Chronological Changes of Soil Carbon Stock in Korea

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Abstract: Soil organic carbon (SOC) is illustrated as a potential capacity to store some of the excess atmosphere C. SOC is composed of the debris of plant and microorganism of which growth is related to temperature and soil properties. Monitoring SOC store in the soils is prerequisite to figure out C sequestration potential and guides to make an effective policy of mitigating atmosphere C controlling climate change. Korea developed an agricultural soil information system covering soil map and fertilizer recommending system in which soil testing data was accumulated. Several projects on soil testing were performed as follows: 1) "Ten years project on integrated soil improvement for paddy soils" from 1980 to 1989, 2) "Five years project on integrated improvement of upland soils" from 1995 to 1999, 3) "Soil testing on the fields of cultivating strategic crops" from 2000 to 2004, 4) "Soil testing on the fields for major crops" from 2005 to 2008, 5) Soil testing for farm land in 2009". To figure out chronological changes of SOC according to management practices and soil properties these project data were analyzed. Chronological SOC change of paddy soils was kept a constant content but that of upland soils was increased in early 2000s. Although SOC was changed as soil properties varied, C sequestration was depended on management practices. Best management practices are needed to increase SOC for mitigating air C and preserving soil fertility.

Keywords: C sequestration, Soil organic carbon, Chronological changes, Soil properties

1. Introduction

Soil organic carbon (SOC) is composed of a plant debris and decomposition intermediates and microorganism. The C occurs in four pools: atmosphere, terrestrial biota, soil, and ocean (IPCC. 2001; Janzen 2003; Schimel 1995). These pools contain 760 Pg C in atmosphere, about 500 Pg C in terrestrial biota, about 1,500 to 2,000 Pg C in soil, and 39,000 Pg C in the oceans. The amount in soils is at least 2 times that in the atmosphere. Can the soils accumulate more carbon? It is an answer to know how much C was sequestered in soil and how much C sequestration potential is. Because these pools are not static, SOC can contribute to mitigation of climate change.

C sequestration potential is different from soil site characteristics and management practices and soil properties. C sequestration according to where the soil is located is governed by its altitude and vegetation. Because the higher altitude is the lower temperature, SOC is different from altitude. SOC is governed by the kind of vegetation and soil properties including parent material and soil texture (Ohkura et al. 2003) and drainage (Beerbaum 2003), etc. To know C sequestration potential, it is prerequisite to monitor SOC status in the soils.

Korea has established fertilizer recommending system since 1980 and has used SOC for recommending N fertilizer. The C in the soils consists in organic form and it can be determined by total organic C. Korea has performed projects on soil testing in which more than 150 county laboratories have taken part. The projects were: 1) "Ten years project on integrated soil improvement for paddy soils" from 1980 to 1989, 2) "Five years project on integrated improvement of upland soils" from 1995 to 1999, 3) "Soil testing on the fields of cultivating strategic crop" from 2000 to 2004, 4) "Soil testing on the fields for major crop" from 2005 to 2008, 5) Soil testing for farm land in 2009". The data of sol testing has been input in agricultural soil information system to utilize for making a guideline on management practices and it can be input multiplicative to recommend fertilizers for several crops. It is meaningful to categorize by the period of projects.

We extracted and calculated the analyzed data from multiplicative data of agricultural soil information system. Soil attributes of the system were used in calculation. The aims of this study were to understand chronological changes of SOC according to different management practices and to figure out the C sequestration on soil properties.

2. Chronological changes of SOC in Korea

Chronological changes of SOC were insignificant for paddy soils, but significant for upland soils as shown in Table 1. SOC of paddy soils was sustained from 13.2 g C kg^{-1} in the 1980s through 13.6 g C kg^{-1} in the 2000s and 13.3 g C kg^{-1} in 2009. Because the SOC input in paddy soils was decomposed within a year due to water, it is difficult to raise C sequestration potential. Contribution of paddy soils to climate change could be little due to inability of keeping C. SOC of upland soils was 14.0 g C kg^{-1} in the later 1990s, but it was increased to 15.8~16.9 g C kg^{-1} in the 2000s. All arable lands were sampled by the projects accomplished in the 1990s and in 2009 but the more fertile soils cultivating beneficial crops of county were sampled in the 2000s. A tendency of applying compost to cultivate beneficial crops could increase SOC of upland soils.

