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Supplement of

Assessment on the rates and potentials of soil organic carbon sequestration in agricultural lands in Japan using a process-based model and spatially explicit land-use change inventories – Part 1: Historical trend and validation based on nation-wide soil monitoring

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11 **Supplementary Material A.** Method to create inventory of spatially-explicit land-use change in
12 Japan during year 1976-2006.

13

14 *Grid system*

15 The grid system created in this study has geographical dimensions and coordinate system identical to those in
16 Standard Grid Cell (SGC) system created by former Management and Coordination Agency, the Government of
17 Japan, which has been employed in national statistical surveys in Japan. SGC has four class of layers differs in
18 cell size and its fourth class has same spatial resolution as our grid system created for this study, with spatial
19 resolution of 1/1200 and 1/800 degree (3.0 and 4.5 second), along latitudinal and longitudinal lines, respectively.
20 Size of individual cell of the grid equivalents to a parcel of a square land ca. 100 m on a side, with an area of ca.
21 10,000 m² (1 hectare).

22

23 *Geographical data sources and interpretation of land-use/land-cover*

24 Brief description on each geographical data sources (with their abbreviated titles in bold) are listed below;

25 1) **LU**: Land Use Fragmented Mesh Version 1.1 in National Land Numerical Information, created by Ministry
26 of Land, Infrastructure, Transport and Tourism, the Government of Japan. Spatial resolution of 100 x 100 m,
27 along latitudinal and longitudinal lines, respectively. LU map products have been synthesized from various data
28 sources, such as topographical maps, current land usage status maps, satellite images (Landsat, Terra-Aster,
29 ALOS etc.), in combination with several data tables on land-use statistics. Created for fiscal year (FY) 1976,
30 1987, 1991, 1997, and 2006. From 11 to 16 land-use classifications (paddy field, upland field, orchard, forest,
31 waste area, building use, trunk transportation land, lake, river, etc.) were employed, with the number of
32 classifications differing among some groups of survey periods.

33 2) **VG**: Vegetation map from Vegetation Naturalness Survey conducted in National Survey on the Natural
34 Environment, created by Ministry of Environment (MOE), the Government of Japan, under authority of Article 4
35 of the Nature Conservation Law. The VG is a collection set of vector maps with approximately 270 legends of
36 plant communities. Map products created in FY 1983-1986, FY 1989-1993, and FY 1994-1998, compiled in the
37 3rd, 4th, and 5th survey, respectively, were selected and used in this study. A new nation-wide legend, produced
38 in the 6th survey to unify and arrange locally legends used in predecessor maps, was employed in this study and
39 applied to all predecessor maps by using a legend conversion table provided by MOE.

40 3) **AL**: Agricultural land map from Basic Survey on Improvement of Agricultural Production Base, created by
41 Ministry of Agriculture, Forestry, and Fisheries (MAFF), the Government of Japan. Vector maps of agricultural
42 fields classified into 4 land-use types (paddy field, upland field, orchard, and grassland). Created in 1992 and
43 2001. In synthesis of this map product, in some cases, polygons of these types of agricultural fields had been
44 modified so that sum of the area of polygons in each land-use category to be consistent with the agricultural
45 statistics at prefectural level, and thus, may include some bias.

46 A decision tree was created to decide land-use of each grid cell using legends in LU, VG, and AL as input

47 parameters, to enable compilation of different datasets having different type of information on land-use, legends,
 48 and time period. The decision tree was built using structured query language (SQL) and implemented as a
 49 PostgreSQL function. The LU, VG, and AL, in overlapping, nearby, or different periods were selected and
 50 compiled together to make 6 different groups tagged with different time period, and were applied as input data for
 51 the decision tree as summarized in Table A1. As result, grid cells were classified into 9 land-use types; 01 paddy
 52 field (PD), 02 upland field (UP), 03 orchards (OC), 04 managed grassland (MG), 05 unmanaged grassland (UG),
 53 06 forest lands (FL), 07 wetlands (WL), 08 settlements (ST), and 09 other lands (OL).

54 As any of these three geographical data sources alone could not fulfil requirement for our nation-wide
 55 simulation due to insufficient classification, accuracy, or time interval, we employed strategy to compile these
 56 different geographical data sources to set off merits against the deficit, and to interpret it; e.g. LU had more time
 57 series data than other data sources, however, in FY 1991-2006, its classification on agricultural land had only two
 58 legend items, 'paddy field' and 'other agricultural fields'. VG had more detail classifications but had only three
 59 time series data. Thus LU in FY 1991-2006 was superimposed with VG to enable subdivision of the legend item
 60 'other agricultural fields' in LU into 'paddy field', 'upland field', 'orchards', and 'grasslands'.

