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Effect of Land Use Change on Distribution of Nutrient Elements and Carbohydrates Within Water-stable Aggregates of Two Cultivated Soils in Northern Iran

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Abstract: Forest and pastureland soils in highland of northern Iran are being seriously degraded and destructed due to extensive agricultural activities. These land use changes are usually accompanied by a decrease in concentration of soil organic carbon or nutrients and deterioration of soil structure in these regions. However, studies on concentration of nutrients and carbohydrates in the soil suggest that the location of these nutrients within aggregates of each size should be determined. This study was to evaluate the nutrient element and carbohydrate distribution within water-stable aggregates (WSA) of two natural ecosystems, virgin forest and pasture lands, under different land uses. In September 2006, soil samples were collected from depths of 0-20 cm in Typic Haploxerolls soils. The overall pattern indicated that mean weight diameter (MWD) and WSA were greater in the virgin pasture and forest soils compared with the adjacent cultivated (ex-forest and ex-pasture) soils and aggregates of >1.0 mm size were dominant in the virgin soils, whereas the cultivated soils comprised aggregates of the size =0.5 mm. Distribution of organic carbon, nitrogen, phosphorus and carbohydrates within the WSA showed preferential enrichment of these parameters in the macroaggregate fraction (4.75-1.0 mm) for the virgin soils and microaggregate fraction (>0.25 mm) for the exposed soils. Cultivation of virgin forest and virgin pasture decreased the concentration of carbohydrates by 23.6 and 20.6% respectively. Average distribution of total exchangeable bases within WSA showed that the cultivation of forest and pasture soils significantly led to reduce in these nutrient in the 4.75-2.0 mm fraction and increase in concentration of these exchangeable cations in <0.25 mm fraction. In general, results indicated that cultivation significantly led to 71% and 6% reductions in total exchangeable bases within the 4.75-2.0 and <0.25 mm aggregate fraction, respectively, for virgin soil. Since smaller aggregates are preferentially removed by erosion, this study emphasizes the need for sustainable soil management practices that they will minimize nutrient loss when forest or pastures lands are converted to cropland.

Key words: Aggregate stability · soil degradation · land use change · alborz mountains range

INTRODUCTION

Soil organic matter (SOM) is an important source of inorganic nutrients for plant production in natural and managed ecosystems. The conversion of forests and pasturelands into croplands known to deteriorate soil properties, especially reduce Soil Organic Carbon (SOC) and changes in distribution and stability of soil aggregates [1, 2]. Loss of SOC with cultivation is connected to the destruction of macroaggregates [3], as a result, soil becomes more susceptible to erosion since macroaggregates are disturbed [4]. Initial and rapid loss of nutrient and SOC decay occur mainly due to plant uptake and organic matter oxidation [1]. Soil carbohydrates, which represent from 5 to 25% of SOM [5], constitute a significant part of the labile pool of SOM and are most affected by land use changes [6, 7]. Due to the temporary biological stability of carbohydrates [8], their long-lasting role in improving soil physical properties may not be assumed in all soil conditions [9, 10] and large emphasis had been given to the action of polymeric carbohydrates in stabilizing soil structure [11, 12]. The effect of cultivation on the nutrient and microbial characteristics of soils are observed in the C and N-enriched small macroaggregate fractions (2.00-0.25 mm) [13, 14]. Dormaar [14] reported that SOM, polysaccharides, polyuronides and phenols were associated with the >0.25 mm water-stable aggregates (WSA). Christensen [15] observed that whereas the C/N, C/P and N/P ratios of water-stable macroaggregates

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were smaller than those of microaggregates, the microaggregates contained less SOM associated with silt plus clay than the macroaggregates. Mbagwu and Piccolo [16] with working on some north central Italian soils reported that, in terms of total contents, C, N and P are preferentially concentrated in the macroaggregates. They further noted a similarity in the dynamics of C and N in the amended and control plots, while P distribution is not uniform within the aggregated irrespective of the types of amendments added. Generally, most studies on physico-chemical properties [17-20] with respect to management practices concentrated on whole soil (<2 mm) analysis, while a proper understanding of nutrient dynamics requires an evaluation of the location of these nutrients within aggregates. On the other hands, the location gives an indication of their potential accessibility for microbial degradation and on their storage and loss by erosion when forest and pastureland are converted to cropland [21].

