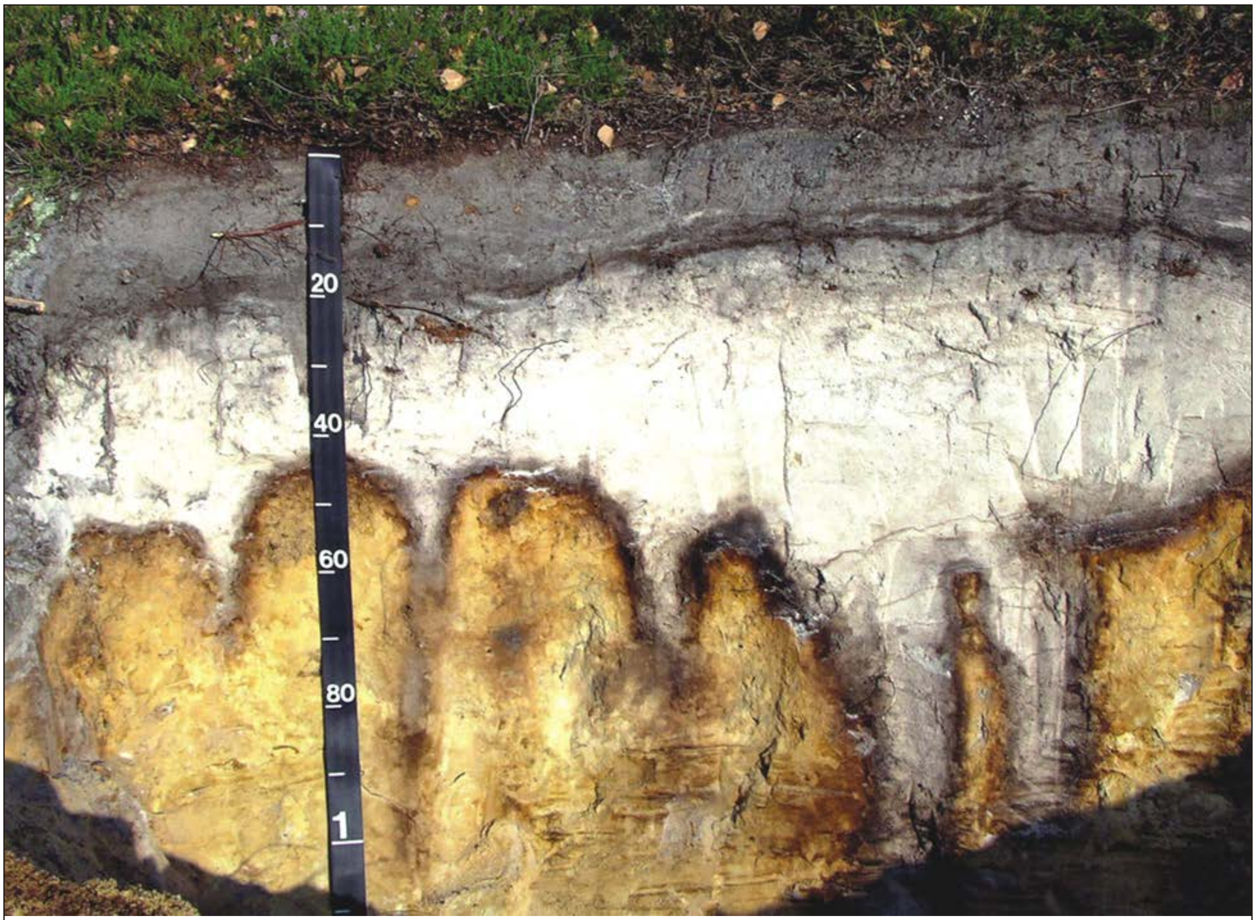

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Morphology and Micromorphology of Paddy Soils under Different Soil Moisture Regime and Ground Water Table in Mazandaran Province, Northern Iran, Amol

