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THE ROLE OF PARENT MATERIAL ON SOIL PROPERTIES IN SLOPING AREAS UNDER TEA PLANTATION IN LAHIJAN, IRAN

Shiva BAKHSHANDEH[1*], Mehdi NOROUZI[2], Saber HEIDARI[3] & Shirin BAKHSHANDEH[4]

[1]*Department of Soil Science, College of Agriculture, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran*

[2]*Department of Soil Science, Faculty of Agriculture, University of Guilan, Rasht, Iran*

[3]*Department of Soil Science, Faculty of Agriculture, University of Tabriz, Tabriz, Iran*

[4]*Department of Agronomy, College of Agriculture, Islamic Azad University, Fasa, Iran*

[*] *Correspondence author; E-mail: sh.bakhshandeh@hotmail.com*

Abstract: Slope and parent materials play critical roles in determining the soil erosion level. In this study the effects of slope position and parent material on soil properties of tea gardens were investigated in Lahijan, Guilan province, Iran. Four profiles on two different parent material based sites (i.e. granite and phyllite) were selected. Soils were classified as Typic Udorthents, Typic Dystrudepts, Inceptic Hapludalfs and Ultic Hapludalfs, respectively. Results showed that parent material had a significant effect on thickness of the solum and properties such as sand, clay, soil moisture percentage, pH, CEC, total exchangeable bases and base saturation values and the effect of slope position on properties such as electrical conductivity, organic carbone, phosphorous and total nitrogen was noticeable. Soil micromorphology results showed that quartz lithorelicts (rock fragments) and various Fe/Mn oxide nodules were abundant in all soil thin sections derived from granite parent material. The accumulation of illuvial clay as clay coatings and infillings inside the voids was major micromorphological evidence in soils derived from phyllite parent material. Soil development in those derived from phyllite parent material was higher than soils derived from granite parent material. Generally, it seems that parent material had greater effect on properties of soils and soil development than slope position.

Keywords: Granite, Phyllite, Slope position, Soil micromorphology

1. INTRODUCTION

Water is a key factor in the most parts of Iran that limits distribution and abundance of vegetation. Lahijan region in Guilan Province is one of the regions that the abundance of precipitation and relative air humidity creates favourable conditions for non-irrigation agriculture. The main product of this region is tea which is mainly planted in the hill slopes (Khormali et al., 2007). Sloping area in Lahijan used to be covered by forest, but nowadays natural forest covers are removed for gaining more cultivation area such as tea (Darvishi Foshtomi et al., 2011).

The spatial variation of soil properties is significantly influenced by some environmental factors such as climate, topography, parent materials, vegetation, and disturbance due to human activity (Chen et al., 1997). Slope and parent materials are important factors in soil erosion. Severe erosion cases occur most frequently in moderate resistance parent material and slope of >30% (Mohammadkhan et al., 2011). This trend indicates that soil erosion is affected by both slope and parent materials (Mohammadkhan et al., 2011).

The soil may exhibit a sharp interface when developed on hard rocks but this is not guaranteed as a general trend. The transition between the C horizon and the saprock or the saprolite may be progressive suggesting that soil formation and weathering are a single phenomenon (Velde & Meunier, 2008). Soil parent material, regardless of its state of weathering or consolidation, is the material responsible for forming soil (Lacoste et al., 2011). Parent materials affect different soil characteristics such as texture, water holding capacity, acidity, weathering, etc. (Gökbulak & Özcan, 2008).

Granite is a common type of intrusive, felsic, igneous rock which is granular and phaneritic in texture. This rock consists mainly of quartz, mica, and feldspar (Karimpoor, 2008). Granite is nearly always massive (lacking internal structures), hard and tough, and therefore it has gained widespread use as a construction stone (Karimpoor, 2008). The average density of granite is between 2.65 and 2.75 g.cm^{-3} (Karimpoor, 2008). Granite with large phenocrysts necessarily weather into larger mineral fragments comparing to Schist composed of small mineral grains (Schaetzl & Anderson, 2005). Olowolafe (2002) reported that the deficiencies in soils with granite parent material are more constraints to agricultural land use. Soils derived from granite estimated as 25% of the Lahijan region, northern Iran (Ramezanpour & Pourmasoumi, 2012). Pourmasoumi and Ramezanpour (2012) stated that higher depth of soil under andesitic basalt in comparison to granite was the morphological evidence of intense weathering effects of humid condition in Lahijan site for different minerals.

Marshak (2012) reported that phyllite (foliated metamorphic rock created from slate that is further metamorphosed so that very fine grained white mica achieves a preferred orientation) is primarily composed of quartz, sericite mica, and chlorite. Phyllite has fine-grained mica flakes in a preferred orientation, whereas slate has extremely fine clay flakes that achieve a preferred orientation, and schist has large mica flakes in a preferred orientation. Among foliated metamorphic rocks, it represents a gradation in the degree of metamorphism between slate and schist.

Despite of the geological diversity in north of Iran, especially Lahijan site, less information have been found in the bibliographic search. Some researches were conducted on the effect of different parent materials on soil characteristics in forest areas of Lahijan (Ramezanpour & Pourmasoumi 2012, Pourmasoumi & Ramezanpour (2012) and Ramezanpour et al., (2008)). Here we studied the effect of parent material and slope position on morphological, physical, chemical and micromorphological soil properties under tea plantation in Lahijan are north of Iran.

2. MATERIAL AND METHOD

2.1. Field Description

This study was conducted in Guilan province in north of Iran, as a part of Gorgan-Rasht tectonic zone. Because of its location in rainy forest and dense topography the geology of the area is still poorly known. Geologically, the region is composed of Quaternary Caspian deposits and mainly of Jurassic and Cretaceous volcanic rocks (Anells et al., 1975). The major geological formations of study are composed of Cretaceous basaltic rocks, Triassic granite rocks and Carboniferous metamorphic phyllitic and schistic rocks (Darvishzadeh, 1991).

The study area is located between 37° 5´ to 37° 15´ northern latitude and 50° 0´ to 50° 10´ eastern longitude (Fig. 1). After interpretation of aerial photographs and output results obtain from DEM/GIS, twelve profiles were dug. We selected four representative soil profiles (Profile 1 located in upper slope in granite parent material, Profile 2 located in lower slope in granite parent material, Profile 3 located in upper slope in phyllite parent material, and Profile 4 located in lower slope in Phyllite parent material) (Table 1).

