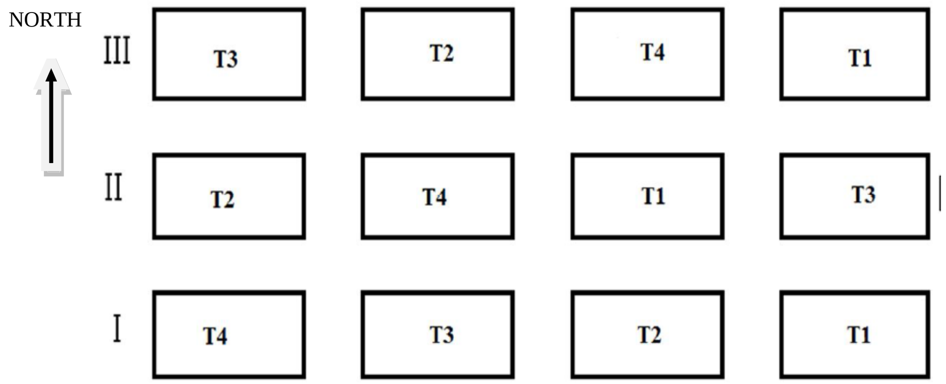

Figure 1 Mode of arrange and implementation plan

(T_1: Control treatment, T_2: two passing heavy tractor, T_3: four passing heavy tractor, T_4: six passing of a heavy tractor)

At the time of the creation of artificial compaction, soil moisture was 21%. Use of agricultural inputs (chemical fertilizer application rates, herbicides, etc.) was the same for all treatments. Prior to cultivation and based on the recommendation made by the extension commissioners, 160 kg ha^{-1} phosphorus, 160 kg ha^{-1} potassium and 50 kg ha^{-1} nitrogen fertilizers were applied to the fields. Because dry farming was the common agricultural practice in the study area, so the precipitation received (Mean precipitation 339 mm) to all parts of treatment plots was the same.

Traits studied in this experiment are as follows: soil's carbon and nitrogen sequestration, soil physical (aggregate stability, saturated soil moisture content, bulk density and soil porosity) and soil chemical (EC, pH, organic carbon and nitrogen) properties.

Soil bulk density is determined by a core sample (Klute, 1986).Total porosity was worked out using the same soil samples those were collected for soil bulk density. Total porosity (%) was calculated by using of the following formula (Equation 1, 2).

$$\text{Total porosity} = 100 - (B.D/P.D \times 100) \qquad (1)$$

$$P.D = \frac{\text{Mass of soil sample}}{\text{Volume of water displaced}} \qquad (2)$$

The mean weight diameter of aggregates (MWD) was obtained by using following equation (Equation 3) (VanBavel, 1949):

$$MWD = \sum_{i=1}^{n} XiWi \qquad (3)$$

where ‘x’ was the average diameter of the openings of 4 consecutive sieves, and ‘W’ was the weight ratio of aggregates remaining on the ‘i’ sieve.

Soil organic matter was measured by wet oxidation method (Nelson, 1982). The percent of nitrogen in soil was calculated by using the obtained percent of carbon (Equation 4):

$$\text{Total Nitrogen (\%)} = \text{percent of organic matter} \times 0.05 \qquad (4)$$

The amount of pH and EC are determined by pH meter and EC meter in saturated mud.

The obtained final experimental data were analyzed by SPSS 16.0. Statistical software. Treatment means were compared with LSD test at 1% level.

3 RESULTS AND DISCUSSION

The results showed that soil compaction has a significant impaction all physical and chemical parameters. The effect of treatment 4 (6 times

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passing heavy tractor) on all measured parameters was significantly higher than other treatments.

3.1 Soil physical features

The result of variance analysis was showed in Table 1. Comparison of mean measured parameters showed significant differences in some parameter at 5 and 1% level in 0-20 cm soil depth due to increasing compaction. Table 2 summarized effect of subsoil compaction on soil physical properties.

3.1.1 Soil bulk density and total porosity

Comparison of mean bulk density (Table 1) showed that increasing soil compaction has been caused an increase in soil bulk density. The result showed that minimum (1.45 g cm^{-3}) and maximum (1.97 g cm^{-3}) of bulk density was belong to control treatment and treatment 4, respectively. There was no significant difference between 2 and 4 to-and-fro tractor treatments and only 6 times to-and-fro treatment had a significant effect on soil bulk density. Soil bulk density in 2, 4 and 6 times to-and-fro treatment increased 21, 8 and 39% in comparison to control treatment (Table 1). Similar trend was observed for total porosity. Maximum porosity reduction (25%) caused via T_4 where six passes of tractor were applied. The results of this study were confirmed with researches of Hasan *et al.* (2007), Al-Adawi and Reader (1996), Bouwman and Arts (2000), Motavalli *et al.* (2003) and Baiat *et al.* (2005). They stated that other physical parameters are affected by increase of soil density and compaction so that aggregate is closed together and is removed soil coarse pores. Aggregate sticking to each other causes decreasing porosity and increasing soil bulk density (Elliout, 1986). Bertolino *et al.* (2010) stated increase of bulk density is due to reduction of soil coarse pores and reduction of total soil volume subsequently. Raza *et al.* (2005) reported that soil density causes increasing amount of bulk density in tillage layer significantly.