Table 1. Chronological changes for Korean arable soils

Soils	Project period	Sample sites (No.)	SOC (g C kg^{-1})	
			Mean	Standard deviation
Paddy soils	1980~1988	616,687	13.2	5.2
	2000~2004	393,292	13.5	8.0
	2005~2008	493,927	13.6	8.5
	2009	348,950	13.3	5.5
Upland soils	1995~1999	890,588	14.0	9.1
	2000~2004	136,786	16.9	13.3
	2005~2008	399,004	16.5	14.4
	2009	240,393	15.8	12.3

Because SOC of paddy soils was increased by continuous applying compost (Kim 2003), C sequestration potential could be higher than the monitored SOC. The best scheme to sequester air C into soil should consider what kind of management practices suitable for soil properties. SOC depends on agricultural management practices which are prominently different between paddy soils and upland soils because of putting water. SOC of paddy soils was decomposed to a certain level within a year by waterloging but that of upland soils is sustained for several years. Management practices for upland soils are more important than those of paddy soils.

Crops of upland soils were cultivated in order of red pepper, soybean, Chinese cabbage in Korea. Chronological change patterns of major crops were similar to those of upland soils as shown in Fig. 1. SOC of the soil cropping red pepper was increased till 2008 but decreased in 2009. Increase in C sequestration depends on management practices of these major crops in Korea.

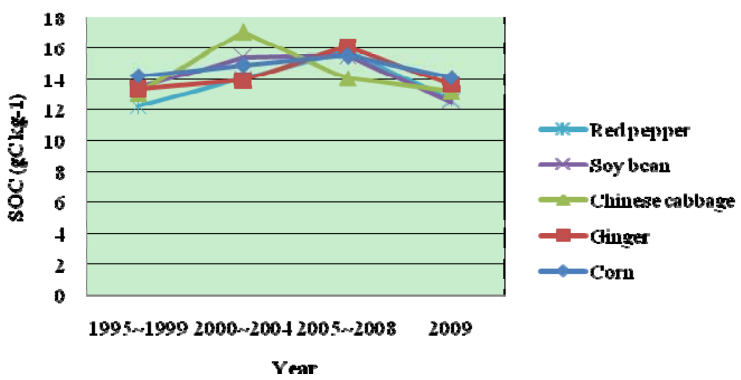

Fig. 1. Chronological changes of SOC of upland soils cropping major crops
(Legend boxes in all figures are arranged in order of number of sampling sites)

3. The effects of soil properties on SOC

1) Paddy soils

As no chronological changes of SOC appeared in every soil properties, the paddy soils seem to be close to steady-state by traditional management practice. Because rice straw was removed from soil to utilize as cattle food, SOC of paddy field could be at least C sequestration potential. It is necessary to establish C sequestration potential of paddy soils according to soil properties. Returning organic matter to paddy soils will increase SOC content till full C sequestration bound. How much organic matter is needed to increase C sequestration? The answer is to establish best management practices for mitigating air C and preserving soil fertility.

SOC of paddy soils located in plain and valley were about 13 g C kg^{-1}, but SOC of paddy soils located in the foot of mountain and alluvial fan were higher than that in the others (Fig. 2). High SOC in the soil of foot of mountain was caused by high altitude and that in alluvial fan was by accumulation of SOC.