The study area was a mountain physiographic unit and was cultivated by tea (*Camellia sinensis*). The average annual precipitation and temperature of the region are 1312 mm and 16.5°C, respectively. Annual air humidity and annual evaporation rate are 77.41% and 884mm (estimation of potential evapotranspiration by Penman-Monteith method and CROPWAT software) respectively. Climatic data is reported from Rasht synoptic weather forecasting data station (Fig. 2) and Lahijan climatology center. The soil moisture and temperature regimes are udic and thermic respectively. Soils were described and classified according to Soil Taxonomy system (USDA, Soil Survey Staff, 2010) and WRB (IUSS, 2006). Profile 1 classified as Typic Udorthents and Regosols, profile 2 classified as Typic Dystrudepts and Cambisols, profile 3 classified as Inceptic hapludalfs and Luvisols, profile 4 classified as Ultic Hapludalfs and Luvisols. Abbreviated morphological properties of horizons for the selected profiles are presented in table 2.

Table 1. Environmental information and classification of the eight soil profiles

Profile number	Parent material	Slope position	Slope (%)	Solum thickness (cm)	Soil classification	
					WRB systems [a]	Soil taxonomy [b]
1	Granite	Upper slope	26	28	Regosols	Typic Udorthents
2	Granite	Lower slope	12	96	Cambisols	Typic Dystrudepts
3	Phyllite	Upper slope	28	58	Luvisols	Inceptic Hapludalfs
4	Phyllite	Lower slope	15	85	Luvisols	Ultic Hapludalfs

[a] IUSS Working Group WRB (2006), [b] Soil Survey Division Staff (2010) classified in Sub-group level.

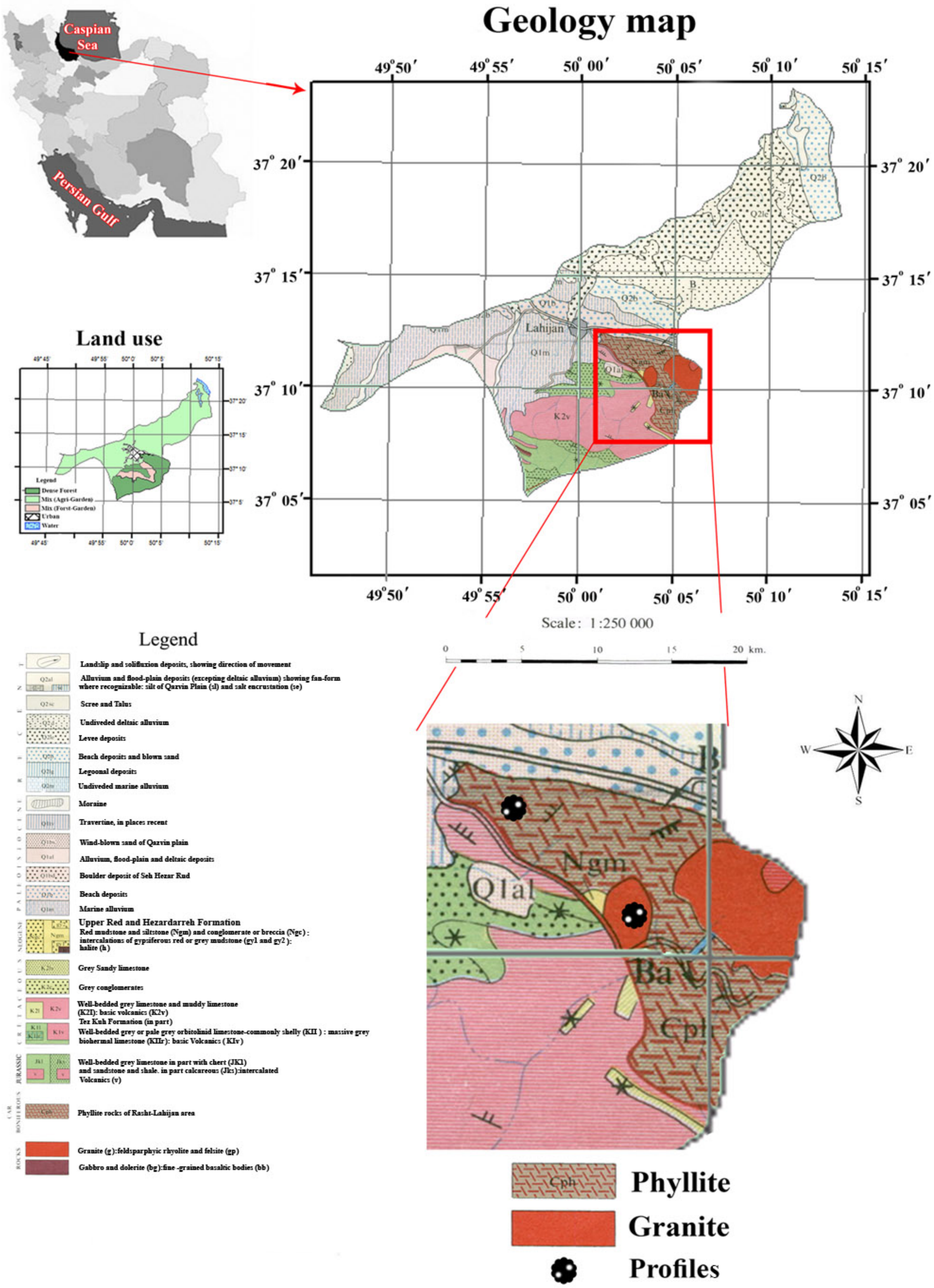

Figure 1: Study area in Lahijan, north of Iran

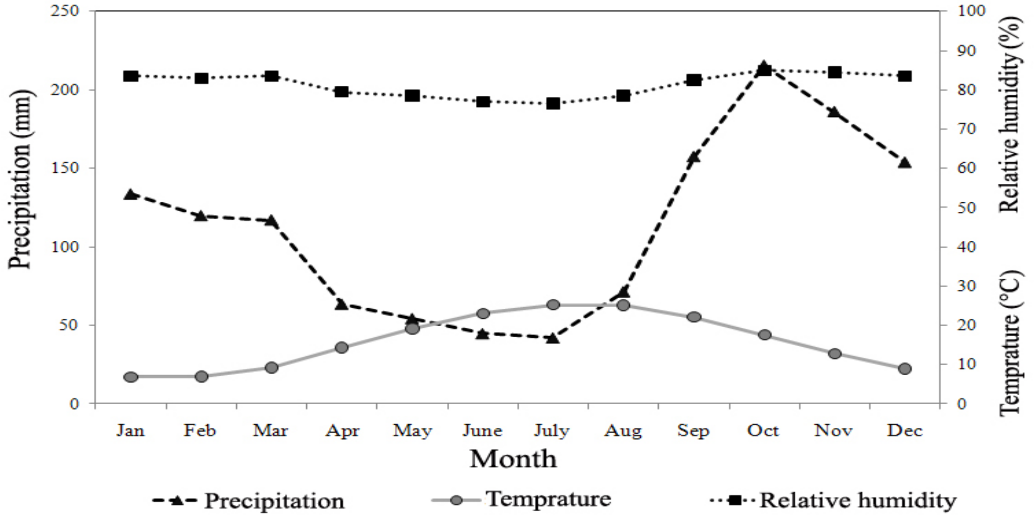

Figure 2. The meteorological information of study area (Climatic data from 1975–2005 were derived from Rasht synoptic station