Table 1 Variance analysis of chemical parameters in different treatments of compaction

Variation sources	Degree of freedom	Mean squares			
		Soil bulk density (g cm^{-3})	Porosity (%)	Aggregate stability (mm)	Soil saturated moisture (%)
Frequency	2	0.003	0.0005	0.204	0.001
Soil Compaction	3	0.155^{ns}	0.022^{ns}	1.322*	0.009**
Error	8	0.045	0.006	0.188	0.001

** Significant at 1% level, * significant at 5% level, ns: non-significant

Table 2 Effect of subsoil compaction on soil physical properties

Treatments	Soil bulk density (gcm^{-3})	Porosity (%)	Aggregate stability (mm)	Soil saturated moisture (%)
Control	1.45^{a}	0.45^{a}	5.32^{a}	0.67^{a}
2 Times passing of tractor	1.57^{a}	0.36^{a}	5.24^{a}	0.59^{b}
4 Times passing of tractor	1.75^{a}	0.38^{a}	4.68^{a}	0.56^{c}
6 Times passing of tractor	1.97	0.25^{b}	3.88^{b}	0.55^{d}

In the table Letters a, b, c, d indicates significant levels. Treatments with different letters have a significant difference with together

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3.1.2 Aggregate stability(MWD)

The results showed that all soil compaction treatments significantly decreased soil aggregate stability as compared to control. However, T_4 had significantly higher negative effect on MWD (As an indicator of the aggregate stability) in comparison to control and also other soil compaction treatments (MWD changed from 5.32mm in control to 3.88 mm by T_4) (Table 1).

The effect of soil compaction on aggregate stability has been investigated in several studies. Carter (1998) stated that decrease in aggregate stability implies the unstable use of land. Aggregate dispersion leads to creating a crust on the soil surface and subsequent infiltration reduction. This, subject affects soil conductivity and soil stability to retain air and water (Karimi *et al.,* 2008).

3.1.3 Saturated soil moisture

The results indicated that the effect of all soil compaction treatments have caused a significant reduction on saturated soil moisture values. Saturated moisture percentage was reduced from0.67% in control to 0.55% in T_4 where six passing tractor was applied. Similarly, T_2 and T_3resulted in lower saturated moisture (0.59 and 0.56%, respectively, viaT_2 and T_3) as compared to control (Table 1).

The effect of soil compaction on saturated moistures largely governed by larger pores (Ehlers, 1983; Lin *et al.*, 1996, 1999; Lipiec *et al.*, 1995), which are negatively related to soil compaction (Carter, 1998).

Gysi *et al.* (1999) reported that moist soil responded at a depth of 12-17 cm to a ground contact pressure with an increase in bulk density and consolidation pressure, as well as with a decrease in air permeability and macro-porosity. Degradation of soil aggregates and pores among and decreased of soil aggregates stability in turn leads to reduced water infiltration into the soil (Horn *et al.*, 1995).

3.2 Soil chemical features

Variance analysis showed a significant difference among different levels of compaction on soil carbon and nitrogen sequestration, pH and EC (Table 3).

Table 3 Variance analysis of chemical parameters in different treatments of compaction

Variation sources	Degree of freedom	Mean squares pH	EC (dS m^{-1})	C sequestration	N sequestration
Frequency	2	0.001	0.003	4.63	1.779
Soil Compaction	3	0.008*	0.041**	323.64*	11.679*
Error	8	0.001	0.003	55.68	2.817

**Significant at 1% level, *significant at 5% level, ns: non-significant

Table 4 Effect of subsoil compaction on some soil chemical properties

Treatments	C (%)	N (%)	EC (dS m^{-1})	pH
Control	1.65 ^{a}	0.12 ^{a}	0.58 ^{c}	7.93 ^{d}
2 times passing tractor	1.2 ^{b}	0.1 ^{b}	0.66 ^{c}	8.05 ^{c}
4times passing tractor	0.87 ^{c}	0.08 ^{c}	0.8 ^{b}	8.07 ^{b}
6times passing tractor	0.6 ^{d}	0.07 ^{d}	0.83 ^{a}	8.09 ^{a}

In the table letters a, b, c, d indicates significant levels. Treatments with different letters have a significant difference with together

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3.2.1 Organic carbon and total nitrogen

The results indicated that the effect of soil compaction on soil organic carbon, total nitrogen in all treatments was significant and carbon and nitrogen sequestration was significant in T_3 and T_4 ($P < 0.05$). Soil compaction decreased soil organic carbon and total nitrogen respectively from 1.65 and 0.12% (in the control) to 0.6 and 0.07% by T_4 (Table 4).