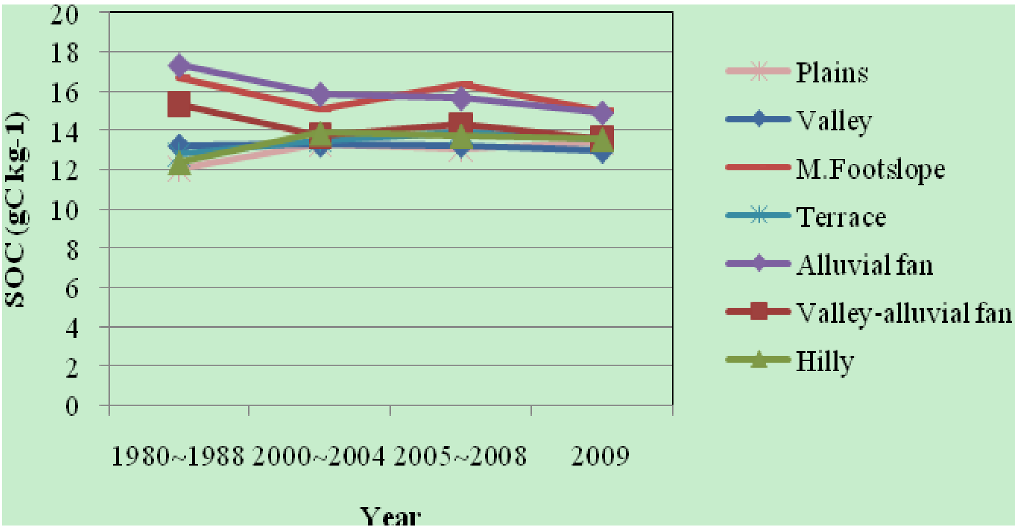

Fig. 2. Chronological changes of SOC of paddy soils located in different topography

Although chronological changes of SOC according to parent material were constant, SOC of paddy soils located in acid rock alluvium and porphyry alluvium were higher than the others. SOC of paddy soils in acid rock colluviums and porphyry alluvium were higher than the others as shown in Fig. 3. Parent material did not contain SOC at the beginning but affected SOC increase by aggregation and microbial activity.

Fig. 4 showed that SOC content of gray soil, alluvial soil and red-yellow soil were 13 g C kg^{-1} but that of saline soil was lowest. Alluvial soil of which subsurface was red-yellow soil was high. Management practices of applying organic matter is recommended on saline soil. Alluvial soil of which subsurface was red-yellow soil had high SOC, because it was mainly located in acid rock colluviums of foot of mountain.

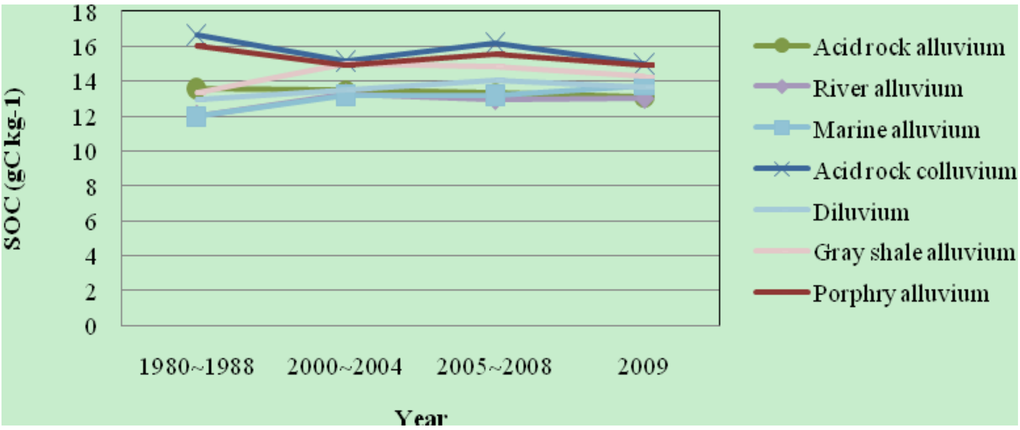

Fig. 3. Chronological changes of SOC of paddy soils located in different parent material.