Table 2. Abbreviated morphological properties of horizons for the selected profiles

Horizon	Depth (cm)	Color (Moist)	Boundary [a]	Texture [b]	Structure [c]	Consistence [d]		Clay film [e]
						Moist	wet	
Profile 1, Granite parent material, upper slope								
Ap	0-8	10YR 5/3	AW	SL	1fgr - 1fsbk	fr	ss/ps	-
BC	8-28	7.5YR 5/6	CS	SL	1fsbk	fi	ss/ps	-
C	28-70	7.5YR 6/6	-	SL	m	fi	so/po	-
Profile 2, Granite parent material, lower slope								
Ap	0-18	10YR 4/6	CW	SCL	1fgr	fr	ss/ps	-
AB	18-44	10YR 5/6	CS	L	1fabk	fi-fr	ss/ps	-
BC	44-96	7.5YR 5/6	GW	SCL	m	fi	ss/ps	-
Cr1	96-138	7.5YR 5/6	GW	SCL	m	fi	ss/po	-
Cr2	138-150	7.5YR 6/6	-	SCL	m	vfi	so/po	-
Profile 3, Phyllite parent material, upper slope								
Ap	0-12	10YR 5/3	CW	C	1mgr	fr	ss/ps	-
AB	12-24	7.5YR 4/5	AS	CL	2mabk	fi	ss/ps	-
Bt	24-58	7.5YR 4/6	GS	C	2mabk-sbk	fi	s/p	1mk
C	58-150	7.5YR 5/4	-	C	m	fi-vfi	s/ps	-
Profile 4, Phyllite parent material, lower slope								
Ap	0-16	10YR 4/3	CW	C	2fgr	fr	ss/ps	-
ABt	16-22	10YR 4/4	GW	C	1f-msbk-1fgr	fr-fi	s/p	-
Bt1	22-42	10YR 4/5	GW	C	2msbk-abk	fi	s/p	1mk
Bt2	42-70	10YR 4/6	GW	C	2mabk-sbk	fi	vs/ vp	2mk
Bt3	70-85	10YR 4/6	GS	C	2cabk-sbk	fi	s/p	2mk
C	85-150	10YR 5/4	-	C	m	fi	ss/ps	-

[a] A - abrupt, C - clear, G - gradual; S - smooth, W - wavy; [b] C- clay, SL- sandy loam, SCL- sandy clay loam, CL- clay loam; [c] 1 - weak, 2 - moderate; f - fine, m - medium, c- coarse, gr - granular, abk - angular blocky, sbk – sub-angular blocky, m- massive; [d] fr - friable, fi - firm; so- not sticky, ss - slightly sticky, s - sticky, vs- very sticky, po- not plastic, ps - slightly plastic, p - plastic, vp- very plastic; [e] 1- few, 2- common, mk- moderately thick.

2.2. Laboratory analysis

Soil morphological characteristics were described based on the field book for describing and sampling soils (Schoeneberger et al., 2012). Soil samples were collected from each horizon of the profiles for physical and chemical analyses. Soil color was measured according to Munsell soil color charts. After removing large stones, the soil samples were air-dried and passed through a 2 mm (10 mesh) sieve. Particle size distribution was determined by the hydrometer method (Gee & Or, 2002). The masses of sand and clay fractions were used to calculate the sand to clay (SC) ratio. Soil pH was measured in deionized water and 0.01 M $CaCl_2$ in 1:1 and 1:2 soil: solution (Thomas, 1996). Electrical conductivity (EC) was determined in a saturation extract of soil using conductivity meter (Rhoades, 1996). Organic carbone (OC) was determinate according to the Walkley–Black wet oxidation method (Nelson & Sommers, 1996). Available phosphorus by Olsen method (Kuo, 1996) and total nitrogen by Kjeldahl method (Bremner, 1996) were determined. Cation exchange capacity (CEC) was determined by saturation with 1 M ammonium acetate (NH_4OAc) at pH=7.0 (Sumner & Miller, 1996). Total exchangeable base (TEB) was obtained from sum of potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na) cations. These cations were extracted using 1M NH_4OAc (pH=7.0) and were determined by atomic absorption and flame emission spectrometer (Suarez, 1996; Helmke & Sparks, 1996). Base saturation is defined as the percentage of the soil exchange sites (CEC) occupied by basic cations such as Ca, Mg, Na and K.

2.3. Thin sections preparation

For micromorphological studies, undisturbed soil blocks were taken from the horizons from selected profiles. The thin sections were prepared from air-dried undisturbed and oriented clods using standard techniques described by Murphy (1986) then examined under a polarized microscope and described according to the terminology of Bullock et al., (1985). Thin section micrographs of soils were investigated using both plane polarized light (PPL) and cross polarized light (XPL).

3. RESULTS

3.1. Soil texture

Results showed that sand content of soils derived from granite parent material (profiles 1 and 2) were higher in comparison to soils derived from phyllite parent material (Fig. 3a).