Rapid population growth in northern Iran requires additional farmlands for food production. One way to expand the cropland is clear cutting the forests and converting pasturelands to the croplands. This results in destruction of natural ecosystems and reduction of the current or future capacity of soil to produce. It can be because of erosion, decline in fertility, changes in aeration and moisture content, salinization or change in soil flora or fauna [22]. Apart from reports of reductions in soil aggregate stability and their relationship to SOM content, especially in tropical conditions, when land is cultivated after land use change, there is no detailed study in the northern Iran with sub humid condition on the dynamics of nutrient elements and carbohydrates and their distribution in different aggregate fractions. In addition, since different aggregate fractions are selectively removed during erosion; characterizations of these aggregates are needed in understanding nutrient dynamics during fertility erosion. Therefore, this paper reports on the distribution of C, N, P, exchangeable cations and carbohydrates within different WSA fractions of soils under different land use, i.e., virgin forest and pasture soils and ex-forest and ex-pasture soils in the Alborz mountains range of the northern Iran. We hypothesized that cultivation of virgin soils (ex-forest and ex-pasture) changes the distribution of materials and cations within aggregates of different diameters.

MATERIALS AND METHODS

Description of the study area: The study was conducted in the southeast Sari city, Mazandaran province; in the Alborz mountain range (35°15'-36°10' latitude and 53°35'-53°30' longitude) of the northern regions of Iran. The study area has about 1900 m of elevation above the sea level. It is a plateau lying east to west and covers about 3150 ha, with 1500 ha of forest, 800 ha of pasture and 600 ha of cropped land. The rest used for roads, rivers and residual areas. The prevailing climate of study area is a typical Mediterranean climate with the 'precipitation of 620 mm, temperature of 18°C, soil water regime of xeric and soil temperature regime of thermic. Most precipitation is during the winter and spring (November-May) and dominant soils in the study area are Typic Haploxerolls [23]. The physiographic units of the study area are dominantly as a hilly type and on average, the soil depth is 55 to 60 cm with a slope ranges from 10 to 15%. No salinity and drainage problems exists and carbonate calcium equivalent, electrical conductivity were 22% and 1.01 dS m^{-1}, respectively, while general slope aspect of soils was similar.

Concurrently, increasing population and the absence of new land for cultivation have transformed former virgin pastureland and forest (natural ecosystem) to rainfed land and cropped land, in fact, thereby increasing the intensity of cultivation. Dominant tree species in the forests are *Acer Persicum, A. Pojark, Pinus nigra, P. brutia* and, because the pasture has been overgrazed, plant cover ranges from 80% to 60%.. Dominant grass species could be mentioned as *Agropyrom intermedium (Host), P. Beauv, Hurdeum bulbosum L., Festuca ovina.* Most of virgin pasturelands and forest soils have been converted to rainfed wheat (*Triticum aestivum* L.) in 1988 and wheat grown each year since 1988. The Passes during tillage is considerable and stubbles were burned after harvesting in these regions. Some bulk soil physical and chemical properties of these two natural ecosystems i. e. virgin forest and pastureland are shown in Table 1.

Soil sampling: Soil samples were collected in September 2006, when the wheat crop has been harvested. The sampling design involved selection of five sites from each forest and pasture soils i.e. five virgin forests, pasture soils and five adjacent exposed soils. All of the sites located on the same physiographical units and the same slope aspect under each land use. These sites were either adjacent to one another or divided into a country roads, maximum distance separating the sites was 1100 m. Sixteen random soil samples were collected from 0-20 cm depth in each site with the aid of spade to maintain the soils, relatively, in their natural aggregates. These soil samples were air-dried for 1 week, pre-sieved with 4.75 mm sieve and then bulked into four composite samples per site (i.e.