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Abstract: The morphology and micromorphology of paddy soils under different soil moisture regime and groundwater table of Northern Iran were investigated. Aquic conditions in soils are often associated with redoximorphic features. The depths at which the features occur are often used as an indicator of the location of the seasonal water table. Morphological and micromorphological characteristics could be used to identify the hydromorphism degree of soils and their properties. In this study, morphological and micromorphological characteristics of paddy soil samples with different water table depth and drainage were investigated. Thirty nine undisturbed blocks of soil were taken. Thin sections were observed with a polarized microscope and described according to thin section interpretation. This study demonstrated the extensive pedogenic changes and micromorphological evidences. Studied soil samples are exposed to alternative fluctuations with water saturation in different time. The various type of iron and manganese oxides show the difference of environment and their movement and formation are the most important factor to form hydragric anthrosol. This study demonstrated that moisture regimes in soils with anthraquic saturation can be characterized in the same way as in soils with either episaturation or endosaturation. And also the effect of irrigation water on pedogenesis with respect to saturation, reduction and redoximorphic features was greater than that of the shallow ground water.

Key words: Hydragric anthrosol, redoximorphic feature, aquic condition, hydromorphism

INTRODUCTION

Paddy soils are a kind of artificial hydromorphism or hydragric Anthrosols; soils with prominent characteristics result from human activities, virtually any soil material, modified through cultivation or by addition of material (Wilding and Ahrens, 2005; Aimrun *et al*., 2003).

Hsue and Chen (2001) confirmed that the formation of redoximorphic features occurred as Fe and Mn concretion and depletion associated with the fluctuations of seasonal water table. Zhang and Gong (2003) found deposition of sediment in area with low groundwater table has changed the soil hydrology. The objectives of this research were to determine: (i) the impact of anthraquic conditions on morphology, the different forms of redoximorphic features and distributions and (ii) the processes responsible for the formation or transformation of soil in general, or of specific features.

MATERIALS AND METHODS

Study Area

The study area (at the east of Amol city) is located in Mazandaran Province, northern Iran, in the southern coast of the Caspian Sea (Fig. 1), with different water table depth (Fig. 2). Studied area has

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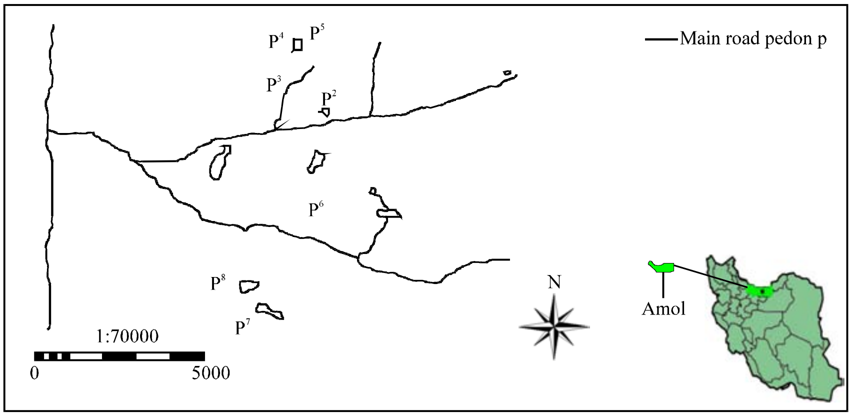

Fig. 1: The location of Mazandaran province and Amol area

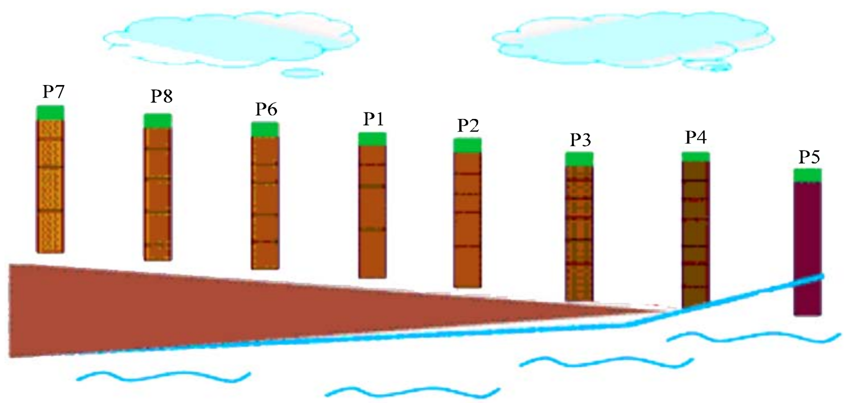

Fig. 2: The location of pedons according to water table depth

general slope from south to east. Its physiographic unit is alluvium plain. A humid climate with moderate temperature characterizes the area. The mean annual temperature is approximately 16.0°C. This area has an average annual rainfall of 848.4 mm (1989-1999). The soil moisture and temperature regimes are Wet Ustic and Thermic, respectively. The parent materials are derived from sediments weathered from primary rocks content Calcite, Dolomite and loess moved to this plain.