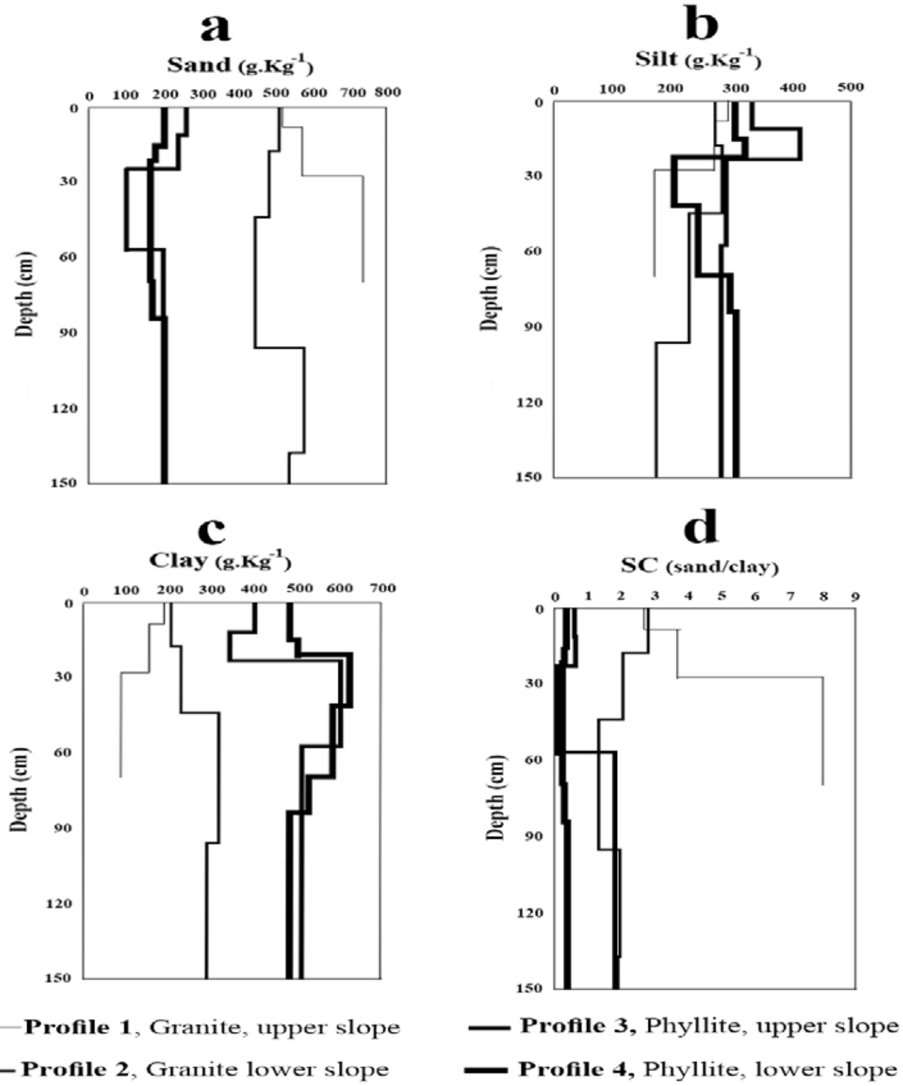

Figure 3. Changes of soil particle size distribution on studied profiles. a- changes of sand, b- changes of silt, c- changes of clay and d- changes of SC (sand/clay) ratio

Furthermore, sand content in surface horizons of upper slope was higher in comparison to lower slope especially in soils derived from granite parent material (Fig. 3a). The content of silt ranged from 200 to 400g.Kg^{-1}. Silt content in sub horizon of soils derived from granite parent material was lower in comparison to soils derived from phyllite parent material (Fig. 3b). The content of clay in soils derived from phyllite parent material was higher from soils derived from granite (Fig. 3c). Maximum content of clay observed in Bt soil horizons derived from phyllite parent materials (Fig. 3c). The SC ratio was higher in upper slope soil derived granite parent material and increased with increasing depth (Fig. 3d).

3.2. Soil moisture and bulk density

Soil moisture percentage (SP) in soils derived from phyllite parent material was higher than soils derived from granite (Fig. 4a). The values of bulk density in surface horizons was low (ranged from 1.2 to 1.3), but maximum values of BD was in Bt horizons of soils derived from phyllite parent material in lower slope (Fig. 4b).

3.3. Soil pH and EC

Results showed that changes of pH in deionized water and 0.01 M $CaCl_2$ in 1:1 and 1:2 soil: solution ratios had the same trend (Figs. 5a and 5b). The values of pH in upper slope and soils derived from phyllite parent material were higher than lower slope and soils derived from granite parent material (Figs 5a and 5b). The EC of depth soil is low, but in surface soil, it shows significant changes. A sequence of decreasing EC values in surface soil as profile 2 > profile 1 > profile 4 > profile 3 can be generalized (Fig. 5c).

3.4. Organic carbone, total nitrogen and phosphorous

The distribution of OC and N in the four different profiles is illustrated in figyres 6a and 6b. The contents of OC and N show the same trend as change of OC and N in sub horizons were very low (Figs 6a and 6b).The contents of OC and N have decreased with depth and maximum and minimum contents of OC and N observed in profile 4 and 1, respectively (Figs. 6a and 6b). In all profiles, the available P content is generally greater in depth than at the surface soil. Maximum and minimum content of available P observed in lower and upper slopes soils derived from phyllite parent materials (Fig. 6c).

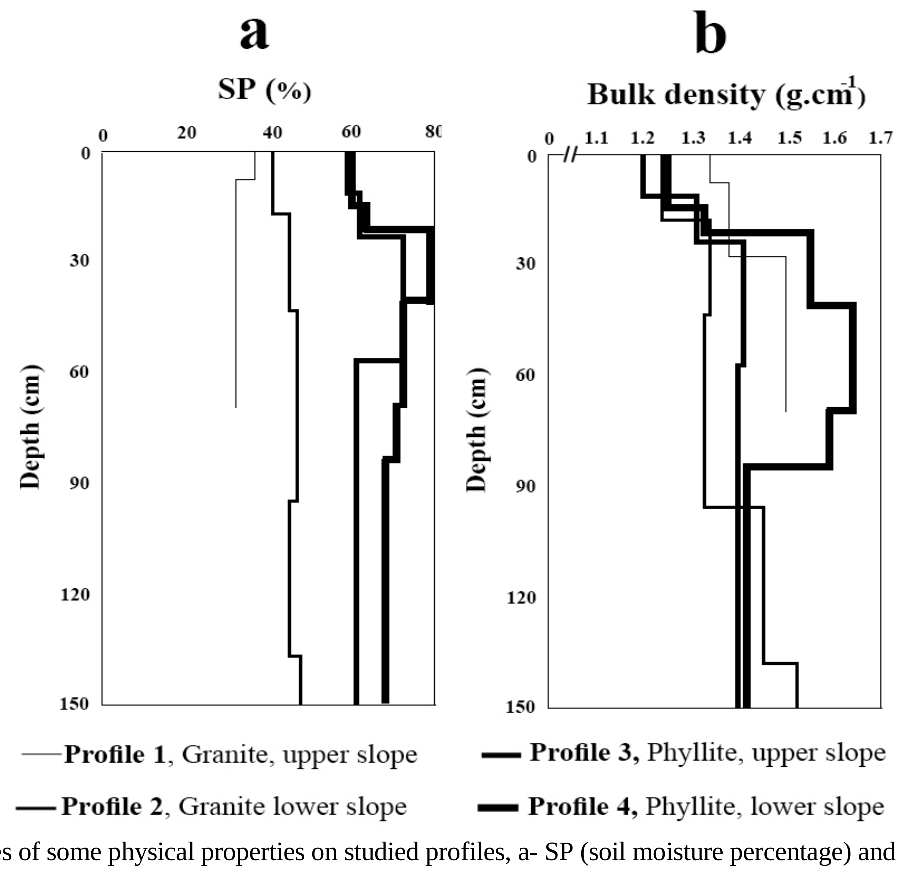

Figure 4. Changes of some physical properties on studied profiles, a- SP (soil moisture percentage) and b- changes of BD (bulk density)