Carbon and nitrogen sequestration also decreased significantly with increasing soil compaction levels. So that sequestration of carbon and nitrogen was reduced from 48.07 ton ha^{-1} and 4.14 ton ha^{-1} in the control treatment to 23.87and 2.05 ton ha^{-1} in T_4, respectively (Figures 2 and 3).

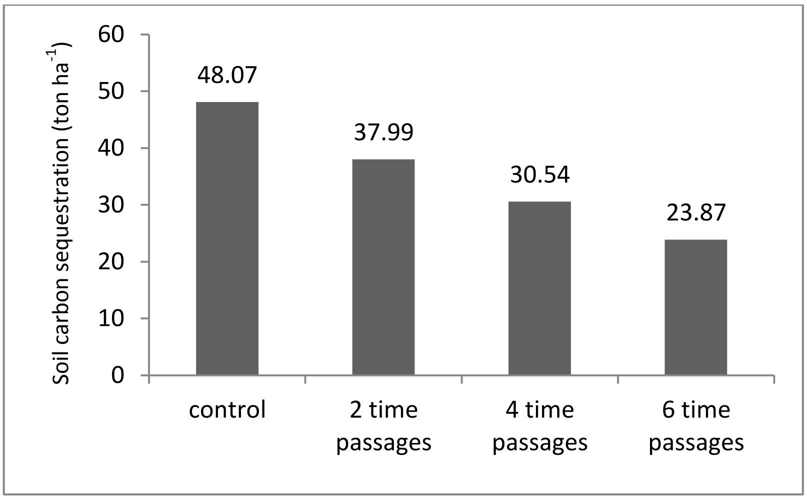

Figure 2 Effect of soil compaction on soil carbon sequestration

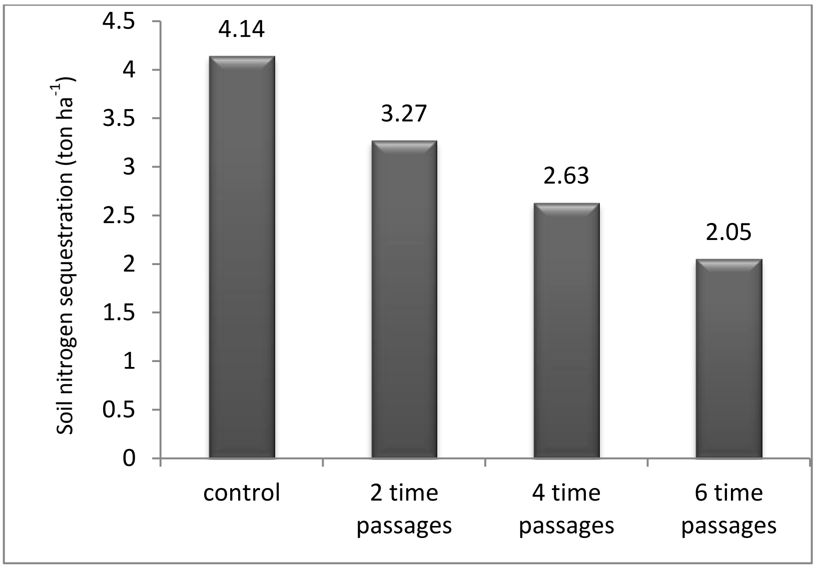

Figure 3 Effect of soil compaction on soil nitrogen sequestration

Golchin *et al.* (1994) stated that by the effects that soil compaction leaves on the formation of aggregates, the level of soil carbon is also affected. By reducing the access of enzymes to the materials within the soil aggregate, soil organic matter is physically maintained. Wright and Hans (2005) also concluded that agricultural land management practices increase carbon and nitrogen sequestration in the soil. Maximum storage of carbon and nitrogen exist in larger aggregates since improper tillage operation destroys larger soil aggregates thus it makes aggregates more susceptible to carbon and nitrogen mineralization. The results correspond with the findings of other researchers such as Tisdall and Oades, 1980; Hollender *et al.,* 2005. They expressed that intense and compressed tillage system reduced the aggregate stability and organic carbon and nitrogen that they are causes of the soil quality and long-term sustainability of agriculture. The primary reasons for changes in N availability in compacted soils are: decreased soil aeration resulting in increased denitrification, reduced N mineralization and decreased symbiotic N fixation; changes in soil water properties affecting N transport and leaching and; changes in soil structure altering root dynamics (Lipiec and Stepniewski, 1995). In addition, soil nitrate degradation in compacted soil and nitrogen losses to groundwater and the atmosphere in this soil more than non-compacted soil(Khalilian *et al.,*1991).Soil compaction through its effect on soil aggregates may have negative effect on soil organic carbon (Golchin, 1994).

3.2.2 Acidity

Soil acidity may be changed due to different management of lands (NRCS, 1998).The results of mean comparison showed that pH rate increased significantly in all levels with increasing compaction. Maximum (8.09) and minimum (7.93) amount of pH were obtained in treatment 4 and control treatment, respectively (Table 1). The increase of pH prevents of creating aggregate by increasing the critical concentration of coagulation and lead to collapse of minerals and release of cations. Increase in soil pH also causes aggregates degradation, swelling and dispersion of clay particles, crusting and reducing porosity and permeability (Landy, 1994). Horn and Franzluebbers (1996) and Dick (1983) reported soil pH increased by intensity of agricultural and tillage operation because of different processes such as mineralization organic matters, increasing nitrification and root exudation.

3.2.3 Electrical conductivity

