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Note

Natural Ripening versus Artificial Enhancing of Silty Reclaimed Tidal Soils for Upland Cropping Tested by Profile Characterization

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This study was performed to produce basic data for silty reclaimed tidal lands and to develop techniques of environmentally-friendly utilization in agricultural system. We chose the two sites in Saemangeum reclaimed tidal lands, one (Site I) has been treated with cultivating green manure and conducting the desalinization process through submergence since April, 2007 and the other (Site II) has been under natural condition without artificial treatment. *In situ* and *ex situ* physic-chemical properties were determined and comparisons were made for soil profiles examined at these two sites in April 2009. Surface soil of Site I had lower EC and higher field saturated hydraulic conductivity than those of Site II, uncultivated land. Especially, exchangeable sodium content was lowest in Site I Ap1 layer than in other layers. This is probably due to flooding desalination and green manure cultivation. Besides, Ap1 and A2 layers of soil profile in Site I showed brighter soil color and more root observation than those of Site II. This is probably due to green manure cultivation. By the large, for high cash upland crops and intensive agricultural use of silty reclaimed tidal land, site-specific soil ripening such as flooding desalination and green manure cultivation could be useful.

Key words: Reclaimed tidal land, Soil profile, Silty soils

Introduction

Ever increasing development in recent years has created the need of more land especially land near to the developed areas for agricultural purposes. Korea has large coast-line areas; one instant option is to develop more land from reclaimed coastal areas. But there are variations in soil texture causing great impact on production system. When it comes to the use for agricultural purpose, then it is very important to consider all the parameters and properties to ensure sustainable and stable crop production. For example, these soils contain usually high content of soluble salts but plant available nutrients may be deficient, although it largely depends on the texture. Flooded rice cropping resulting in rice production and simultaneously desalination has been a main land use in Korean reclaimed tidal land (Koo, 1998; Yang et al., 2008). Recently, upland field cropping in reclaimed tidal land has been attempted because of high rice stock and low rice price (Kim, 2005; Lee et al., 2003; MAF and KARICO, 2004). Upland cropping requires well-developed structure and a plant favorable physico-chemical properties of soils. Newly reclaimed land from submerged area by sea water has relatively poor structure and high salt content. As time passes, the soil pedogenic processes (dewatering and/or compaction, oxidation of reduced iron, manganese and sulphur) result in the development of soil structure and formation of accumulating horizons and organic matter decomposition etc. (Giani and Landt, 2000; Giani et al., 2003; Mueller-Ahlten, 1994). This has been called as ripening of reclaimed soils (Larsen, 1973).

Saemangeum tidal land reclamation action which was the biggest land reclamation projects in Korea, was started in 1992 (MAF and KARICO, 2004). In this area, various soil textures were identified-including

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sand, sandy loam, loam, and silt, indicating different desalination period. Sonn et al. (2006) reported 108 years and 12 years of estimated natural desalination period for fine loamy and coarse loamy soils, respectively. Fine texture, including silty soil, could result in longer desalination period compared to coarse textured soil such as sandy soil, probably due to lower permeability (MAF and KARICO, 2004). Artificial flooding and green manure cultivation could enhance desalination and structure formation in reclaimed soils. We chose the two sites in Saemangeum reclaimed tidal lands (recently reclaimed), one (Site I) has been treated with cultivating green manure and conducting the desalinization process through submergence since April, 2007 and another one (Site II) has been under natural condition without artificial treatment. In this study, we compared of soil profile characteristics under between natural condition without artificial treatment and artificial treatment including flooding and green manure cultivation in silty reclaimed tidal soil, located in Saemangeum tidal land.

Materials and Methods

Investigated sites The presented investigations were carried out at two sites, located in Saemangeum tidal land, namely Site I (35°50′1.21″ N and 126°42′0.72″ E) and Site II (35°49′58.93″ N and 126°42′37.22″ E) in April, 2009. The investigated sites is presented in Fig. 1. Site I has been cultivated with green manure including sesbania, rye, and barley, after desalinization through flooding by fresh water in April, 2007. Site II has been under natural condition without any artificial treatment.