Table 1: Main characteristics (means±SD) of bulk soil chemical and physical of two virgin soils that was collected on September 2006 from 0-20 cm

Soil[1]	Sand (%)	Silt(%)	Clay (%)	pH (1:1 H_2O)	OC[2]($g\ kg^{-1}$)	TN[3]($g\ kg^{-1}$)	Bulk density($gr\ cm^{-3}$)
Virgin forest	21.3±0.2	38.9±0.2	39.8±0.1	7.4±0.1	38.9±.2	3.62±0.2	1.28±0.1
Virgin pasture	20.6±0.3	40.8±0.2	38.6±0.2	7.7±0.1	41.2±0.4	3.81±0.1	1.21±0.1

[1]Values are means of triplicate soil samples (<2 mm); [2]Organic Carbon; [3]Total Nitrogen

two for virgin soil and two for exposed soils). These represent five replications for each land use type. This added up 10 soils composite samples for each land use (i.e. for virgin or exposed soil) and 40 soil samples for all land use investigated were sent to laboratory from the study area. Because the main objective of this study was to assess the changes in soil properties, results from surface perturbations samples were taken only at depth of 0-20 cm (the approximate plow layer).

Soil aggregate size fractionation and stability: In this procedure, 50 g of the < 4.75 mm aggregates were placed on the topmost of a nest of sieve of diameters 2.0, 1.0, 0.5 and 0.25 mm. The samples were left immersed in the water for 10 min and then sieved by moving the sieve 3 cm vertically 50 times during a period of 2.0 min. The mass resultant aggregates on each sieve were dried at 105°C for 24 hours, weighted and stored for analysis of carbohydrates, C, N, P and exchangeable cations. The percent water-stable aggregates (% WSA) on each of the following size ranges: 4.75-2.0, 2.0-1.0, 1.0-.05, 0.5-0.25 and <0.25 mm were then determined. Thus,

$$\%WSA = ((M_{a+s} - M_s)/(M_t - M_s)) \times 100$$

Where M_{a+s} is the mass of the resistant aggregates plus sand (g), M_s the mass of the sand fraction alone (g) and M_t the total mass of the sieved soil (g). The model of Van Bavel [24] as modified by Kemper and Rosenau [25] used to determine the mean weight diameter (MWD) of wet-stable aggregates. Thus,

$$MWD = \sum_{i=1}^{n} X_i W_i$$

where X_i is the mean diameter of each size fraction (mm) and W_i the proportion of the total mass in the corresponding size fraction after deducting the weight of stones (upon dispersion and passing through the same sieve) as indicated above. The higher values of MWD indicate the dominance of the less erodible and large aggregates of the soil [26].

Chemical properties: Soil composite samples that were obtained from resultant aggregates on each sieve or last pan in each site of land use types were analyzed for chemical properties. SOC was determined by the Walkley and Black [27] as modified by Allison [28] dichromate oxidation procedure. Total nitrogen (N) was determined with the Kjeldahl method [29], available phosphorus (P) was measured by the Olsen method [30]. The concentration of acid-hydrolysable in water-stable aggregates was determined using the phenol-sulphuric acid procedure [9]. The monosaccharide concentration in the hydrolysates was measured colorimetrically as glucose equivalents. All measurements were expressed as glucose concentration in gkg^{-1} of water-stable aggregates. Exchangeable bases were determined by ammonium acetate replacement procedure as described by Thomas [31] and Ca, Mg, K and Na were measured [32].