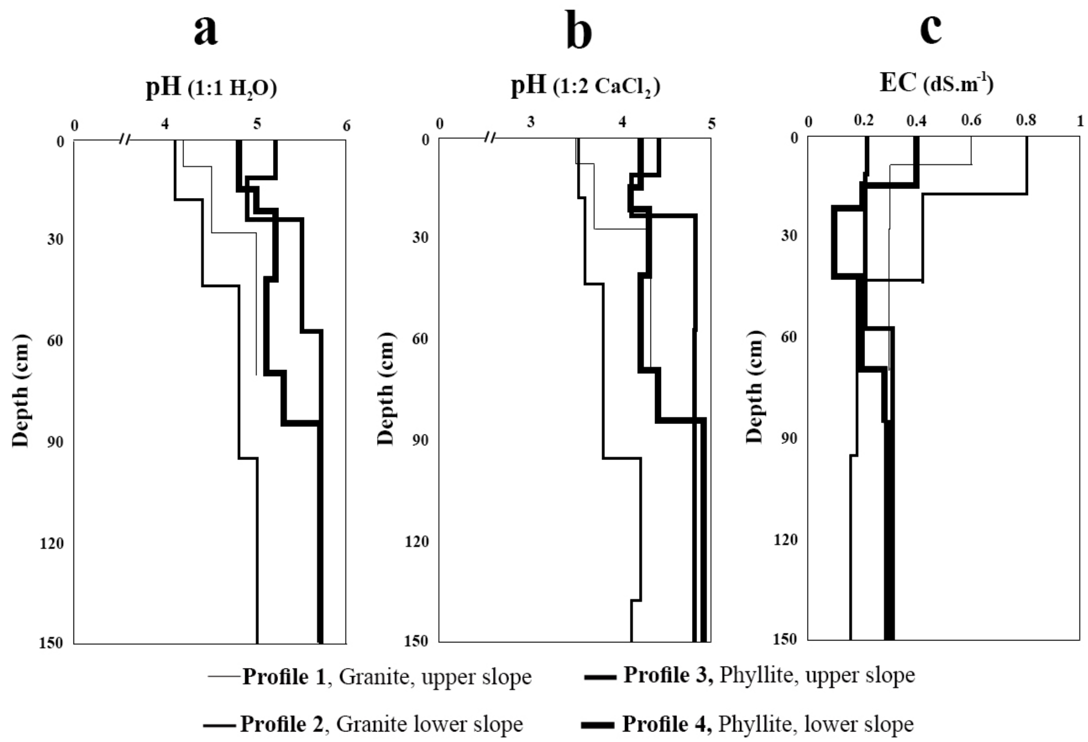

Figure 5- Changes of soil reaction and EC (electrical conductivity) on studied profiles, a- changes of pH in solution of soil: deionized water (1:1), b- changes of pH in solution of soil: 0.01 M $CaCl_2$ (1:2) and c- changes of EC

3.5. CEC, TEB and BS

CEC of upper slope in soils derived from granite parent material were less than other soils (Fig. 7a). The maximum content of CEC observed in Bt horizons of soils derived from phyllite parent material (Fig. 7a). TEB content was higher in soils derived from phyllite parent material than soils derived from granite parent material and it showed significant changes in surface horizons compare to sub horizons (Fig. 7b). The BS values of soils derived from phyllite parent material were higher than that of from granite parent material especially in sub horizons (BS>80%).

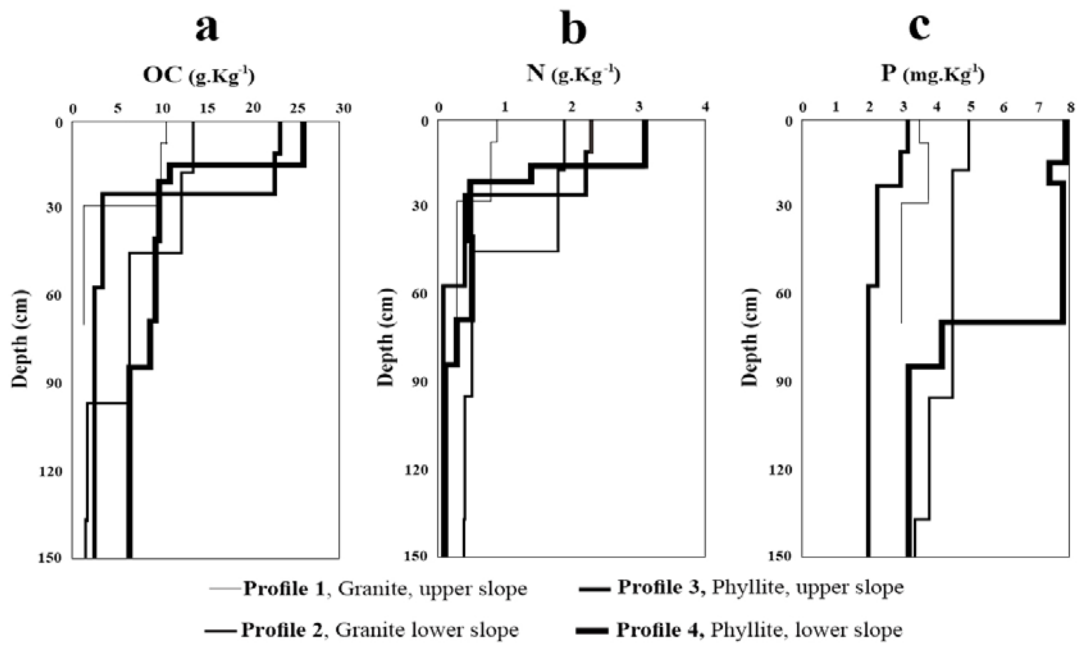

Figure 6. Changes of soil organic carbone (OC), and chemical elements in studied profiles. a- Changes of OC, b- changes of total nitrogen (N) and c- changes of phosphorous (P)