Soil layers The procedure for soil layer identification and description was referred from Ibrahim et al. (2012). At each site, the soil profile was described individually and was divided into different layers based on the similarity of the soil genesis. Soil color and morphological description of each layer was determined by Munsell® soil color chart and USDA-NRCS field book (Schoeneberger et al., 2002) based on Soil Taxonomy (Soil Survey Staff, 1999). The individual soil profile with different soil layers is presented in Fig. 2.

***In-situ* measurements** Infiltration rate and field saturated hydraulic conductivity were *in-situ* measured with Disc tension infiltrometer (Soil moisture equipment corp., USA), and Guelph permeameter (Soil moisture equipment corp.,, USA), respectively. Soil samples were taken in three replicates and brought to the laboratory to determine the soil water contents by gravimetric method. Yamanaka hardness was measured with push-cone (DIK-5553, Japan), one of hand-push type hardness meter. The soil cores and bulk samples were taken from individual soil layers and brought to the laboratory for further determinations. Bulk density was measured using soil core samples, Φ7.5 cm × h7.5 cm, using methods described by Klute et al. (1986).

Laboratory methods All analyses were carried out on the fine earth fraction (< 2 mm). Particle-size analysis was performed by the hydrometer method after dispersion with Na-hexametaphosphate (Klute et al., 1986). Soil pH was measured potentiometrically in H_2O (1:5 w/v) with a pH meter (Orion, USA). The electrical conductivity (EC) was determined as the

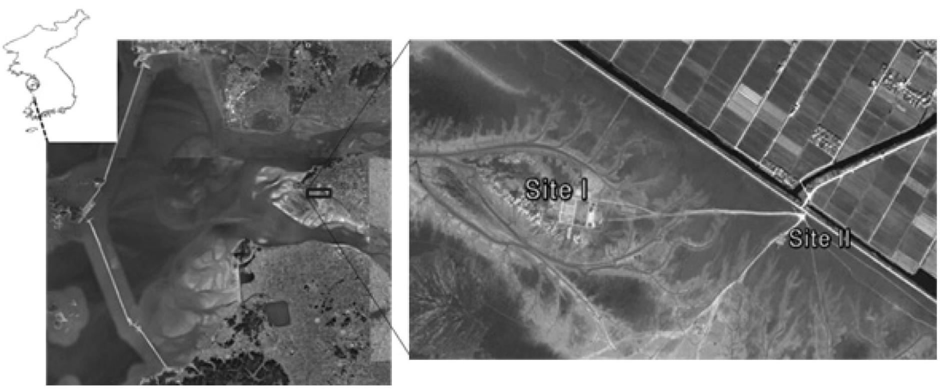
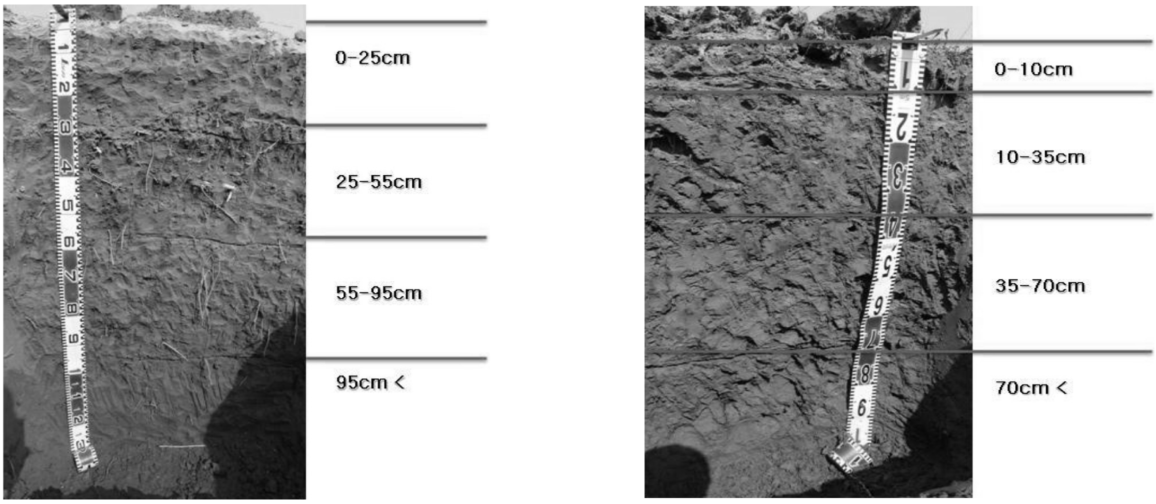


Fig. 1. Map showing the location of the investigated tidal lands.



a. Site I **b. Site II**

Fig. 2. Profile pictures showing different soil layers at the investigated sites.