The results of mean measured EC in different levels of compaction showed the lowest (0.58) and highest (0.83) rate of EC are belonging to control and 4 times to-and-fro treatments respectively (Table 1). Also the effect of treatment 3 (4 times to-and-fro) and treatment 4 (6 times to –and-fro) on soil EC was significant. Baker and Nie (1994) reported that increasing agricultural activity increases the electrical conductivity of the soil and with decreasing water absorption by the roots, reduces photosynthesis in plants and thereby affect the operation of the plant. Westcot and Ayers (1985) also concluded that salinity affects on available water for plant in soil and reduces its performance and thereby crop production and cultivation in many part of the world is a risk (Ekez and Yilmaz, 2003). Salinity also causes an imbalance of available nutrient in salinity soils and is limited plant growth (Qadir, 2004; Asgari *et al.*, 2013b). With increasing salinity, is reduced carbon accumulation, net assimilation rate and dry matter yield, the ratio of dry weight root to stem, leaf area, plant height and amount of perspiration (Bernard *et al.,* 2000). Shabanpour *et al.* (2011) concluded that in non-saline soils plant resist against highly soil compaction but with increasing salt and compaction, absorption rate of elements strongly reduced.

4 CONCLUSION

Recent advances in upgrading agricultural production in the field in an intense manner bring about unwelcome changes in ecology, sociology and economy. From the latter one might include soil erosion, soil salinity, soil quality and quantity deterioration, soil contamination with agricultural chemicals, depreciation of social structures, weakening the economic power of traditional societies and phenomena like these.

Soil compaction can also have a severe negative effect on agricultural crop production. In total, even low levels of soil compaction (the treatment of two passings heavy tractor) is able to remarkably alter soil physiochemical attributes and thus carbon and nitrogen sequestration in soil.in nitrogen and carbon sequestration levels are important for who concerned of global warming and climate change.

Intensified mineralization of organic carbon and wasting soil organic content and their related nutrients can be done through collapse of aggregates and degradation of soil organic storage, which are under protection of fine aggregates.

In present study, by increasing compaction, aggregate stability was reduced so that MWD reduced from 5.32 mm in control treatment to 3.88 mm in T_4 which in turn decreased soil organic content. Breaking the balance between the processes of humus formation and mineralization leads to reduction of available Nitrogen that its negative effects are considered on cation exchange capacity.

In this research, organic carbon and total soil nitrogen respectively were reduced from 1.36 and 0.12 in control treatment to 0.78 and 0.07 in T_4.Obviously, results of this study showed that the negative effects of soil compaction on soil physiochemical properties. Soil physical and chemical properties are negatively affected include: increasing EC and pH from 0.58 and 7.93 in control to 0.83 and 8.09 in T_4, respectively. Moreover, a significant reduction in saturated soil moisture percentage was observed (from 0.67 in control to 0.55 in T_4).