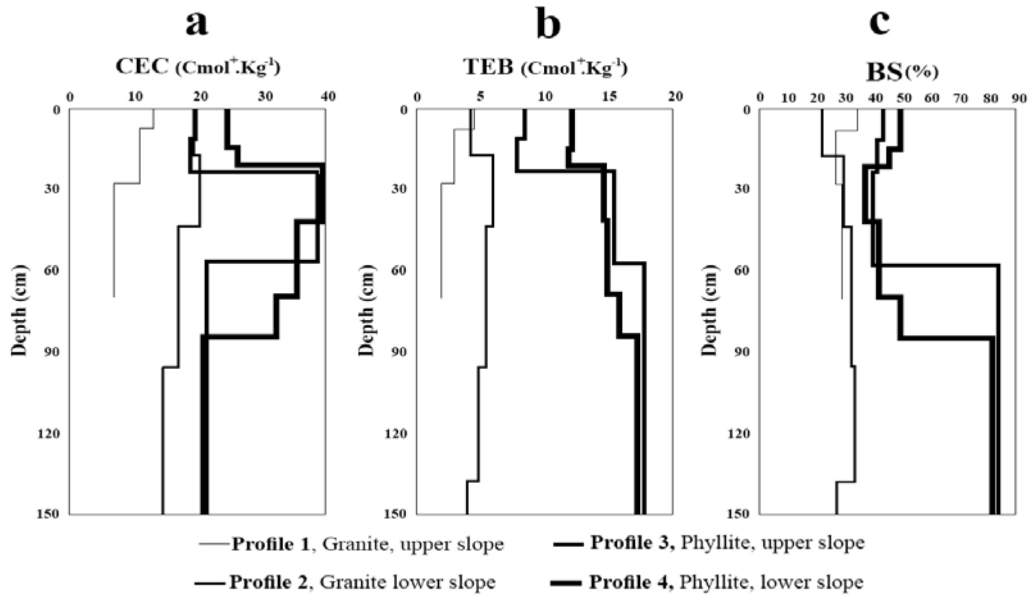

Figure 7- Changes of soil chemical properties in studied profiles, a- changes of cation exchange capacity (CEC), b- changes of total exchangeable bases (TEB) and c- changes of base saturation (BS)

3.6. Micromorphological studies

Rock thin sections of granite and phyllite are presented in figure 8. Granite thin section had dusty appearance in plane light (Fig. 8b). There were quartz, alkali feldspar and plagioclase minerals that formed in a complex pattern (Figs. 8a and 8b). Plagioclase minerals showed extreme alteration to clay minerals that was more than alkali feldspar. Phyllite thin section had fine-grained quartz, biotite and muscovite minerals. Alteration of biotite to chlorite is shown in figure 8c and 8d. The results of Ramezanpour et al., (2008) in Lahijan site showed that minerals in phyllite thin section were mica and chlorite that stratified with vermiculite.

Plant root residues (tea) are mostly observed in Ap horizon of all profiles (Fig. 9b) and root growth in Ap horizons was mostly in 5-10 cm of depth soil. Quartz grains and lithorelicts (rock fragments) were abundant in all soil thin sections derived from granite parent material (Fig. 9). Organic amorphous pedofeatures are mostly observed in soil profiles (Fig. 9a). Hypocoating iron (Fe)/ manganese (Mn) hydroxides in groundmass around vugh, channel and chamber voids were very usual in profiles derived from granite parent material (Fig. 9c). Various Fe/Mn oxide nodule observed in soil profiles especially in soil profiles derived from granite parent material (Fig. 9d). Clay illuviation features as pale yellow and highly micro-laminated were the major micromorphological evidences in soils derived from phyllite parent material (Fig. 10d). The b-fabric of studied soils was mostly stipple speckled, undifferentiated, crystallitic, mono-striated, parallel-striated, poro-striated. Grano-striated b-fabrics were observed in some phyllite thin section (Fig. 10 a). Fragment of thin coating of well-oriented, micro-laminated, yellow clay (in XPL) around voids (channel) was observed in phyllite thin sections (Fig. 10b). Papules or microlaminated clay fragments were found randomly distributed in Bt soil horizons of phyllite parent material (Fig. 10c).

4. DISCUSSION

The microstructure arranged from weak fine granular in surface horizons to moderate medium subangular or angular blocky in Bt horizons of soils derived from phyllite parent material. The soil textures of that from granite parent material were sandy clay loam, sandy loam and loam. These findings were in contrast with results of Olowolafe (2002) that reported soils developed in granites are mainly loamy textured and the dominant textural classes are sandy clay loam, clay loam and sandy loam. The textural differences between Ap and Bt horizons in the soils derived from phyllite parent material were due to parent material and moderate to prominent clay illuviation features were presented in both slope position, and were also found in thin sections. The content of clay in soil sub horizons of phyllite parent material was higher than soils derived from granite parent material. Sand/clay ratio is a criterion for determining soil evolution (Nettleon et al., 1989) which was maximum in Bt horizons of soils derived from phyllite parent material. Hence, soils derived from granite parent material are well-developed soils.