Statistical analysis: Each soil physical and chemical properties in composite samples for each site of different land use types were averaged at 0-20 cm depth to perform statistical analysis. Analysis of variance was performed using SAS software. Means were compared by least significant difference (LSD) at $P < 0.05$ or $P<0.01$ level.

RESULTS AND DISCUSSION

Aggregate size distribution and stability: In Table 2, the distribution and stability of WSA shows that in ex-forest and ex-pasture soils, the macroaggregates fractions (>0.25 mm) decreased significantly with cultivation. In the virgin forest and pasture soils, most soils were found in 0.25-4.75 mm size macroaggregates and to a lesser extent in microaggregates (<0.25 mm). In the virgin forest soils, cultivation decreased the WSA proportion of 4.75-2.0 mm fraction in depth 0-20 cm by 5 times, while the decrease was 1.3 times for 2.0-1.0 mm aggregate fraction. The effect of cultivation on pasture soils followed the pattern observed with forest soils; showing 4.5 times deceases for 4.75-2.00 mm fraction and 1.9 times decease for 2.0-1.0 mm fraction.

However, in the ex-forest and ex-pasture soils, a significantly large proportion of the soil was retained as microaggregate and small macroaggregates (<0.5 mm). Since small aggregates size (<1.2 mm) was found to be a useful indicator of soil degradation [32], tillage in the virgin soils of two natural ecosystems disintegrated the

Table 2: Aggregate size distribution (%WSA) and stability (MWD[1]) (means±SD) of soils of two virgin forest and pasture soils and their adjacent ex-forest and ex-pasture soils

	Aggregate sizes (mm)^A					
Ecosystems	4.75-2.00	2.00-1.00	1.00-0.50	0.50-0.25	< 0.25	MWD (mm)^B
Virgin forest	28.2±4.4a	20.7±2.2 a	14.8±2.4 b	19.2±2.4 a	17.1±2.3b	3.62±0.1A
Ex-forest	5.7±1.2c	15.8±1.8b	16.2±3.2b	32.2±2.4 a	30.1±3.1a	2.20±0.1B
Virgin pasture	23.4±1.2a	23.9±1.1a	22.2±2.4a	20.4±0.8ab	10.1±2.9b	3.55±0.1A
Ex-pasture	5.2±2.1d	12.5±2.4c	10.2±3.1c	33.9±2.8b	38.2±3.2a	2.13±0.1C

[1]Mean weight diameter, ^{A} Within each row, data (aggregate sizes) followed by different letters, differ significantly ($p<0.05$), ^{B}Within the column, data (MWD) followed by different letters, differ significantly ($p<0.05$)

Table 3: Distribution of carbohydrates (gkg^{-1}) (means±S.D.) in aggregates size fractions of two virgin forest and pasture soils and their adjacent ex-forest and ex-pasture soils

	Aggregate sizes (mm)^A					
Ecosystems	4.75-2.00	2.00-1.00	1.00-0.50	0.50-0.25	< 0.25	Bulk soil^B
Virgin forest	11.3±0.2a	8.43±0.4ab	8.7±0.6ab	7.84±0.7ab	4.07±0.3c	40.34±0.7A
Ex-forest	4.6±1.1b	5.8±0.8b	6.2±0.6b	5.20±0.5b	10.80±0.3a	32.60±0.6C
Virgin pasture	13.2±1.7a	11.3±1.1a	8.1±0.3b	7.80±0.2b	6.20±0.3c	46.60±0.3A
Ex-pasture	7.2±0.3b	5.1±0.5b	6.4±0.4b	6.90±0.3b	13.10±1.1a	38.70±0.5B

^{A}Values with different letters in rows indicate significant differences ($p<0.05$), ^{B}Values (<2 mm) with different letters in column indicate significant differences ($p<0.05$)

large aggregates into smaller aggregates, resulting in higher proportion of small aggregates (<0.25 mm) in this soils. This could be attributed to the breakdown of aggregates by tillage, differences between the four-land use types in annual organic matter input that gives cementing agents and the enmeshing effects of roots and associated micro and macro organisms.