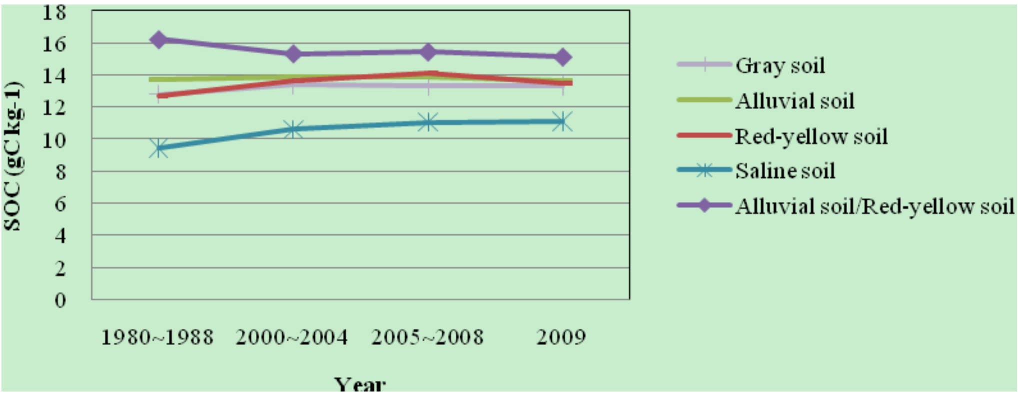

Fig. 4. Chronological changes of SOC of paddy soils by categorizing with great soil group.

Soil properties also had related to SOC content of paddy soils (Fig. 5, 6, 7, 8). SOC content of paddy soils of which drainage condition was poor was low. SOC content of paddy soils was related to gravel content. SOC content was high in the soils of containing more than 10 percentage of gravel in paddy soils (Fig. 6). SOC of paddy soils was highest in clayey soil but lowest in sandy soil (Fig. 7). Chronological change in SOC of coarse silty soil was increased. This was similar to the result of Six et al (2002), Ohkura et al. (2003), and Leifeld et al. (2003). SOC of paddy soils lower than 20 cm in effective soil depth was lowest. But there was no difference between the soils of higher than 20 cm in effective soil depth. Establishing new management practices such as soil brought from another place and improving drainage should be recommended to increase SOC in paddy soils.

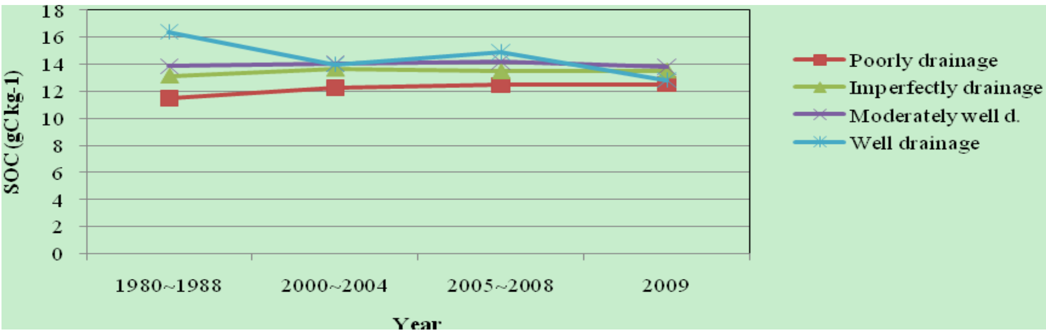

Fig. 5. Chronological changes of SOC in different condition of paddy soils.