Table 1. Soil profile description of investigated sites.

Sites	Layer (Depth)	Description
I	Ap1 (0-25 cm)	Grayish brown (2.5Y 5/2) silt loam; few fine prominent yellow red (5YR 4/6) and few fine prominent yellowish brown (10YR 5/6) mottles; weak fine granular structure; friable, slightly sticky and slightly plastic; many fine mica; common fine wild grass roots; abrupt smooth boundary.
	A2 (25-55 cm)	Olive gray (5Y 5/2) silt loam; common fine to medium prominent strong brown (7.5YR 5/8) mottles; weak medium platy structure; friable, slightly sticky and slightly plastic; mica as above; many fine to coarse roots; few fine pores; gradual smooth boundary.
	Cg1 (55-95 cm)	Olive gray (5Y 5/2) sandy loam; common fine to medium prominent light olive brown (2.5YR 5/6) and common fine to medium prominent strong brown (7.5YR 5/8) mottles; friable, slightly sticky and slightly plastic; mica as above; many coarse roots; few fine pores; clear smooth boundary.
	Cg2 (95 cm+)	Dark gray (2.5Y 4/1) - sandy loam; few fine to medium prominent strong brown (7.5YR 5/8) mottles; weak medium platy structure; friable, slightly sticky and slightly plastic; mica as above; no root; few fine pores
II	A1 (0-10 cm)	Dark gray (2.5Y 4/1) silt loam; few fine prominent yellow red (5YR 4/6) and few fine prominent yellowish brown (10YR 5/6) mottles; weak fine platy structure; friable, slightly sticky and slightly plastic; many fine mica; few fine roots; abrupt smooth boundary.
	A2 (10-35 cm)	Dark gray (5Y 4/1) silt loam; few fine prominent yellow red (5YR 5/8) mottles; weak fine to medium platy structure; friable, slightly sticky and slightly plastic; mica as above; few fine roots; gradual smooth boundary.
	Cg1 (35-70 cm)	Dark gray (5Y 4/1) silt loam; common fine to medium prominent light olive brown(2.5YR 5/6) mottles; weak fine to medium platy structure; friable, slightly sticky and slightly plastic; mica as above; no root; diffuse smooth boundary.
	Cg2 (70 cm+)	Dark gray (gley1 4/) silt loam; common fine to medium distinct olive gray (5Y 5/2) and common fine to medium prominent light olive brown (2.5YR 5/6) mottles; structureless (massive); friable, slightly sticky and slightly plastic; mica as above.

EC (1:5) value in supernatant 1:5 soil: water solution multiplied by the correction factor of 5 (NIAST, 2000). Organic carbon was determined by wet digestion method as described in Tyurin (1931) and expressed as organic matter (OM) using Van Bemmelen factor 1.724. The cation exchange capacity (CEC) and the exchangeable cations were determined by the extraction using 1*N* NH_4OAc solution buffered at pH 7 followed as Sumner and Miller (1996). The cations in 1*N* NH_4OAc extracts were measured with ICP (GBC, Australia).

Table 2. Particle size distribution of each layer in soil profiles of investigated sites.

Site	Layer	Sand fraction†					Sand	Silt	Clay	Soil texture
		VCS	CS	MS	FS	VFS				
		%								
I	Ap1	0.0	0.0	0.0	0.2	44.5	44.7	51.0	4.3	Silt loam
	A2	0.0	0.0	0.0	0.0	41.4	41.4	54.3	4.3	Silt loam
	Cg1	0.0	0.0	0.0	0.0	58.3	58.3	37.4	4.3	Sandy loam
	Cg2	0.0	0.0	0.0	0.0	49.8	49.8	46.0	4.3	Sandy loam
II	A1	0.0	0.0	0.0	0.0	16.3	16.3	72.4	11.3	Silt loam
	A2	0.0	0.0	0.0	0.0	18.8	18.8	80.0	9.2	Silt loam
	Cg1	0.0	0.0	0.0	0.0	21.9	21.9	70.9	7.2	Silt loam
	Cg2	0.0	0.0	0.0	0.0	22.8	22.8	70.0	7.2	Silt loam

†Defined size class used by USDA classification scheme; VCS: very coarse sand; CS: coarse sand; MS: medium sand; FS: Fine sand; VFS: very fine sand.