Since soil compaction, especially in the deeper layers is not easily resolved, prevention is the best way to tackle the problem. Regarding the inability of deactivating soil compaction adverse effects in the deep soil layers of agricultural fields is the best way of handling and preventing soil compaction. Using these sluggish renewable resources should be consistence with land capability and its physical nature. This type of land use will result in sustainable development. From the remarks given here, it might be concluded that revising agricultural regimes and production methods is inevitable. On this ground, revisiting current agricultural systems should be considered and an urgent demand for state of the methods consistent with environmental objectives is being felt.

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تأثیر فشردگی خاک بر ترسیب کربن و نیتروژن در خاک و برخی خصوصیات فیزیکی و شیمیایی خاک (مطالعه موردی: اراضی شمال آق قلا)

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چکیده فشردگی خاک به یک مشکل فراگیر در سطح دنیا تبدیل شده و یکی از عوامل مؤثر در تخریب اراضی به‌خصوص در اراضی کشاورزی مناطق خشک و نیمه خشک به‌شمار می‌رود. هدف از این تحقیق، بررسی تأثیر فشردگی خاک بر توان ترسیب کربن و نیتروژن در خاک و خصوصیات فیزیکی خاک (ثبات خاکدانه‌ها، رطوبت اشباع خاک، وزن مخصوص ظاهری و تخلخل) و خصوصیات شیمیایی (هدایت الکتریکی، pH، کربن آلی و نیتروژن) می‌باشد. این تحقیق در قالب طرح بلوک کامل تصادفی با ۴ تیمار و ۳ تکرار مورد بررسی قرار گرفت. تیمارهای این تحقیق شامل شاهد (بدون فشردگی مصنوعی)، تیمار ۲ (۲ بار عبور تراکتور سنگین)، تیمار ۳ (۴ بار عبور تراکتور سنگین) و تیمار ۴ (۶ بار عبور تراکتور سنگین) بود. در این راستا، پس از اندازه‌گیری خصوصیات مورد نظر، تجزیه و تحلیل آماری داده‌ها با استفاده از نرم‌افزار SPSS 16.0 انجام شد و برای مقایسه میانگین تیمارها نیز از آزمون LSD در سطح ۵ درصد استفاده گردید. نتایج نشان داد که سطوح مختلف فشردگی خاک باعث افزایش معنی‌دار جرم مخصوص ظاهری خاک گردید. نتایج هم‌چنین نشان داد که تمام تیمارهای فشردگی خاک باعث کاهش معنی‌دار ترسیب کربن و نیترون در خاک، پایداری‌خاکدانه‌ها و رطوبت اشباع خاک شد. از سوی دیگر میزان شوری و اسدیته خاک بر اثر تیمارهای فشردگی خاک افزایش یافت. نتایج نشان داد که سطوح مختلف فشردگی خاک، اثر معنی‌داری بر ویژگی‌های فیزیکی و شیمیایی خاک داشت. براساس نتایج به دست آمده ۶ بار عبورتراکتورهای سنگین (تیمار ۴) به‌طور معنی‌داری باعث کاهش تخلخل خاک و ثبات خاکدانه‌ها (به‌ترتیب از ۰/۴۵ درصد و۵/۳۲ میلی‌متر در تیمارشاهد به ۰/۲۵۵ درصد و ۳/۸۸ میلی‌متر) شد در حالی که به طور معنی‌داری جرم مخصوص ظاهری را در مقایسه با تیمارهای دیگر (از ۱/۴۵گرم بر سانتی‌مترمکعب در تیمارشاهد به ۱/۹۷گرم در سانتی‌متر مکعب) افزایش داد. تیمارهای ۴ و ۶ بار عبور تراکتور باعث کاهش معنی‌دار ترسیب کربن و نیتروژن خاک به ترتیب از ۳/۲۶ تن در هکتار و ۱۴۹/۶۲کیلوگرم بر هکتار (در تیمارشاهد) به ۱/۷۰ تن بر هکتار و ۴۸/۱۶کیلوگرم بر هکتار برای تیمار T_4 شد، اما به طور معنی‌داری باعث افزایش EC در مقایسه با سایر تیمارها شد (از ۰/۵۸دسی‌زیمنس بر متر در تیمارشاهد به ۰/۸۳دسی-زیمنس بر مترافزایش یافت). هم‌چنین تمام تیمارهای فشردگی باعث افزایش pH خاک به‌طور قابل توجهی شدند به عنوان مثال pH از ۷/۹۳ در تیمار شاهد به ۸/۰۹ در تیمار T_4 افزایش یافت در حالی که تیمار منجر به کاهش معنی‌داری در مقدار کربن آلی، ازت کل و رطوبت اشباع خاک شدند.

کلمات کلیدی: تخریب سرزمین، خصوصیات خاک، فشردگی مصنوعی