Effects of soil management on changes of soil carbon content in alluvial paddy soil in Niigata

Toshimitsu Honma[A], Hirotomo Ohba[B] and Takuji Ohyama [C]

[A]Niigata Agricultural Research Institute, Japan, Email homma.toshimitsu@pref.niigata.lg.jp
[B]Niigata Agricultural Research Institute, Japan, Email ohba.hirotomo@pref.niigata.lg.jp
[C]Graduate School, Science and Technology, Niigata University, Email ohyama@agr.niigata-u.ac.jp

Abstract
Effects of soil management on carbon content in alluvial paddy were investigated using past soil survey data of Niigata prefecture, Japan. The changes of soil management were as follows; (1) slight decrease in nitrogen and phosphate fertilizer application rates, (2) decrease to half in the application of soil amendments, like calcium silicate, (3) decrease in compost application and increase in rice straw application, (4) increase in pipe drainage. In spite of these changes, negligible change of carbon content in the plow-layer of alluvial paddy soils had been observed for past twenty-five years. However, without rice straw application and paddy-upland rotations, the soil carbon content had been decreased. Carbon content of alluvial paddy soils classified into Gley Lowland soil (Fluvisol or Gleysol) at the depth of 0-30 cm was calculated about 49-103 g/kg and gross carbon sequestration was calculated 7.68 Mt in the paddy field soils in Niigata prefecture.

Key Words
Carbon sequestration, soil survey, alluvial paddy, soil management.

Introduction
Pedscape stocks a large amount of soil carbon. The amount of global carbon stock is estimated at 1,200-1,600Gt, which is more than that of vegetation biomass (Paustian *et al.* 1997). Therefore, changes of soil carbon contents may affect global climate change, through the changes in CO_2 concentrations in the air. Improvement of agronomic practices for carbon sequestration in the agricultural soils is very important for the mitigation of climate change (IPCC 2007). It is well known that soil carbon content in agricultural land was affected by soil managements such as the application of organic matter and plowing, etc. For example, application of fermented compost, no-tilled cropping, cover crop and multiple cropping, etc. add carbon to soils (Paustian *et al.* 1997; Franzluebbers 2005; Reicosky *et al.* 1997). The purpose of this study is to clarify the effects of soil management on changes of carbon content in the alluvial paddy soils, which had been used for paddy rice production a major grain in monsoon-Asia, or paddy rice-upland crop rotations, using the past soil survey data in Niigata Prefecture.

Methods
In Japan, the national soil information database was developed with the obtained data from Soil Survey for Maintenance of Farmland Fertility, and Fundamental conducted by the Ministry of Agriculture, Forestry and Fisheries (MAFF). We used the data of Soil-Environment Monitoring Project (Stationary Monitoring) in Niigata prefecture carried out in every 5 years for 25 years (1979-2004). Niigata prefecture is a major rice production area located in the middle of Japan. About 90 % of arable land is paddy field and 70% of paddy fields is the alluvial paddy, which is classified Gray Lowland soil and Gley Lowland soil, mainly (Figures 1, 2). The both soils were classified into Fluvisol or Gleysol by FAO *et al.* (1998). To clarify the effect of soil management on changes of soil carbon content, data of alluvial paddy soils (total number of data was 1,418 and classified as following, Gley Lowland soil: 1,122, Gray lowland soil: 259, Brown Lowland soil: 37) were selected from above survey. Many paddies have pipe-drainage and drain canal, thus a good drainage paddy has been rotated upland and was used for upland crop like soybean and some vegetables frequently. The effects of soil management, such as the application of fertilizer, soil amendments and organic matter in several soil types, on changes of soil psycho-chemical properties (mainly in top soil) were examined with interviewing farmers.