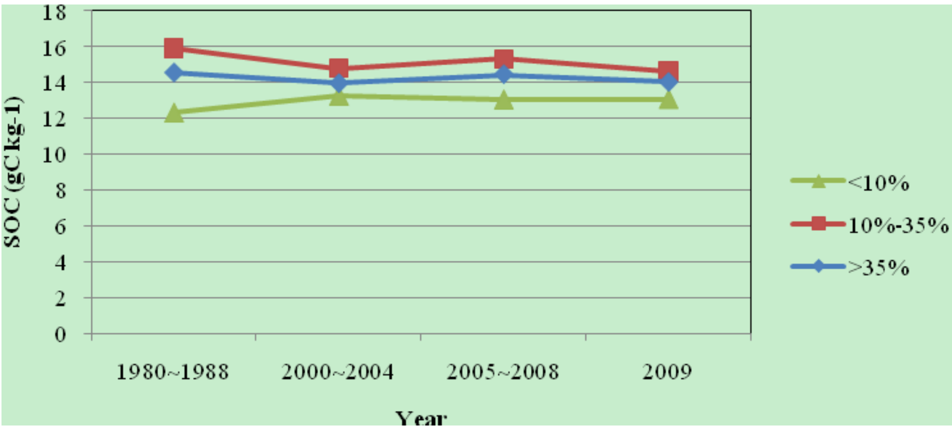

Fig. 6. Chronological changes in SOC according to different gravel content of paddy soils.

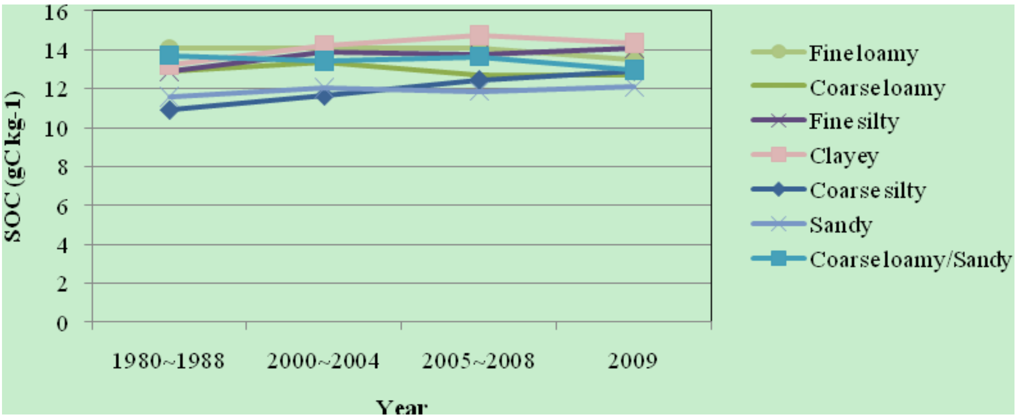

Fig. 7. Chronological changes in SOC according to several soil texture of paddy soils.

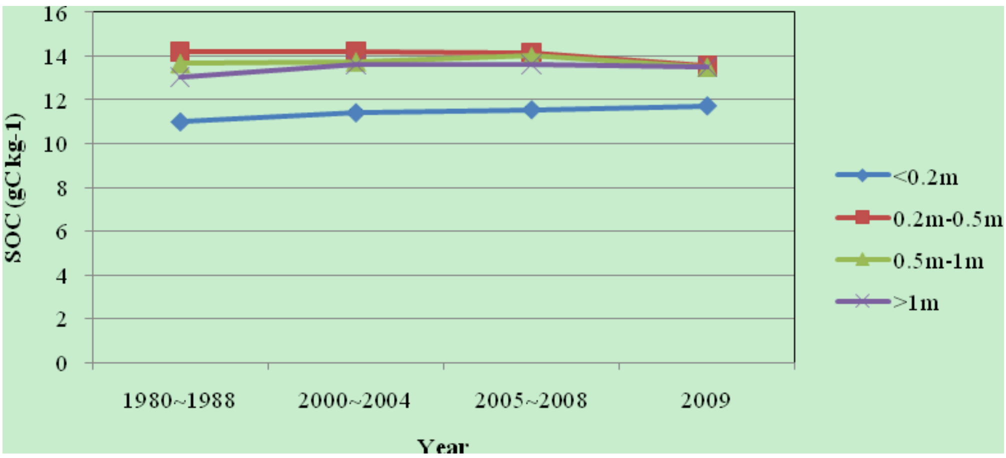

Fig. 8. Chronological changes in SOC of paddy soils according to effective soil depth.