In addition, these results could be related to the former larger amount of living and decaying plant roots, fungal hyphae and especially costs of earthworms and termites that would have been rapidly destroyed by tillage. These results confirm earlier observations that macroaggregates are dynamic in nature the size distribution of macroaggregates being affected by the change in land use and management in tropical conditions [7, 34-36]. A greater shift in water stable aggregates from large macroaggregates with cultivation also induced significant reduction in MWD. The MWD values indicated that cultivation reduced the aggregate stability of soils of the virgin forest area by 1.6 times, whereas tillage operation led to 3.14 reductions in the stability of soils of virgin pastureland area (Table 2). The greater reduction of MWD values observed with soils of virgin pastureland over soils of virgin forest area could be attributed to dominance of grasses that were rapidly removed from surface larger after cultivation. The reduction in the proportion in the macroaggregate fraction (>0.25 mm) following cultivation was also reported by other workers, however, this trend of changes could be appeared in both tropic and sub humid conditions, but in greater extent in tropical condition after short-term cultivation of virgin soils [7, 37, 38]. findings of Haynes [37 in virgin pasture soil and Spaccini *et al.* [7] in virgin forest soil, the >2 and 1-2 mm aggregate fractions compared with cultivated ones were 13 and 4 times, respectively.

Carbohydrate distribution in the WSA: Soils under cultivation had lower carbohydrates content than the adjacent virgin soils under forests and pastureland in whole <2 mm soil samples (Table 3). Cultivation caused 23.6 and 20.6% decreases in total carbohydrates concentration for virgin forest and pasture soils, respectively. The results of carbohydrates distribution within the WSA for two natural ecosystem (Table 3) shows that soil carbohydrates concentration decreased with decreasing water-stable aggregates sizes, while cultivation produced an increase of carbohydrates concentration with decreasing WSA sizes.

Also results indicated a poor correlation (R^2=0.52) between carbohydrates concentration and aggregate stability (MWD) that supports other findings in tropical

Table 4: Carbon (C), nitrogen (N) and available phosphorus (P) content (g kg^{-1} aggregate) (means±S.D.) in aggregate sizes of two virgin forest and pasture soils and their adjacent ex-forest and ex-pasture soils

	Virgin forest			Ex-forest		
Aggregate sizes (mm)	C	N	P	C	N	P
4.75-2.00	47.1±1.2a	4.6±0.4a	43.1±2.1a	22.1±1.2b	2.5±0.4a	19.3±10.1a
2.00-1.00	42.3±4.1a	3.8±1.7a	30.2±9.1a	20.2±1.5b	2.4±1.1a	18.2±3.1a
1.00-0.50	40.9±14.2a	3.6±0.4a	22.8±2.1a	19.8±1.4b	2.3±0.8a	17.2±11.2a
0.50-0.25	36.3±3.5a	3.6±0.9a	22.8±3.1a	24.2±2.3ab	2.8±0.4a	31.3±9.2a
<0.25	28.7±6.1a	2.8±1.1a	21.4±2.1a	39.2±2.1a	3.6±1.2a	34.3±3.5a
	Virgin pasture			Ex-pasture		
	C	N	P	C	N	P
4.75-2.00	51.2±14.1a	5.2±1.1a	45.1±9.2a	20.1±2.3c	2.46±0.3c	18.2±2.1c
2.00-1.00	36.6±5.2a	3.4±0.7a	32.3±14.1a	21±1.5bc	2.5±0.4c	15.3±1.7c
1.00-0.50	39.1±3.4a	3.4±0.9a	28.8±3.4a	19.2±1.7c	2.3±0.3c	15.3±1.2c
0.50-0.25	37.7±6.4a	3.9±1.1a	23.1±4.2a	28.2±2.1b	3.23±0.1b	29.2±0.9b
<0.25	33.3±12.2a	3.3±1.8a	20.4±11.2a	38.1±2.7a	4.06±1.1a	32.3±2.4a