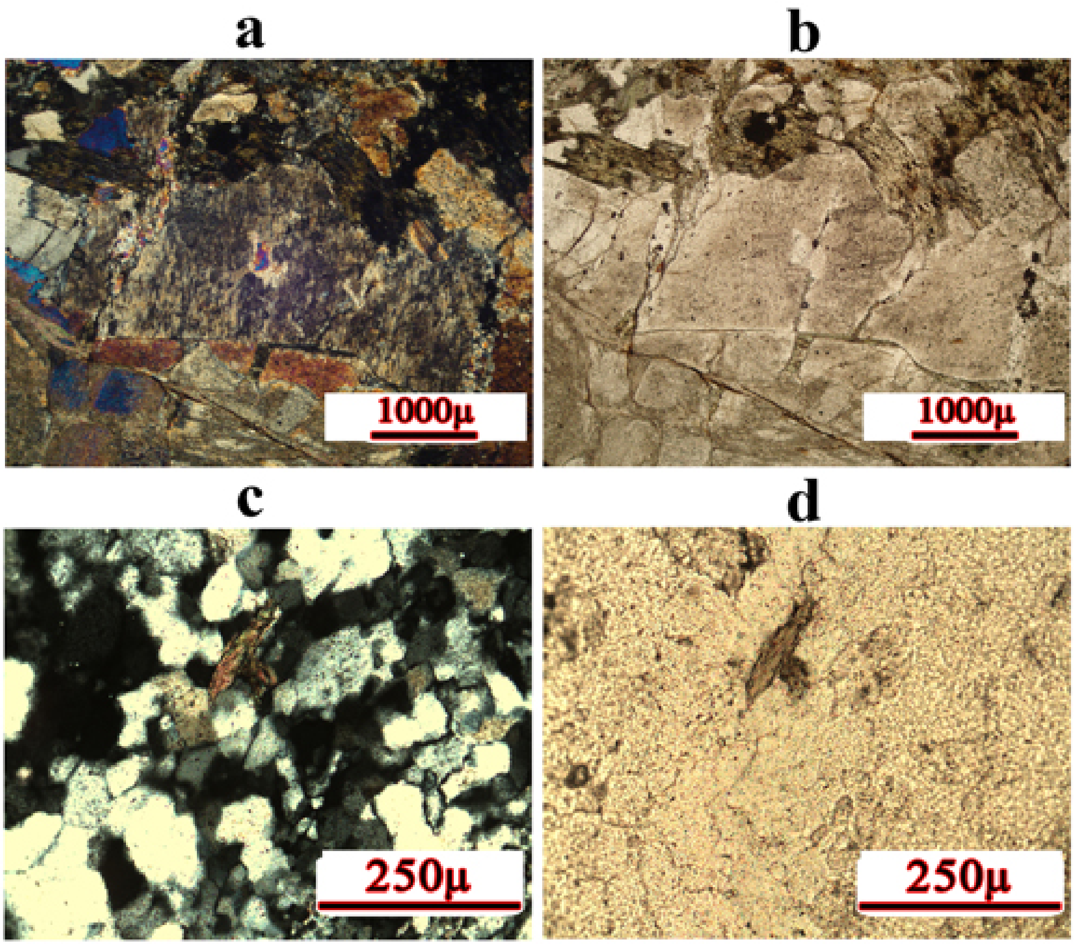

Figure 8. Micrographs related to the rocks, a- granite (XPL), b- granite (PPL), c- phyllite (XPL), d- phyllite (PPL).

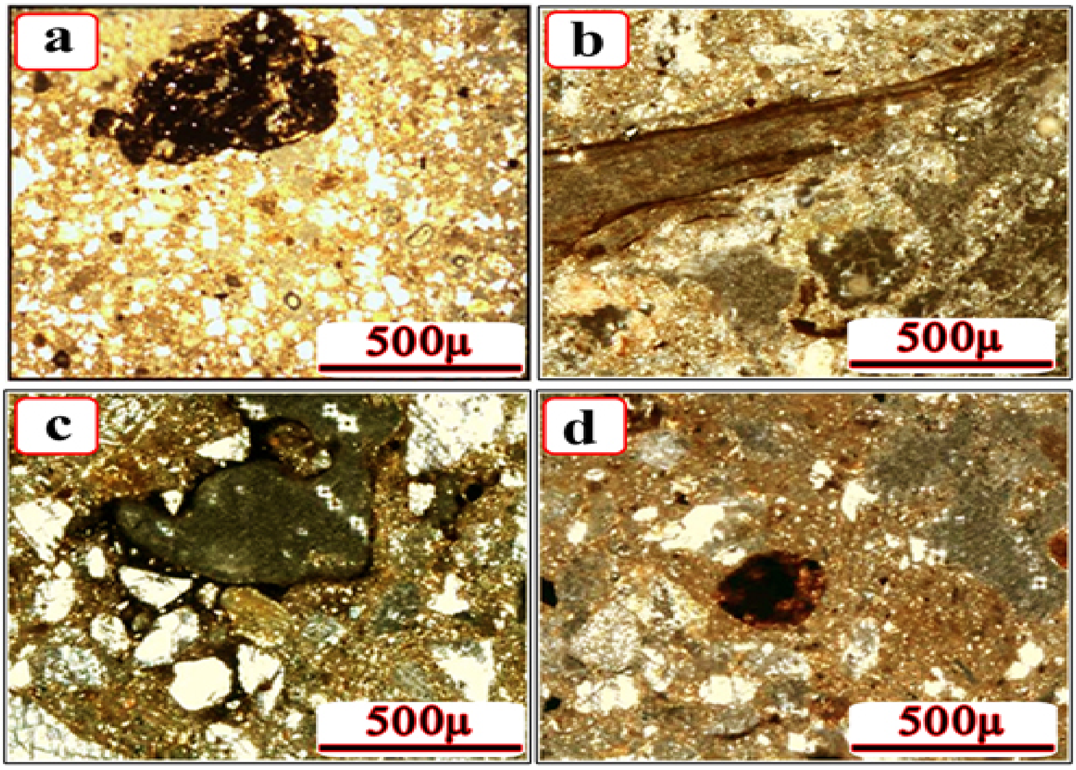

Figure 9. Micrographs related to soils derived from granite parent material (profiles 1 and 2), a- Organic amorphous pedofeatures (in PPL), b- plant root residues (in XPL), c- Hypocoating Fe/Mn hydroxide in groundmass around void (in XPL), d- Fe/Mn oxide nodule (in XPL)