Results
Changes of soil management
The changes of paddy soil management in twenty years were shown in Table 1. The amount of nitrogen and phosphate fertilizer applied had been decreased slightly, for a production of good-taste rice grain. The

amount of soil amendments, such as calcium silicate, was decreased to half, for cutting production cost and reducing labor, while phosphate materials were increased for enhancing soil fertility. In contrast, the ratio of compost application was reduced and the ratio of rice straw application was increased markedly. Thus, it was considered that the measures for enhancing soil fertility had been changed from compost, which is getting hardly and need much cost, to rice straw. The ratio of pipe drainage was increased markedly for efficient machinery work and avoiding wet injury.

Actual conditions of soil carbon content

Figure 3 showed that the changes of soil carbon content of plow-layer in alluvial paddy fields for twenty five years (1979-2004). There was a dispersion widely in Brown Lowland soils due to a little sample number. The rough carbon content of several soil types was as follows: 30 g/kg for Gley Lowland soils, 20 g/kg for Gray Lowland soils, a little less than 20 g/kg for Brown Lowland soils. Although the soil management, such as manure and compost applications and pipe drainage, in this survey period had been changed, no changes of soil carbon content had been observed statically. Generally, pipe drainage forced to lower of groundwater level in paddy field. Therefore, especially Gley Lowland soil changes into Gray Lowland soil with the reduce of soil carbon gradually. It is considered that one of the reasons for no-change of soil carbon content in the past survey is the effect of the rice straw application, which avoids the soil carbon decrease in well-drained paddy fields. The soil carbon content in several layers in Gray Lowland soils and Gley Lowland soils had been shown in Figure 4. The carbon content in Gray Lowland soil was lower than that of Gley Lowland soil, and was lower toward subsoil, while a little decrease of carbon content of subsoil had been observed in Gley Lowland soils. It is recognized that the carbon content of surface horizon in arable land is high, because of accumulation of organic matter and root residues. Some Gley Lowland fields, however, had been included the peat in subsoil; therefore, a large amount of carbon is sequestered in subsoil than Gray Lowland field. Thus, the carbon content of subsoil should be more decreased than the surface horizon by the convert from poor-drained to well-drained in Gley Lowland soils using pipe drain.

Effect of soil managements on changes of soil carbon content

Table 2 showed the effect of paddy-upland rotation on changes of soil carbon content in several soil types. The history of paddy-upland rotation was classified as follows: rotation which had experienced irrigated paddy rice and upland crop rotation in past five years, no-rotation, which had not been converted into upland at all in past five years. Carbon content in Brown Lowland soils and Gley Lowland soils were lower than that of no rotational cropping significantly. The decrease in carbon content was observed in Gray Lowland soils. Therefore, the paddy-upland rotations might provoke decreasing carbon content in paddy soil.

The effect of rice straw application had been examined by comparison of carbon content recorded in first survey (1979-1982) and in forth one (1994-1997) (Table 3). The carbon content in Gray Lowland soils and Gley Lowland soils were observed to decrease without application of rice straw. While, carbon content of plow layer was the same or increased by rice straw application.

Sumida *et al.* (2005) had reported that the total carbon content in soils was on the same level or increasing by continuous irrigated paddy rice without application of rice straw and were increasing conspicuously with application of rice straw, while the carbon content in soils rotated paddy and upland were markedly lower than that in the continuous paddy field in field experience. The same phenomenon was observed in this study using the data of Soil-Environment Monitoring Project (Stationary Monitoring). Thus, it was suggested that rice straw application and continuous irrigated paddy rice in alluvial paddy fields was the important management for mitigation of the depletion of soil carbon content.

Trial's calculation of carbon content in Gley Lowland soils

Carbon sequestration of Gley Lowland soils, which was 70 % of paddy fields in Niigata prefecture, had been calculated using area classified several soil types of Soil Survey for Maintenance of Farmland Fertility. Carbon content was calculated using carbon concentration in several layers, bulk density and layer depth, which contained in the data of Soil-Environment Monitoring Project (Stationary Monitoring). These soil surveys had been conducted by the Ministry of Agriculture, Forestry and Fisheries (MAFF). As a result, carbon content of Gley Lowland soils to a depth of 30 cm was calculated about 49-103 t/ha and gross carbon sequestration was calculated 7.68 Mt in Niigata prefecture (Table 4). Moreover, it was recognized that fine texture and poorly drained soil such as Strong Gley Lowland had much carbon.