Field Work

This study was accomplished from September 2005 to September 2006. Seven pedons (35 paddy soil samples) and 1 pedon (4 soil samples) as a blank (soil under cultivation of citrus fruit) were selected and sampled according to genetic horizons when the fields were drained after rice harvest. Soil Samples described and classified, according to Keys to soil taxonomy (Soil Survey Staff, 2006).

Micromorphological Analysis

Thirty nine undisturbed blocks of soil were taken with Kubiena boxes in order to have representative sampling of the different horizons of pedons. In order to avoid structural modifications, all of the blocks were impregnated with a polyester resin after replacing water by acetone. After air drying, vertical and horizontal oriented thin sections with a thickness of 30 micrometer were prepared. Finally, thin sections were observed with a polarized microscope (euromex type) and described according to guidelines of Stoops (2003).

Physiochemical Analysis

Air-dried soil samples were crushed and passed through a 2 mm sieve. Samples were dispersed using sodium hexametaphosphate for determination of sand, silt and clay fraction by the hydrometric method (Bouyoucos, 1962). Organic matter was measured by wet oxidation (Nelson and Sommers, 1982). Alkaline-earth carbonate (lime) was measured by acid neutralization (Ali Ehyaee and Behbahanizade, 1993). Soil pH was determined with a glass electrode in saturated paste (Ritvo *et al*., 2003). Electrical conductivity (total soluble salt) was measured in the saturation extract (Ali Ehyaee and Behbahanizade, 1993). Cation Exchange Capacity (CEC) was determined using sodium acetate (NaOAc) at a pH of 2/8 (Bower and Hatchea, 1966).

RESULTS AND DISCUSSION

Soil profile description and some physical and chemical properties are reported in Table 1. In studied area pedon 5 is located northern and lowland part of this region. The water table was at (or close to) the surface through out the year. Only some years in harvesting time and 2-3 weeks after harvesting is not flooded, but the soil surface is mostly wet because of arrival deposition from top land. Soil development of this pedon is the last, which has undergone little soil formation. The other pedons were not saturated all of the year and the water table fluctuation was influenced by cropping and flooding of the rice-growing and rainfall. Pedon 7 and 8 were at southern of studied area that have the height water table depth and locate in top land. Pedons 1, 2, 3 and 4 were located between pedons 5 and 7. Water ponding as in paddy soils, usually leads to development of aquic characteristics in the surface and subsurface horizons where under natural conditions such characteristics would be absent or only weakly developed. In paddy soil samples with high water table, completely reduced layer is located below the 100 cm depth and saturation condition from the surface and oxidized zone have been seen in A_{pg}, A_g and B_g1 below the plow layer and between these two layer respectively. In pedons with low water level and poorly drainage (pedon 5), water level is stayed at 70 cm and soil texture in this pedon is sandy and the thickness between saturated layer in surface and depth is the least. Because of arrival deposition of sediment from top land, soil evolution of this pedon is low. Soil color patterns and redoximorphic features are the most significant soil characteristics affected by water table depth and its fluctuation in studied soils that include low chroma and gray color. They could be used to predict where seasonal saturation occurs in soils and reflect the environment conditions according to He *et al*. (2003) and Jien *et al*. (2004). The redoximorphic features are the main sign of aquic condition in saturated soils with low water level and the distribution patterns of pedogenic oxides are depending on intensity of reduced condition. Stolt *et al*. (2001) and Fiedler and Sommer (2004) also reported this observation. Alternating cycles of reduction and oxidation in soils over prolonged periods and the consequent mobility and accumulation or depletion of Fe and Mn, result in the formation of redoximorphic features associated with water table depth that is according to Costantini *et al*. (2006), Hsue and Chen (1996) and Khan and Fenton (1996). One of the most important phenomena occurs in plow layer of studied rice soils is also reduced Fe and Mn leaching and their different kind of features. In reduced condition, ferrous iron is far more soluble than ferric iron, thus creating an increase in Fe mobility. The Fe transported within soils and landscapes via soil solution. Areas with frequent reducing conditions lose Fe^{+2} with out flowing water. This redistribution is visible in the field by the change from brown to gray colored soil horizons. In some of the samples, a large part of reduced Fe became oxide by drainage and dryness. Brown spots and rusty mottles formed that show oxidized