Mean within a columns that have the same letters are not significant at ($p<0.05$)

conditions suggesting that polysaccharides can not be always considered as persistent structural stabilizers because of their rapid degradation by microbial activities [8, 26, 39]. In ex-forest and ex-pasture with lower physical quality, a general and significant increase in carbohydrates was found in microaggregates (<0.25 mm). in this aggregates size fractions the presence of a high concentration of humified organic matter controls the biological stabilization of carbohydrates in that they may become protected from microbial degradation by incorporation into the less polar domain of stable organic matter such as humic substances [39]. But the high aggregate stability of the virgin forest and pasture soils because of favorable condition provided a relatively high carbohydrates concentration in larger aggregate size (>0.25 mm), where the products deriving from initial decomposition of plant residues in both natural ecosystem tend to accommodate [6].

Carbon, nitrogen and phosphorus concentration of aggregate fractions: Data on SOC, Nitrogen (N) and available phosphorus (P) content (gkg^{-1}aggregate) of the different aggregates size fractions are reported in Table 4. In the soils under virgin forest and pastureland, none of the parameters shows significant differences among size fractions. In contrast, SOC and nitrogen concentration, in the ex-forest and ex-pasture soils in both natural ecosystems, were significantly different among the different size fractions and appeared to decrease as sizes increased from 0.25 to 4.75 mm diameter (Table 4). The SOC, N and P concentrations associated with each macroaggregate size in the two virgin soils, were two-to-three-fold higher than the corresponding values in the cultivated soil, although the differences generally were not statistically significant. The aggregate fraction >4.75 mm had least value of SOC in the two cultivated soils. This could be attributed partly to the redistribution and/or transfer of SOC from the large aggregates to smaller ones either in the process of biodegradation or by mechanical disruption of the large macroaggregates [14, 15, 36].

While data from exposed soils revealed an increase of available P with decreasing aggregate sizes (Table 4) the available P distribution within the WSA for the virgin forest and pasture soils followed the trend observed with SOC and N. This trend shows significant increase ($p<0.05$) in distribution of available P in smaller aggregate with cultivation. The distribution pattern of P showing preferential enrichment of the smaller aggregates than the larger aggregates in both two ex-forest and ex-pasture soil, contradicts the observation of Adesodun *et al.* [38], Mbagwu and Piccolo [16]. Cultivation in this study indicated higher accumulation of C, N and P in the WSA of the both virgin soils. This could be attributed to this fact that cultivation leads to exposure of more surface area to microbial attack, oxidation, burning effect of temperature and preferential removal of the smaller aggregates by erosion.

The relationship between WSA, SOC, N and P concentrations was not significant, suggesting that other factors such as inorganic soil constituents [40], the