2) Upland soils

Chronological changes in SOC of upland soils were increased in the 2000s but decreased to in 2009 (Fig. 9). All the arable soils were sampled in 1990s and 2009 and the soil cropping major beneficial crops were sampled in the 2000s. Much organic matter was input into soil to cultivate beneficial crops. As same patterns in chronological change of SOC to all soil properties (From Fig. 9 to 15) were interpreted as the higher organic matter increased SOC, it should be possible to contribute to C sequestration by establishing the management practices to increase SOC of upland. SOC of the 2000s was higher about 3 g C kg^{-1} than that of the 1990s which was equivalent to about 3 Mg ha^{-1}. Upland soils could sequester the air C by different management practices (Gumbert 2003; Pretty et al. 2003).

Chronological changes of SOC were same patterns in topography and similar to those of upland soils (Fig. 9). The soil in the foot of mountain and alluvial fan were high in SOC as paddy soils. Chronological changes of SOC were also same patterns in parent materials (Fig. 10). The soils in granite gness residuum and acid rock colluviums were higher in SOC than others. The soils composed of acid rock colluviums contained high SOC in both paddy soils and upland soils. There were no significant differences among great soil groups (Fig. 11). As a result of above how much organic matter input was more effective to increase SOC than where the soil located.

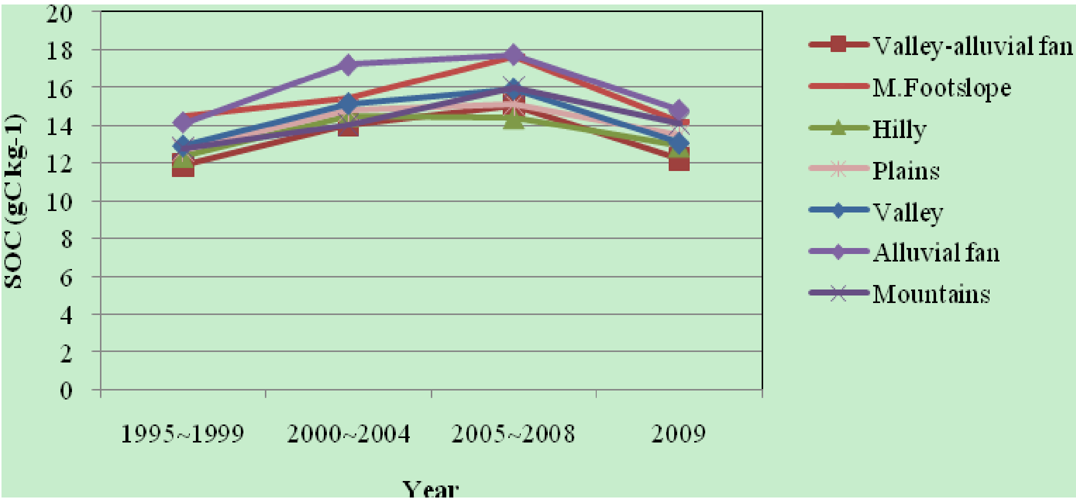

Fig. 9. Chronological changes of SOC of upland soils located in different topography