Table 1: Selected physical and chemical properties of soils

Horizon	Depth (cm)	Moisture matrix color	Sand (%)	Silt (%)	Clay (%)	Texture	$CaCo_3$ (%)	OM (%)	EC	pH	CEC
Pedon 1 (Paddy soil) Fine, mixed, (calcareous), superactive, thermic, Fluvaquentic Endoaquolls											
A_{pg}	0-15	2.5Y3.2	9.7	46.8	43.5	Si.c	11.0	2.9	1.1	7.5	25.5
B_g1	15-23	2.5Y4.2	17.6	43.0	39.4	Si.cl.l	50.6	2.1	0.5	7.8	23.9
B_g2	23-80	2.5Y4.2	20.0	42.9	37.1	Si.c	10.0	1.7	0.4	7.1	30.4
C_g	>60	2.5Y4.3	13.0	50.1	36.9	Si.cl.l	15.0	1.1	0.4	7.8	32.6
Pedon 2 (Paddy soil) Fine loamy, mixed, (calcareous), superactive, thermic, Fluvaquentic Endoaquolls											
A_{pg}	-017	2.5Y3.3	16.7	49.9	33.9	Si.cl.l	16.0	2.4	2.1	7.6	34.8
AB_g	17-22	2.5Y4.2	12.7	50.3	37.0	Si.cl.l	16.0	2.6	2.2	7.4	39.1
B_g	22-27	2.5Y4.2	39.7	47.6	12.7	l	19.0	1.6	0.5	7.7	13.0
C_g1	27-80	2.5Y4.2	23.3	42.8	33.9	Cl.l	12.0	1.6	0.5	7.7	32.1
C_g2	>80	2.5Y4.2	23.0	56.8	20.2	Si.l	10.0	1.6	0.6	7.7	32.1
Pedon 3 (Paddy soil) Fine loamy, mixed, (calcareous), superactive, thermic, Fluvaquentic Endoaquolls											
A_{pg}	0-15	2.5Y3.2	29.8	46.8	23.4	l	16.0	1.8	1.4	7.4	31.1
AB_g	15-27	2.5Y3.2	26.2	46.8	27.0	Cl.l	17.0	1.9	3.5	8.0	31.1
B_g1	27-40	2.5Y3.3	23.7	45.7	30.6	Cl.l	12.5	1.4	0.4	8.0	30.4
B_g2	40-46	2.5Y3.3	23.6	46.8	29.6	Cl.l	13.0	1.4	0.4	7.7	30.9
C_g1	46-80	2.5Y4.3	16.2	50.3	33.5	Si.cl.l	9.5	1.6	0.4	7.9	32.0
C_g2	>80	2.5Y4.3	16.7	48.7	34.6	Si.cl.l	11.0	1.4	0.4	7.7	30.5
Pedon 4 (Paddy soil) Fine, mixed, (calcareous), superactive, thermic, Fluvaquentic Endoaquolls											
A_{pg}	0-17	2.5Y3.2	23.6	52.6	23.8	Si.l	15.5	3.3	1.8	7.4	16.3
AB_g	-1722	2.5Y4.2	7.0	55.8	37.2	Si.cl.l	13.5	3.1	0.9	7.5	19.4
C_g1	-2626	2.5Y4.2	10.4	55.8	33.8	Si.cl.l	18.5	1.3	0.4	7.8	17.6