61 Formulation of the decision tree was rather arbitrary and, thus, preliminary. A preliminary validation on the
 62 land-use maps using geographical reference dataset on agricultural land management collected in the Basic Soil
 63 Environment Monitoring Project, Stationary Monitoring conducted in year 1979-1998 showed that accuracy rate
 64 of the land-use map for paddy field, upland field, orchards, and managed grassland were 89, 76, 75, and 71 %,
 65 respectively, on average through four waves of the monitoring survey.

66
 67

Table A1 Dataset used to composite land-use map.

Dataset	Period	land-use map				
		1976	1987	1991	1997	2006
Land use fragmented mesh data, Version 1.1 (LU) ¹⁾	FY 1976	•				
	FY 1987		•			
	FY 1991			•		
	FY 1997				•	
	FY 2006					•
Vegetation map (VG) ²⁾	FY 1983-1986	•	•			
	FY 1989-1993			•		
	FY 1994-1998				•	•
Agricultural land map (AL) ³⁾	FY 2001					•

68 1) National Land Numerical Information (Land Use Fragmented Mesh), Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan.
 69 <http://nlftp.mlit.go.jp/ksj-e/jpgis/datalist/KsjTmplt-L03-b.html>

70 2) Vegetation map, Vegetation Naturalness Survey, National Survey on the Natural Environment, Ministry of Environment, Japan.

71 3) Agricultural land map, Basic Survey on Improvement of Agricultural Production Base, Ministry of Agriculture, Forestry, and Fisheries, Japan.

72

73 Table A2 Spatial-temporal inventories employed in simulation.

Data type	Spatial resolution	Begin	End	Description
agricultural activity	Prefectural	1970	2008	estimate based on national statistics and survey on agriculture
climate	latitude: 1/120 ° longitude: 1/80 ° (ca. 1 x 1 km)	1970	1978	10 years mean values from observation between 1979 and 1988
		1979	2009	Observations
land-use	latitude: 1/1200 ° longitude: 1/800 ° (ca. 0.1 x 0.1 km)	1970	1976	identical to land-use map 1976 (no temporal change)
		1976	1987	interpolation of land-use map 1976 and 1987
		1987	1991	interpolation of land-use map 1987 and 1991
		1991	1997	interpolation of land-use map 1991 and 1997
		1997	2006	interpolation of land-use map 1997 and 2006

74

75 Transformation of geodetic reference system, rasterization of the vector map, were performed using GDAL,
 76 OGR, GRASS GIS, Quantum GIS (QGIS), and tools provided by The Open Source Geo-spatial Foundation
 77 (OSGeo). Computational operations to compile LU, VG, and AL dataset and to superimpose them on the grid
 78 system were performed using PostGIS on PostgreSQL database.

79 **Supplementary Material B. Key quantities on agricultural activity estimated for year 1970-2008**

80

81 **Table B1. Area of each land-use (employed in simulation), unit: 10³ ha.**

Land-use ¹⁾	1970	1980	1990	2000	2008
01 PD	2,866	2,586	2,139	1,875	1,642
02 UP	1,453	1,621	1,845	1,806	1,809
03 OC	611	570	454	347	304
04 MG	505	560	647	630	580
<i>sub-total</i>	<i>5,435</i>	<i>5,337</i>	<i>5,085</i>	<i>4,657</i>	<i>4,335</i>
05 UG	956	1,024	1,235	1,500	1,537
06 FL	442	434	393	296	357
07 WL	48	46	38	38	38
08 ST	64	89	153	351	519
09 OL	85	100	126	188	245
<i>Total</i>	<i>7,030</i>	<i>7,030</i>	<i>7,030</i>	<i>7,030</i>	<i>7,030</i>

82 1) PD: paddy fields; UP: upland crop fields; OC: orchards; MG:
83 managed grasslands; UG: unmanaged grasslands; FL: forest lands.

84

85 **Table B2. Amount of plant residue input to fields (employed in
86 simulation), unit: Gg C yr⁻¹.**

Land-use ¹⁾	1970	1980	1990	2000	2008
01 PD	4,204	3,460	3,923	4,338	3,947
02 UP	992	1,205	1,425	1,397	1,303
03 OC	341	331	294	275	252
04 MG	1,231	1,367	1,655	1,592	1,429
05 UG	3,634	3,891	4,695	5,700	5,841
06 FL	884	868	787	593	714
<i>Total</i>	<i>11,286</i>	<i>11,122</i>	<i>12,779</i>	<i>13,895</i>	<i>13,486</i>

87 1) PD: paddy fields; UP: upland crop fields; OC: orchards; MG:
88 managed grasslands; UG: unmanaged grasslands; FL: forest lands.