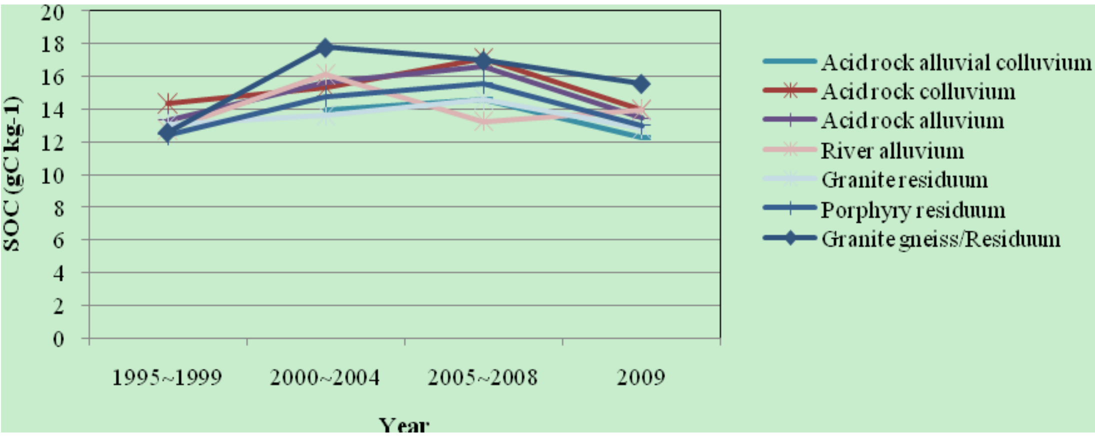

Fig. 10. Chronological changes of SOC of upland soils located in different parent material

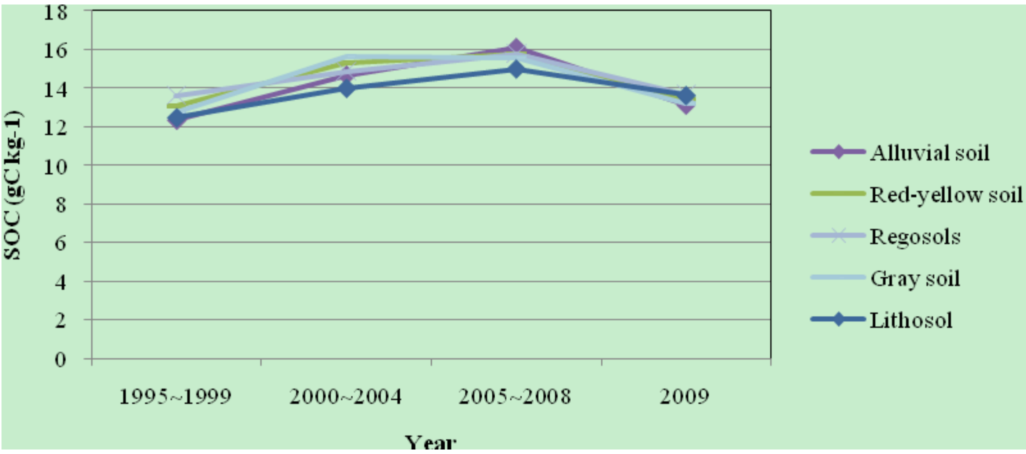

Fig. 11. Chronological changes of SOC of upland soils by categorizing with great soil group

SOC of upland soils were also affected by soil properties. Effect of all of soil properties on SOC of upland soils were significant but not exceed chronological changes. SOC contents of upland soils were slightly differed from soil drainage (Fig. 12) and gravel content (Fig. 13) and soil texture (Fig. 14) and effective soil depth (Fig. 15). The poorly drained upland soils was low in SOC. Low SOC in the poorly drainage soil was the same as paddy soil. The more gravel content the more SOC in upland soils. Soil texture affected SOC in upland soils as the more clay the more SOC. SOC level could categorize by soil texture (Beerbaum, 2003; Leifeld et al. 2003; Ungaro et al. 2003). Soil texture is used for SOC indicators (Hernandez 2003; Paustian et al. 2003). SOC of upland soils deeper than 50 cm in effective soil depth was low. Although SOC of upland soils was different from between soil properties, SOC was more influenced by how much organic matter input.