Batjes (1996) had reported that the carbon content at a depth of 0-30 cm was as follows; 42 t/ha for Eutric Fluvisol, 58 t/ha for Eutric Gleysol. The same results had been recognized in this study generally.

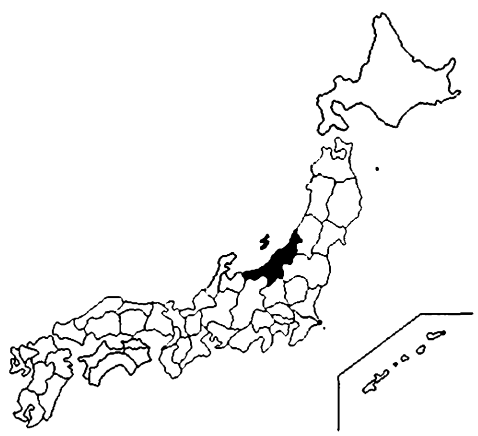

Figure 1. Place of Niggata pref.

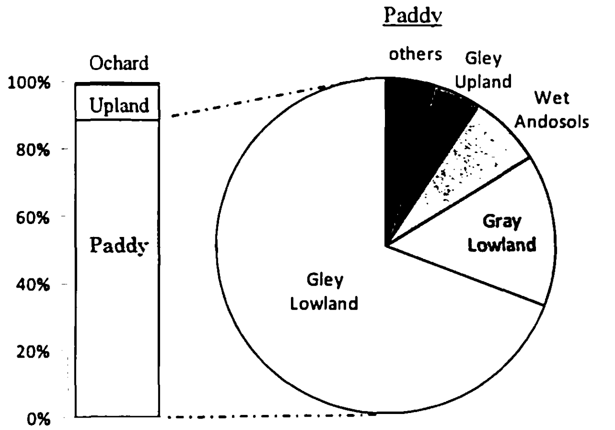

Figure 2. Ratio of arable land area in Niigata pref. *
*Fundamental Soil Survey for Soil Fertility Conservation
Total arable land area :171288 ha

Table 1. Change of Soil management in paddy field.

Item	1st survey (a)※2	4th survey (b)※2	b/a
(Fertilizer application)	$(kg\ ha^{-1})$		
N	74	70	0.95
P_2O_5	85	80	0.94
K_2O	88	89	1.01
(Soil amendments)	$(kg\ ha^{-1})$		
P_2O_5	37	45	1.21
CaO	448	221	0.49
SiO_2	256	120	0.47
(Ratio of area)	(%)		
Rice straw application	34.4	91.9	2.67
Compost application	20.6	4.5	0.22
Pipe drainage	11.3	33.6	2.97

※1 Quotation from " Agriculture in Niigata prefecture"
※2 Basic Soil - Environment Monitoring Project、1st(1980)、4th(2000)

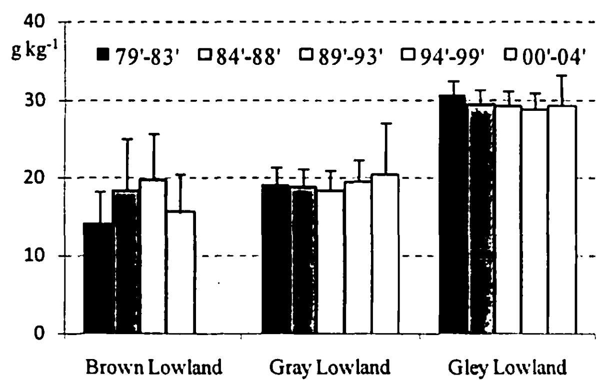

Figure 3. Changes of carbon content of several soil type.