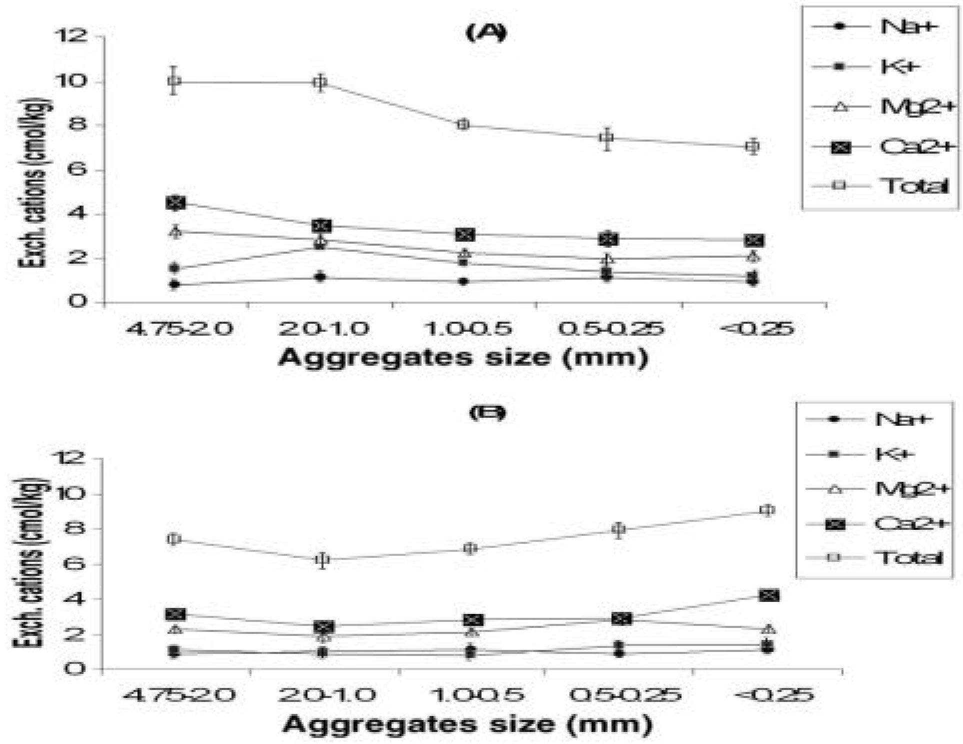

Fig. 1: Exchangeable cations distribution in water-stable aggregates (WSA) of the forest soils. (A) Virgin forest; (B) Ex-forest; I in figure indicates theerror bar

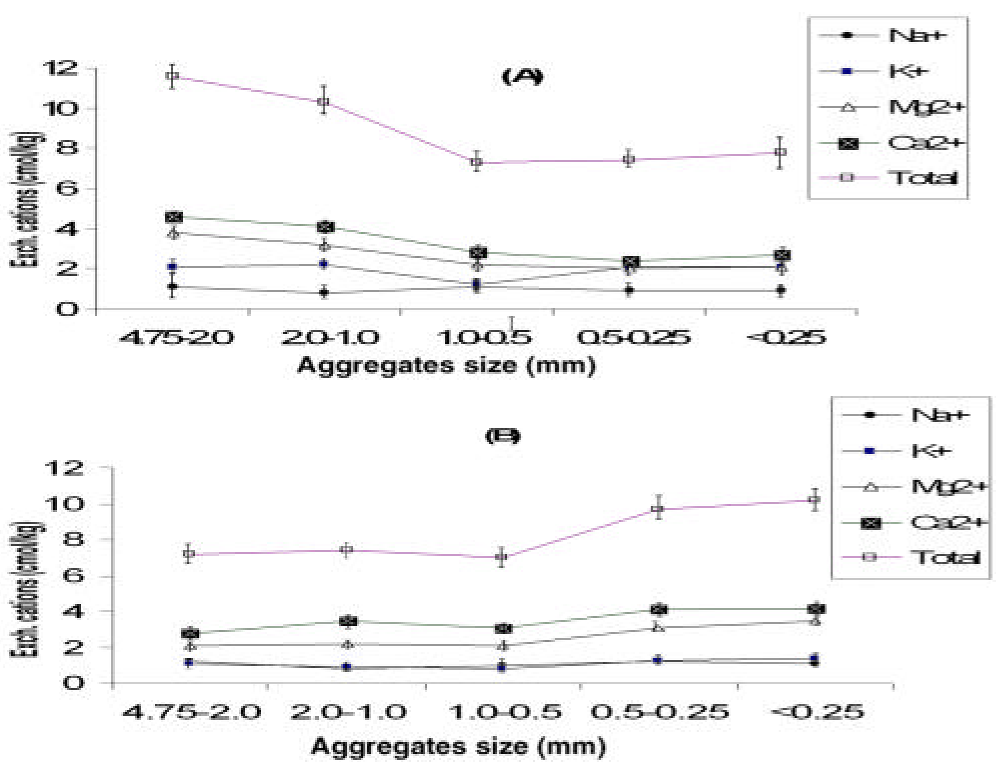

Fig. 2: Exchangeable cations distribution in water-stable aggregates (WSA) of the pasture soils. (A) Virgin pasture; (B) Ex-pasture; I in figure indicates the error bar

arrangement of the organic compound other than the absolute organic matter quality [14], might have participated in the binding of the soil particles into WSA and the relative importance of each varies in differing situations [37].