C_g2	-4040	2.5Y4.2	6.8	52.8	40.4	Si.cl	15.0	1.3	0.4	7.7	33.7
C_g3	-4045	2.5Y4.3	9.4	56.9	43.7	Si.cl	14.5	1.6	0.5	7.8	14.7
Ab	-4560	2.5Y4.3	0.7	49.2	43.8	Si.c.l	16.5	3.9	0.6	7.5	23.9
B_gb	>60	2.5Y3.2	12.9	37.0	50.1	cl	15.0	7.9	0.2	7.4	28.6
		2.5Y3.2									
Pedon 5(Paddy soil) Fine loamy, mixed, (calcareous), active, thermic, Mollic Fluvaquents											
Ap_g	0-15	2.5Y3.1	17.4	45.4	37.2	Si.cl.l	16.5	8.1	1.6	7.4	21.7
A_g	15-60	2.5Y2.1	13.7	49.2	37.1	Si.cl.l	15.0	7.8	0.8	7.5	17.4
C_g	>60	2.5Y3.2	69.6	16.7	13.7	Sa.l	11.0	1.2	2.3	7.6	13.3
Pedon 6 (Paddy soil) Fine loamy, mixed, (calcareous), superactive, thermic Fluvaquentic Endoaquolls											
Ap_g	0-19	2.5Y3.2	23.4	39.9	36.7	Cl.l	9.0	2.7	1.1	7.6	27.2
A_g	19-25	2.5Y3.2	26.7	36.2	37.1	Cl.l	12.0	2.3	0.4	7.8	35.9
B_g1	25-70	2.5Y4.2	19.2	42.5	38.3	Si.cl.l	10.0	2.1	0.4	7.6	21.4
B_g2	70-100	2.5Y3.2	43.0	36.9	20.1	l	9.0	2.4	0.5	7.7	17.6
C	>100	2.5Y4.3	43.8	35.1	21.1	l	9.0	2.1	0.4	7.6	17.5
Pedon 7 (Fruit garden sample) Fine, mixed, (calcareous), superactive, thermic, Fluventic Haplustepts											
A	0-15	2.5Y4.2	10.0	46.2	43.8	Si.cl	10.5	4.9	3.1	7.3	36.9
B_w1	15-53	2.5Y3.2	6.7	49.5	43.8	Si.cl	11.0	3.5	0.5	7.5	32.1
B_w2	53-100	2.5Y3.2	9.7	43.5	46.8	Si.cl	11.0	2.1	0.3	7.5	30.6
C_g	>100	2.5Y4.3	11.8	45.1	43.1	Si.cl	8.5	1.3	0.5	7.4	31.1
Pedon 8 (Paddy soil) Fine, mixed, (calcareous), superactive, thermic, Fluvaquentic Endoaquolls											
Ap_g	0-16	2.5Y3.2	13.3	50.0	36.7	Si.cl.l	12.5	2.1	1.7	7.4	23.5
AB_g	16-15	2.5Y4.2	14.5	51.3	34.2	Si.cl.l	13.0	1.5	0.7	7.7	16.6
B_g1	25-50	2.5Y4.2	16.7	49.5	33.8	Si.cl.l	16.0	1.3	0.3	7.8	16.5
B_g2	50-80	2.5Y3.3	7.0	52.7	40.3	Si.c.l	10.5	2.0	0.4	7.5	32.5
C	>80	2.5Y3.3	17.4	42.6	40.0	Si.c.l	9.5	2.1	0.4	7.7	33.2