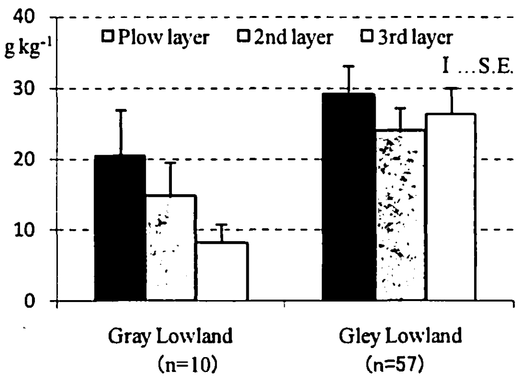

Figure 4. Carbon content of several layers.

Table 2. Effect of paddy-upland rotation in past 5 years on carbon content of plow layer in several soil types.

Histroy	Soil type		
	Brown Lowland	Gray Lowland	Gley Lowland
		($g\ kg^{-1}$)	
No-rotation	24.2 (22)***	19.5 (219)	29.9 (1013)
Rotation	11.5 (17)	18.1 (40)	26.7 (109)
t-test**	**	n.s.	**

*Basic Soil - Environment Monitoring Project

**Significantly different at p <0.01

***Number of survey sites

Table 3. Effect of rice straw application on changes of carbon content of plow layer.

	Gray Lowland		Gley Lowland	
	no-application	application	no-application	application
		($g\ kg^{-1}$)		
1st survey (1979-1982)	18.4	18.8	31.0	30.4
4th survey (1994-1997)	17.4	21.0	28.1	30.3
4th / 1st	0.95	1.12	0.91	1.00

Table 4. Carbon content within 30 com depth of Gley lowland soils in Niigata pref.

Soil type* / Texture	Strong gleyed soil			Gleyed soil			Total
	Fine(25)	Medium(3)	Skeletal(3)	Fine(13)	Medium(2)	Thapto-humic(3)	
Carbon content** ($t\ ha^{-1}$)	73.5	72.5	62.3	54.8	49.3	103.2	
Area*** (×1000ha)	60.1	17.1	5.1	9.8	3.6	9.6	105
Carbon sequestration (Mt)	4.42	1.24	0.32	0.53	0.18	0.99	7.68

* Classification of Cultivated Soil in Japan Second Approximation (1977)

* Carbon content calculated in 30 cm depth using the data of Soil-Environment Monitoring Project (Stationary Monitoring)

** Quotation from results of "Soil Survey for Maintenance of Farmland Fertility"

Conclusion

Changes of soil carbon content were not observed in the alluvial paddy soils in Niigata using past soil survey data. However, decrease of carbon was observed with no-rice straw application and paddy-upland crop rotation. Additionally, it is not to be denied that carbon content might be decreased by a pipe drainage and repeated paddy-upland rotation. To increase of soil carbon sequestration, rice straw application is necessary and suitable times of paddy-upland rotation should be required for keeping soil carbon sequestration in several soil types.

References

Batjes NH (1996) Total carbon and nitrogen in the soils of the world. *Eur. J. Soil Sci.* **47**, 151-164

FAO, ISRIC, ISSS (1998) 'World Reference Base for Soil Resources–World Soil Resources Reports 84'. (FAO: Rome).

Franzluebbers AJ (2005) Soil organic carbon sequestration and agricultural greenhouse gas emissions in the southeastern USA. *Soil Till. Res.* **83**, 120-147

Paustian K, Andreÿn O, Janzen HH, Lal R, Smith P, Tian G, Tiessen H, Van Nooedwijk M, Woomer PL (1997) Agricultural soils as a sink to mitigate CO_2 emissions. *Soil Use Manage.* **13**, 230-244

Reicosky DC, Dugas WA, Torbert HA (1997) Tillage-induced soil carbon dioxide loss from different cropping systems. *Soil Till. Res.* **41**, 105-118

Sumida H, Kato N, Nishida M (2005) Depletion of soil fertility and crop productivity in succession of paddy rice-soybean rotation. *Bull. Tohoku Natl. Agric. Exp. Stn.* **103**, 39-52