Distribution of exchangeable cations in the WSA: Figure 1 and 2 show the results of exchangeable cations distribution such as Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} within WSA for two natural ecosystems after cultivation. Cultivation of these two virgin soils generally led to reduction in the concentration of the total exchangeable cations such as Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} in the macroaggregate fractions (0.25 to 4.75 mm) and increase in concentration of these cations in the <0.25 mm fraction.

In virgin forest soils (Fig. 1), the concentration of Ca^{2+}, for example, ranged from 4.4 cmol kg^{-1} for the macroaggregate fraction (4.75-2.00 mm) to 2.7 cmol kg^{-1} for the microaggregate fraction (<0.25 mm). The range for virgin pastureland soils (Fig. 2) was 4.6 cmol kg^{-1} (4.75-2.00 mm fraction) to 3.1 cmol kg^{-1} for the microaggregate fraction. As a result, the effect of cultivation on virgin pastureland soils followed approximately the pattern observed with virgin forest soils. The observed differences in the Ca^{2+} and Mg^{2+} concentrations, that coagulate particles of clay, in macroaggregates and microaggregates fraction, for both virgin and cultivated forest and pastureland, were significant ($p<0.05$), expert 6.2 cmol kg^{-1} (virgin forest) and 5.4 cmol kg^{-1} (ex-pasture) that were similar.

The general trend showed that in virgin soils in both natural ecosystem, the 4.75-2.00 mm fraction and microaggregates (<0.25 mm) were preferentially enriched with total exchangeable bases (as Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}), whereas cultivation led to redistribution of these nutrient element showing increases in the concentration of the elements of the elements with decreases in aggregate sizes. Results also indicated that divalent cations (Ca^{2+} and Mg^{2+}) were higher in macroaggregate fractions than monovalent cations are more tightly held at the exchange complexes with macroaggregates than the monovalent cations [21]. Researchers in the literature [17, 19] reported the effect of soil chemical properties with respect to management practices concentrated on whole soil (i.e. <2.00 pre-sieved soil) but this study characterized the nutrient distribution within both macroaggregates (>0.25 mm) and microaggregates (<0.25 mm) fractions. Hence, the data in section 3 support the hypothesis that cultivation of virgin soils (ex-forest and ex-pasture) changes the distribution of materials and cations within aggregates of different diameters.

CONCLUSION

The degradation of the highland soils with the restricted depth by cultivation seriously impaired soil properties and especially result in reduction of the proportion water-stable macroaggregates and overall aggregates stability and an increase in the proportion of microaggregates. According to the statistical analysis, there was a significant difference in distribution of nutrient elements and carbohydrate in two forest and pasture soils. The effect of cultivation on amount of macroaggregates was most evident in the >1 mm size aggregates. In virgin soils, more structurally stable soil carbohydrates, elemental C, N and P were more evenly distributed in the size-aggregates, whereas they preferentially accumulated into the macroaggregates (>0.25 mm) and in ex-forest and ex-pasture soil in the <0.25 mm fractions. When carbohydrates are stored in the microaggregate fractions they are protected from microbial degradation as a result of physical and chemical (such as hydrophobic interaction) processes. As a results, cultivation induced redistribution of OC, N, available phosphorus and other nutrient element (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) to the smaller aggregates. Since smaller particles or aggregates are preferentially removed by erosion and reinstate the degraded lands in the study region of the northern Iran.

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