Table 3. Physical properties of each layer in soil profiles of investigated sites.

Site	Layer	Bulk density	Porosity	Vw†	Hardness	Kfs‡
		Mg m^{-3}	%	%	mm	cm hr^{-1}
I	Ap1	1.34 ± 0.01§	49.4 ± 0.5	23.9 ± 0.6	13.8 ± 2.4	0.63 ± 0.15
	A2	1.40 ± 0.02	47.1 ± 0.9	31.4 ± 0.8	21.8 ± 1.3	0.002 ± 0.002
	Cg1	1.37 ± 0.03	48.1 ± 1.1	42.2 ± 0.5	19.4 ± 1.3	0.37 ± 0.22
	Cg2	1.46 ± 0.02	44.9 ± 0.7	44.9 ± 0.6	17.4 ± 1.8	0.46 ± 0.24
II	A1	1.38 ± 0.01	47.9 ± 0.3	32.3 ± 0.5	13.2 ± 1.6	0.003 ± 0.002
	A2	1.46 ± 0.02	44.7 ± 0.7	42.8 ± 0.3	20.0 ± 2.2	0.20 ± 0.02
	Cg1	1.40 ± 0.02	47.1 ± 0.8	45.4 ± 1.1	18.0 ± 1.9	0.0001 >
	Cg2	1.41 ± 0.04	46.7 ± 1.3	46.7 ± 1.0	13.6 ± 1.1	0.34 ± 0.12

†Volume of water; ‡Field saturated hydraulic conductivity; §Standard deviation.

Table 4. Chemical properties of each layer in soil profiles of investigated sites.

Site	Layer	pH	EC	OM†	CEC‡	Exch. Cation				ESP§
						Ca	K	Mg	Na	
		(1:5)	dS m^{-1}	g kg^{-1}	$cmol_c$ kg^{-1}	$cmol_c$ kg^{-1}				%
I	Ap1	8.1	0.61	3	5.8	0.5	0.9	1.4	3.2	55
	A2	6.2	11.3	3	5.3	3.8	0.6	4.4	9.6	181
	Cg1	7.9	3.3	2	5.7	0.9	0.9	2.4	5.0	88
	Cg2	8.0	12.8	2	5.1	1.4	1.3	4.0	10.7	210
II	A1	7.5	4.0	4	8.6	1.0	1.0	3.9	6.5	76
	A2	7.1	6.9	3	7.8	1.3	0.8	4.0	8.4	108
	Cg1	7.2	8.4	3	8.0	1.6	1.0	4.1	8.7	109
	Cg2	7.5	8.5	3	8.4	1.4	0.9	3.7	8.4	100

†OM: soil organic matter content; ‡CEC: cation exchange capacity; §ESP: exchangeable sodium percent. The coefficient of variance between replicates for each mean value in above table was less than 15%.

Results and Discussion

Soil profile description The soil profiles at both sites were separated into different soil layers (Fig. 2). It was noted that each site, the profile is divided into four layers based on the similarity of soil color, texture and visual differences. The depth of different layers at each investigated are different from one another. According to Soil Taxonomy classification (Schoeneberger et al., 2002), the soil profile of Site I was described as Ap1, A2, Cg1, and Cg2 layers. In the same way, the soil profile of Site II was described as 4 layers, A1, A2, Cg1, and Cg2 (Table 1).

Physico-chemical properties The Site I exhibited increase in soil water contents down the profile ranging between 23.9% (Ap1 soil layer) and 44.9% (Cg2 soil layer), water-saturated, as presented (Table 3). It was also noted that soil hardness and soil bulk density increased down the profile with a slightly increase at 25-55 cm soil depth (21.8 mm and 1.40 Mg m^{-3}) for hardness and bulk density, respectively. This slight increase in hardness has also decreased the water movement down the profile and at this soil layer, water percolation was reduced than the layer above and below (Table 3). The bulk density increased down the profile starting from 1.34 Mg m^{-3} (Ap1 cm soil layer) to the maximum 1.46 Mg m^{-3} (Cg2 cm soil depth). At this site, the sub-soil layer (25-55 cm) showed an increased hardness, and bulk density with reduced water movement. The Site II presented different picture and recorded increased soil water contents, hardness, and bulk density at the shallow sub-soil layer (A2 soil layer). But this layer recorded an increased water movement as described by percolation (0.20 cm hr^{-1}). Below this layer, water contents, soil hardness and bulk started decreasing and water percolation to a negligible (0.0001> cm hr^{-1} at Cg1 soil layer). It is also noteworthy that the soil texture was uniform and still behaved differently for different properties in different soil layers.