condition. When reoxidized condition existed in the soil, Fe and Mn were accumulated as coating in the voids, root channels and macropores, particularly in the root channels and other biopores caused by rice cultivation. After alternative redox processes, irregular soft masses were concentrated close to the pedosurface; Fe and Mn nodules were further formed as well. In thin section observations, redoximorphic features have been seen in all studied samples as a different type of Fe and Mn coating, hypocoating (Fig. 3b) and nodules (Fig. 3a). This study confirmed that although Fe-Mn nodules have been seen in all studied samples, the maximums amount and size occur in the optimum reducing and saturation condition. Reverse effects in the development of Fe-Mn nodules are excessive submergence

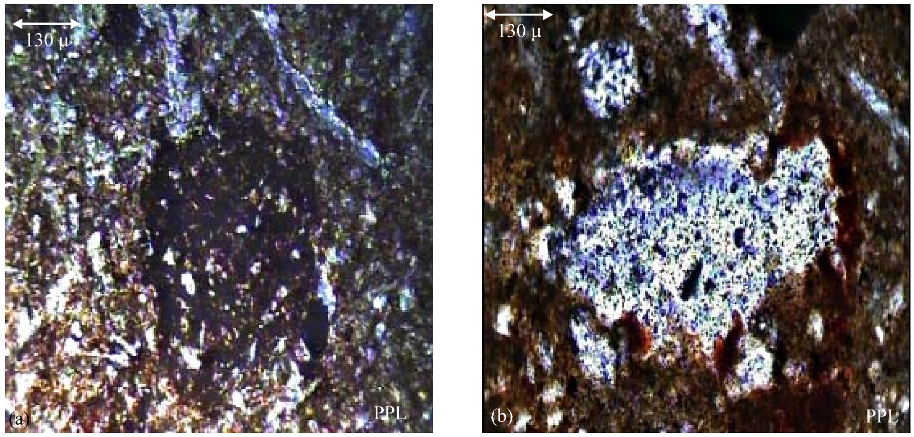

Fig. 3: Fe-Mn oxide orthic nodule (a) coating and hypocoating around void (b) 10X magnification

and less saturation and reduction. The fact that there are much more void type like root channels and other biopores near the plow layer (caused by human activities for rice production) accounts for why the patterns of Fe-Mn nodules tend to have different shapes such as angular, sub angular, slice and imperfectly round shapes. Hydromorphism in the soils led to nodule formation; the intensity of which appears to have a maximum in the wetter, but not the wettest soils. The least amounts of Fe-Mn nodule through the profile were found in pedon 5, which contained the poorest drainage and was closest to the see level. Their coating and hypocoating were also exist in well-drained samples (pedon 1, 2, 6 and 8) to moderate drainage system (pedon 3, 4) that have sharp boundaries relate to matrix and can be seen distinctly. But in poorly-drained paddy soil (pedon 5), because of low chroma of matrix, these pedofeatures have diffused boundaries. In this soil sample shiny iron cutan have been observed that moved with water table fluctuation through the pedon and precipitated *in situ* after the water table comes down. The coating materials is believed to move from the top soil under hydraulic pressure when the soil are flooded; coating is most prominent in deeply flooded soils and least developed in soils that are only shallowly flooded for short periods. The size of coating and hypocoating are estimated approximately 200 to 1000 μ. Nodules are kind of typic (with poorly to moderately saturation), orthic (those formed in situ) and anorthic or lithomorphic (nodular bodies inherited from the parent material), they are about 100 to 1000 μ and the biggest nodules are exist in samples with moderately drainage conditions.

Microstructure studies of soil samples show in A_{pg} horizons, there is no special microstructure as a result of soil compaction. In this case, soils have massive microstructure and most pores are vesicles and vughs (Fig. 4a). Existence of angular and sub angular microstructure in B horizons reflect the effect of accumulation of organic matter, as a result of low ground water table (Fig. 4b). This micromorphological evidence confirmed morphologic field observations.

Micromorphological evidence of poor clay coating in thin sections (Fig. 5a, b) show the clay movement downward the profiles by irrigation and flooded water. Truly, clays have been seen in samples are the particles that formed by cultivation and irrigation water leaching. Additionally, there is no micromorphological sign of increased illuviation such as clay skin in studied wet-cultivated rice lands. The lower clay content near the some surface of wet-cultivated soils is probably due mainly to their weathering associated with alternative flooding and drainage. Another process that can contribute to loss of clay from the surface soil is its removal to the surface water during puddling when muddy water outflows from the higher to the lower fields. Although there is no reason to believe that wet rice cultivation enhances clay illuviation, it probably promotes downward movement of clay, silt and