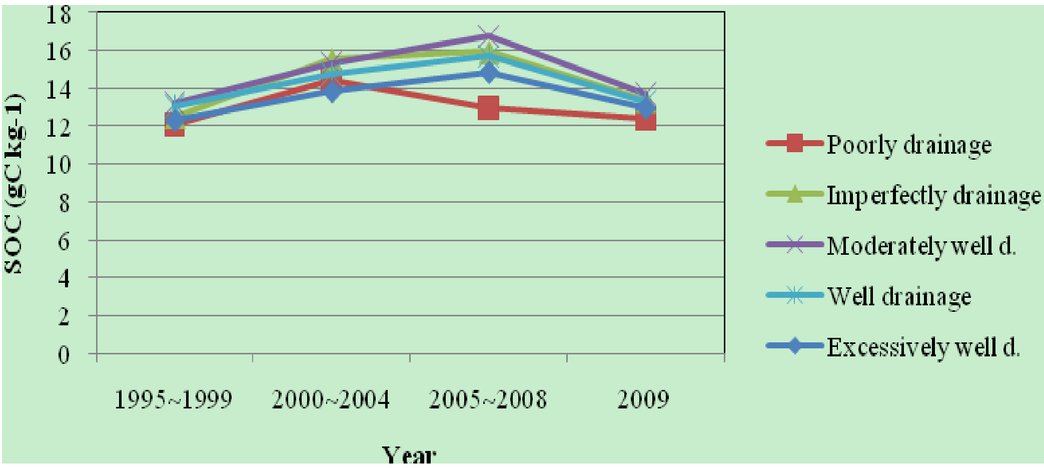

Fig. 12. Chronological changes of SOC in different condition of upland soils.

Fig. 13. Chronological changes in SOC according to different gravel content of upland soils.

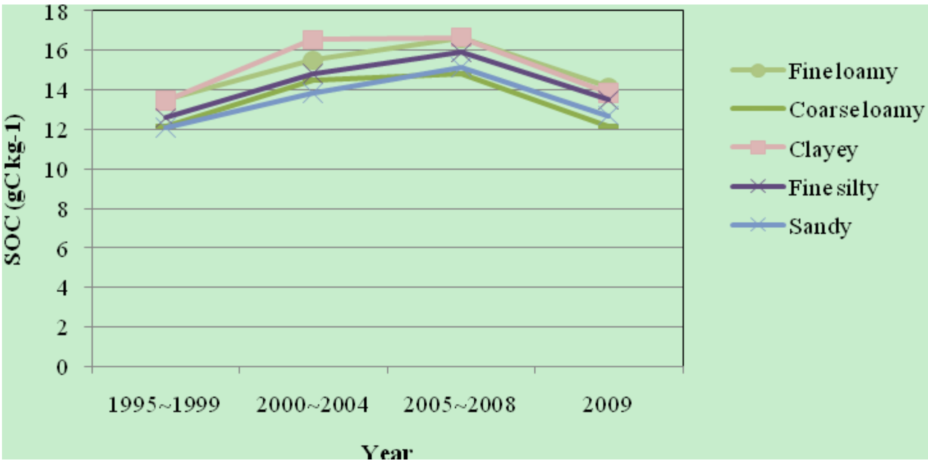

Fig. 14. Chronological changes in SOC according to several soil texture of upland soils.

Fig. 15. Chronological changes in SOC of upland soils according to effective soil depth.

4. Conclusion

Chronological SOC change of fields was mainly depended on how much organic matter input. Chronological SOC change of paddy soils seemed to be close to steady-state because of removing rice straw from paddy soils. Chronological SOC changes of upland soils were high in the year of cultivating beneficial crop. As more organic matter input than decomposable amount causes SOC increase up to a C sequestration potential, C sequestration could calculate with SOC and C sequestration potential which would be established from some projects. Best management practices are needed to increase SOC for mitigating air C and preserving soil fertility.

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