At Site I, the EC at the surface soil (Ap1 soil layer) was 0.61 dS m^{-1} that increased to 11.3 dS m^{-1} at the sub-surface soil layer (A2 soil layer). The similar trend was also found for the concentrations of Ca^{2+}, K^{+}, Mg^{2+} and Na^{+}. Site II also recorded an increase in EC down the profile and ranged between 4.0 dS m^{-1} (A1 soil layer) and 8.5 dS m^{-1} (Cg1 soil layer), while the pH was almost constant at all the layers.

Comparing soil profile characteristics between two sites Soil texture is an important factor in determining the trend of soil properties and Pitt (1987) described texture and soil moisture as the typical factor causing variation in water movement. Sites I and II had a little different particle size distributions, showing finer texture in Site II than that in Site I. Nevertheless, near 100% of soil particles were less than 0.1 mm in diameter in both soils (Table 2). Soil organic matter (OM) at the investigated sites was relatively low values, ranged between 2 and 4 g kg^{-1} and was almost constant down the profile at these sites (Table 4). In soil layer discrimination, both of soil profiles are composed of A-C horizon, indicating initial soil development status.

EC and soil structure are important factors for upland soil quality. Surface soil of Site I, treated flooding desalination and green manure cultivation for two years, had lower EC and higher field saturated hydraulic conductivity than those of Site II which is uncultivated land. Especially, exchangeable sodium content was the lowest in Site I Ap1 layer than in other layers. This is probably due to flooding desalination and green manure cultivation. Besides, Ap1 and A2 layers of soil profile in Site I showed brighter soil color and more root observation than those of Site II. Especially, Ap 1 layer of Site I had week fine granular structure. This is probably due to green manure cultivation. In other words, green manure cultivation could enhance soil structure formation in top layer. On the other hand, A2 layer below Ap1 layer had relatively high EC and low field saturated hydraulic conductivity, probably due to plowing for green manure cultivation. This could restrict water and solute movement. Nevertheless, coarse roots were observed in Cg1 layer (Table 1). Kay (1989) reported pasture such as rye could enhance structural development of deep soil through root elongation. This profile was under green manure cultivation of two year from April 2007 to April 2009. It is expected that the effect of green manure cultivation on soil profile characteristics will be clearer with longer green manure cultivation. Without artificial treatment, Site II had thin A1 layer of 10 cm thickness and very low field saturated hydraulic conductivity less than 0.01 cm hr^{-1}, showing unfavorable condition for upland cropping.

For tidal lands developed recently, it is considered that the profile development and other pedogenic processes require time to be evident (Scalenghe et al., 2002). The studies in Indonesia and Malaysia have shown promising results for agricultural production in case of tidal and reclaimed lands (Chen and Tan, 2002; Koswara and Rumawas, 1984). The soil characteristics are very important from plant growth point of view (Ahmad et al., 2008) especially in case of reclaimed lands and tidal lands (Iost et al., 2007). Land surface of the studied sites in Saemangeum reclaimed tidal lands exposed 17 years ago, changed from water-covered area by sea water subtraction. Nevertheless, soil EC was still too high to sustain plant growth. By the large, for high cash upland crops and intensive agricultural use, site-specific soil ripening such as flooding desalination and green manure cultivation could be useful.

Conclusions

Newly reclaimed tidal land soils exhibited great spatial and temporal variability in different properties. The electrical conductivity and the water movement in these types of soils need to be monitored and managed continuously for sustainable production. Soil texture is also very important from management point of desalination. In silty soil, having a difficulty in a natural desalination and structure formation, an artificial enhancing such as flooding desalination or green manure cultivation could promote soil ripening, especially in surface layer. For high cash upland crops and intensive agricultural use, site-specific soil ripening may be useful.

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