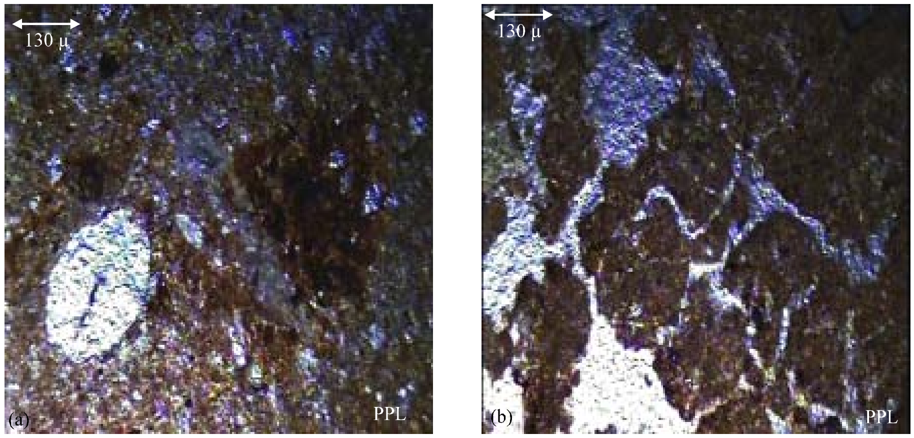

Fig. 4: (a) Massive and Angular blocky microstructure (b) 4X magnification

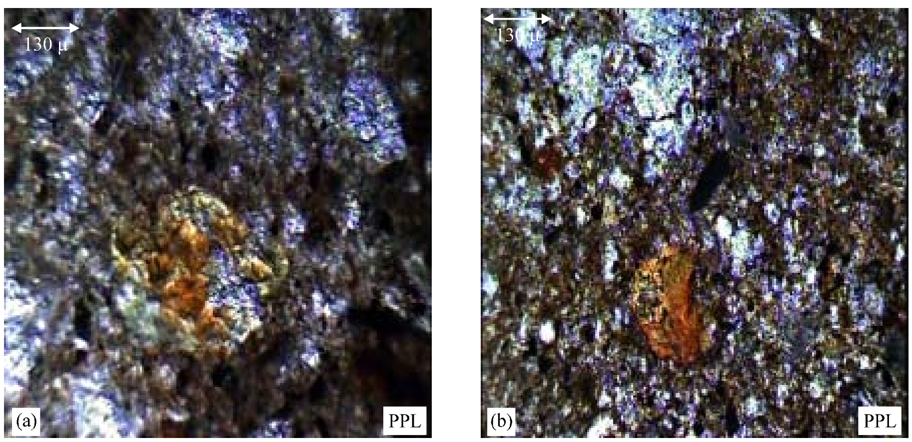

Fig. 5: Slice clay coating in groundmass (a, b) 10 X magnifications

organic matter through cracks and pores that corresponded to Liu *et al*. (2001), Mori *et al*. (1999) and Tuong *et al*. (1996). In pedon 5, clay movement downwards the profile is less than the others, because of low leaching and low water table depth.

CONCLUSIONS

Growing rice in soils on alluvial plains is very popular in northern Iran. Surface water irrigation and shallow ground water influence the soil morphology of these soils simultaneously. The main pedogenic processes forming rice soils have been discussed by many investigators. The most important processes have been influenced by redox condition, addition and removal of chemical components and soil particles and changes in physical, chemical and microbiological properties through irrigation or drainage, or both. In other words, glayzation and eluviations, mottle forming (oxidized illuviation and segregation of iron and manganese and separation of manganese from iron), grayzation, plow-sole forming, illimerization or degradation, cutan forming, redistribution of exchangeable bases, accumulation (or decomposition) and alteration of organic matter and other processes lead to the profile differentiation of rice soils. Results indicated that the effect of irrigation water on pedogenesis with respect to saturation, reduction and redoximorphic features was greater than that of the shallow ground water. On the contrary, shallow ground water was the main contributor to saturation at the depth of 50 cm in the pedon 5. And also this study demonstrated that moisture regimes in soils with anthraquic saturation can be characterized in the same way as in soils with either episaturation or endosaturation. On alluvial plains, the soil conditions range from continuously reducing controlled by high groundwater to alternating reduction and oxidation because of artificial submergence and groundwater fluctuations. Artificially induced leaching losses, previously prevented by a high groundwater table, are partly compensated during paddy cultivation by the rejuvenation process of alluvial deposition. Soil samples with no longer receives river-sediment, are more strongly developed. In the polder area, apparent lowering of groundwater table by deposition of sediment is less developed classified in Entisols order. Micromorphology provides a means to identify the presence of hydromorphic features that may otherwise be missed in the field if only the naked eye is used. The observation of hydromorphic features in thin sections suggests that careful observations in the field, using a hand lens, may increase the likelihood of identification of horizons in problem soils with aquic conditions. Fe nodules may be one of the easiest diagnostic features to find because they have sharp boundaries. However, these small features appear very similar to Fe-coated coarse fragments, and, in addition, nodules with sharp boundaries are often interpreted as relict features. Therefore, the use of nodules with sharp boundaries may result in misinterpretations.