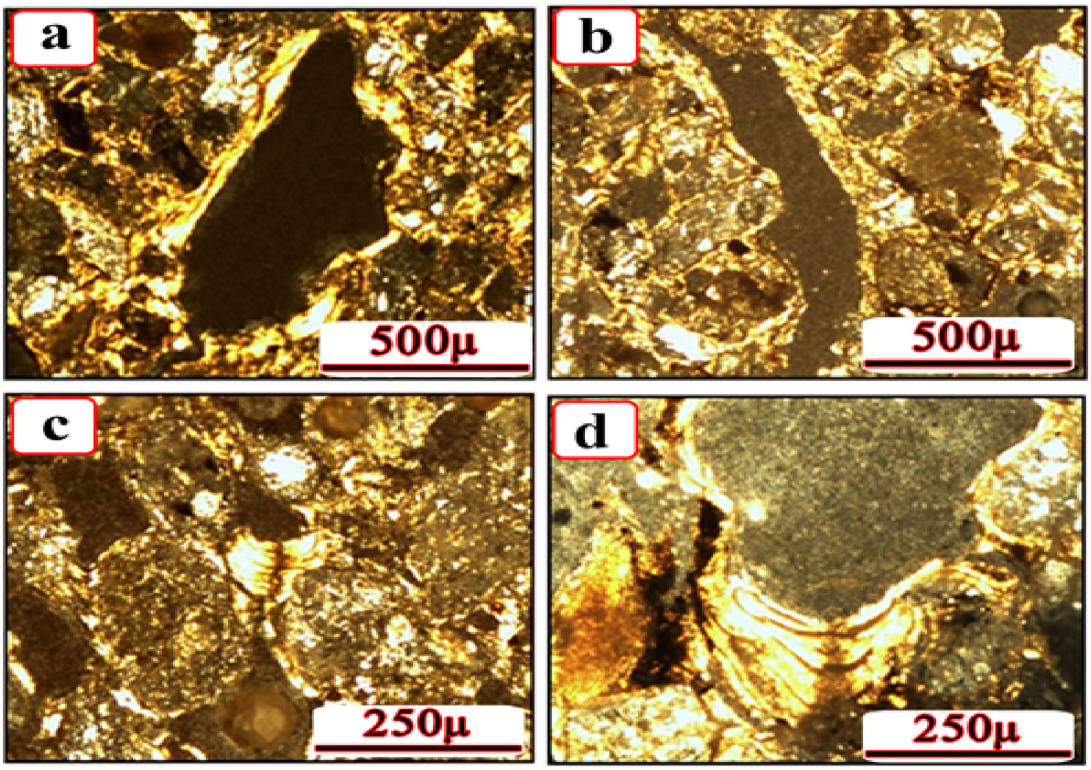

Figure 10. Micrographs related to soils derived from phyllite parent material (profiles 3 and 4), a- grano-striated b-fabric (in XPL), b- thin coating of well-oriented, micro-laminated, yellow clay around channel void (in XPL), c- papule or micro-laminated clay fragment (in XPL), d- micro-laminated clay coatings (in XPL)

The Bt horizons (profiles 3 and 4) were slightly wet and less acidic. The higher soil moisture values in Bt horizons is related to high clay content in soils derived from phyllite parent material. Decreasing the BD with depth can be related to clay content and parent material. Soils had acidic reaction and pH increased with depth due to leaching of bases from upper horizons to lower ones. Olowolafe (2002) showed that soils derived from granite parent material are partly acidic because of the acidic nature of the parent rock. Soil pH is related to parent material not slope position. The results of Khan et al. (2013) showed that slope position had non-significant effect with soil pH. The EC value was greater in surface horizon of lower slope than upper slope position which showed that the EC values is related to slope position. Soluble cations and anions move down the slope with surface runoff and accumulate there which might have caused an increase in EC at the lower slope position (Khan et al., 2013). Erosion process also depletes soil productivity by changing the concentration of salts in the root zone in upper slope position. The results of Darvishi Foshtomi et al., (2011) showed that sloping areas under tea plantation in Lahijan site had marginally suitable land classes.

As a results of increasing soil erosion with increasing in the effective slope. The clay content, OC and other elements will increase in lower slope position. The clay content and OC of the soil are important factors for soil fertility (Clemens et al., 2010). Soluble organic nitrogen plays a vital role in ecosystem N cycling processes and is controlled by a number of biotic and abiotic factors such as slope position (Xing et al., 2011). Soluble organic carbon is probably controlled by OC content. In our studied soils, concentrations of total N were greater in the lower slope positions than in the upper slope position. The results of Xing et al., (2011) showed that concentrations of soil N content were greater in the middle slope and lower slope positions than in the upper slope position under tea plantation. The highest concentration of available P was found in lower slope position of phyllite derived soils. This was mainly related to erosion process. Available P transport in runoff was strongly influenced by the sediment load (Lal, 1998). Generally, both soils are acidic reaction, with pH mostly below 5.5 (in 1:1 soil: H_2O). One of the unique properties of acidic soils is low available phosphorus due to high P-fixation.

The CEC of soils decreases from 39.3 cmol.kg^{-1} in Bt soil horizon derived from phyllite parent material (profile 4) to 7 Cmol.kg^{-1} in C soil horizon derived from granite parent material (profile 1). The higher CEC in profile 4 is largely due to the clay type and clay content that is mostly vermiculite (Ramezanpour et al., 2008). However, the absence of smectite in phyllite might be attributed to more acidic condition or position of the Fe ion in the mineral lattice of chlorite (Ramezanpour et al., 2008). The relationship between pH and base saturation (BS) in acidified soils can be disturbed by processes such as nutrient cycling by vegetation, temporary saturation by ground water that comes into contact with calcareous material, or by upward diffusion of base cations from deeper horizons (Blaser et al., 2008). The values of BS and TEB in soils derived from granite parent material were lower in comparison to phyllite parent material. Blaser et al., (2008) stated that nutrient deficiencies in granite soils present more constraints to agricultural land use.

The coarse mineral fraction of the groundmass in soils derived from granite parent material is dominantly composed of subangular quartz grains, quartz aggregates (coarse sand). Quartz grains appear chemically unaltered, but exhibit abundant microcracks throughout the profile similar to results of Ramezanpour & Pourmasoumi (2012). Rounded Fe and Mn oxide nodules with sharp boundaries and various types of other pedofeatures such as iron oxide coatings were common both soils derived from granite and phyllite parent. The nodules consist of a large amount of amorphous and poorly crystalline Fe and Mn compounds (Szenderi et al., 2012). Black nodules contained more amorphous and poorly crystalline materials than brown ones (Szenderi et al., 2012). Micromorphological evidence of strong clay translocation observed in soil thin sections derived from phyllite parent material that is related to clay movement. The accumulation of illuvial clay as clay coatings and infillings inside the voids were observed in soil thin sections of phyllite parent material. The presence of illuvial clay indicates that water has percolated through the soil and that the soil has experienced periodically dry periods (Boixadera et al., 2003). Fragment of thin coating of well-oriented, micro-laminated, yellow clay around voids indicates periods of clay illuviation (Kuhn et al., 2010).

5. CONCLUSION

Parent material and slope position greatly influence the morphological, physical, chemical and micromorphological characteristics of soils under Tea Plantation in Lahijan. In general, this study showed that parent material had remarkable effect on thickness of the solum and properties such as sand, clay, SP, pH, CEC, TEB and BS values. These properties (except for sand) were high in soils derived from phyllite parent material as compare to soils derived from granite parent material. The effect of slope position on properties such as EC, OC, total N and available P was noticeable. Soils derived from granite parent material are very poor and also susceptible to erosion. Overall, the upper slopes are more prone to erosion. The study area was covered by tea and since of their water uptake by roots and their prevention in rush of water from upper slopes, growth of tea on the slope areas protects soil and prevent severe soil erosion. Despite this fact, Soil degradation is still considered a major problem in Lahijan area. It can be as a result of high annual rainfall, leaching, high soil acidity, deforestation, and poor management culture obtained in this regions.

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