REFERENCES

Aimrun, W., M.S.M. Amin and S.M. Eltiab, 2003. Effective porosity of paddy soils as an estimation of its saturated hydraulic conductivity. Geoderma, 121: 197-203.

Ali Ehyaee, M. and A. Behbahanizade, 1993. Chemical Soil Analysis. 1st Edn. of Agricultural Ministry, Iran Agriculture Educating Research, Iranian Soil Water Institute, Iran, pp: 893.

Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J., 54: 464-465.

Bower, C.A. and J.T. Hatchea, 1966. Simultaneous determination of surface area and cation exchange capacity. Soil Sci. Soc. Am. Proc., 30: 525-527.

Costantini, E.A.C., S. Pellegrini, N. Vignozzi and R. Barbetti, 2006. Micro morphological characterization and monitoring of internal drainage in soils of vineyard and olive groves in central Italy. Geoderma, 131: 388-403.

Fiedler, S. and M. Sommer, 2004. Water and redox conditions in wetland soils, their influence on pedogenic oxides and morphology. Soil Sci. Soc. Am. J., 68: 326-335.

He, Y., M.J. Vepraskas, D.L. Lindbo and R.W. Skaggs, 2003. A method to predict soil saturation frequency and duration from soil color. Soil Sci. Soc. Am. J., 67: 961-969.

Hsue, Z.Y. and Z.S. Chen, 1996. Saturation, reduction and redox morphology of seasonally flooded Alfisoils in Taiwan. Soil Sci. Soc. Am. J., 60: 941-949.

Hsue, Z.Y. and Z.S. Chen, 2001. Quantifying soil hydro morphology of rice growing Ultisol toposequence in Taiwan. Soil Sci. Soc. Am. J., 65: 270-278.

Jien, S.H., Z.Y. Hsue and Z.S. Chen, 2004. Relations between morphological color index and soil wetness condition of anthraquic soils in Taiwan. Soil Sci., 169: 871-882.

Khan, F.A. and T.E. Fenton, 1996. Secondary iron and manganese distributions and aquic conditions in a Mollisol catena of central Lowa. Soil Sci. Soc. Am. J., 60: 546-551.

Liu, F., R.J. Gilkes, R.D. Hart and A. Bruand, 2001. Differences in potassium forms between cutans and adjacent soil matrix in a Grey Clay Soil. Geoderma, 106: 289-303.

Mori, Y., T. Maruyama and T. Mitsuno, 1999. Soft X-ray radiography of drainage patterns of structured soils. Soil Sci. Soc. Am. J., 63: 733-740.

Nelson, D.W. and L.E. Sommers, 1982. Total Carbon, Organic Carbon and Organic Matter. In: Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, Page, A.L. (Ed.). Agron. Monogr., 9. ASA-SSA, Madison, WI, ISBN: 0-89118-072-2, pp: 539-579.

Ritvo, G., Y. Avnimelich and M. Kochba, 2003. Empirical relationship between conventionally determined PH and *in situ* values in waterlogged soils. Aquacalt. Eng., 27: 1-8.

Soil Survey Staff, 2006. Keys to Soil Taxonomy. 10th Edn., Department of Agriculture, Natural Resources Conservation Service, Washington DC., USA.,

Stolt, M.H., Lesinski, B.C. and W. Wright, 2001. Micro morphology of seasonally saturated soil in carboniferous glacial till. Soil Sci., 166: 406-414.

Stoops, G., 2003. Guidelines for Analysis and Description of Soil and Regolith Thin Sections. 1st Edn., Soil Science Society of America, Inc., Madison, Wisconsin, USA.

Tuong, T.P., R.J. Cabangon and M.C.S. Wopereis, 1996. Quantifying flow processes during land soaking of cracked rice soils. Soil. Sci. Soc. Am. J., 60: 872-879.

Wilding, L.P. and R.J. Ahrens, 2005. Provision for *Anthropogenic ally* impacted soil. European Bureau-Res., pp: 7.

Zhang, G.L. and Z.T. Gong, 2003. Pedogenic evolution of paddy soils in different soil landscapes. Geoderma, 115: 15-29.