89

90 **Table B3. Number of livestock, unit: 10³ heads.**

Livestock	1970	1980	1990	2000	2008
Dairy cow milking	888	1,069	1,080	992	862
heifer, dry	314	355	346	259	213
U2Y ¹⁾	608	646	605	513	458
Beef cattle 2YO ¹⁾	831	723	854	870	994
U2Y ¹⁾	984	743	826	826	829
dairy breed	186	716	1,039	1,123	1,067
Pigs fattening	5,667	8,609	10,634	8,807	8,777
breeding	844	1,169	1,182	1,000	967
Poultry hen, 6MO ¹⁾	43	34	40	38	39
hen, U6M ¹⁾	120	124	138	141	143
broiler	55	128	151	108	103

91 1) 2YO: 2 years and older; U2Y: under 2 years old; U6M: under 6
92 months old; 6MO: 6 months and older.

93

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95

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98

99 Table B4. Amount of organic carbon in compost, slurry, and
 100 excreta from different sources (original estimate), unit: Gg C
 101 yr⁻¹.

Sources		1970	1980	1990	2000	2008
Compost ²⁾	LW	1,775	2,259	2,557	2,317	2,247
	BD	300	483	512	394	233
	SM	2,992	3,353	3,755	3,382	3,211
	FW	0	1	4	23	58
	ST	1,279	874	890	535	437
	<i>sub-total</i>	<i>6,346</i>	<i>6,970</i>	<i>7,718</i>	<i>6,651</i>	<i>6,186</i>
Slurry ^{1,2)}	SL_UP	17	18	18	14	12
	SL_MG	11	17	19	20	19
	<i>sub-total</i>	<i>28</i>	<i>35</i>	<i>37</i>	<i>34</i>	<i>31</i>
Excreta ^{1,2)}	EX_MG	15	21	24	25	25
<i>Total</i>		<i>6,389</i>	<i>7,026</i>	<i>7,779</i>	<i>6,710</i>	<i>6,242</i>

102 LW: livestock waste; BD: bedding for livestock; SM: secondary
 103 materials for composting livestock waste; FW: food waste; ST: rice and
 104 wheat straw. SL_UP: slurry applied to upland fields; SL_MG: slurry
 105 applied to managed grasslands. EX_MG: excreta applied to managed
 106 grasslands.

107 1) A conversion factor of 0.5 was applied for above listed values of
 108 slurry and excreta prior to determination of the annual input of
 109 farm-yard manure in RothC to take account relatively fast
 110 decomposition of these organic matters compared to composted manure.

111 2) Values shown in this table were estimated based on agricultural field
 112 area data in national statistics and thus were not identical to those listed
 113 in Table 2 that used area data from land-use map data applied in
 114 simulation.

115 Table B5. Amount of manure applied to fields (employed in
 116 simulation), unit: Gg C yr⁻¹.

Land-use ¹⁾	1970	1980	1990	2000	2008
01 PD	2,191	1,855	1,138	807	692
02 UP	3,457	3,763	3,497	2,782	2,457
03 OC	577	524	381	398	340
04 MG	0	727	2,701	2,510	2,336
<i>Total</i>	<i>6,225</i>	<i>6,869</i>	<i>7,717</i>	<i>6,497</i>	<i>5,825</i>

118 1) PD: paddy fields; UP: upland crop fields; OC: orchards; MG:
 119 managed grasslands.

120 Table B6. Amount of slurry applied to fields (employed in
 121 simulation), unit: Gg C yr⁻¹.

Land-use ¹⁾	1970	1980	1990	2000	2008
02 UP	27	34	36	27	23
04 MG	37	33	39	39	35
<i>Total</i>	<i>64</i>	<i>67</i>	<i>75</i>	<i>66</i>	<i>58</i>

122 1) UP: upland crop fields; MG: managed grasslands.

123 Table B7. Amount of excreta input to field (employed in
 124 simulation), unit: Gg C yr⁻¹.

Land-use ¹⁾	1970	1980	1990	2000	2008
04 MG	54	40	47	49	46

125 1) MG: managed grasslands.

126 Table B8. Rate of plant residue application to fields, unit: Mg C
 127 ha⁻¹ yr⁻¹.

Land-use ¹⁾	1970	1980	1990	2000	2008
01 PD	1.5	1.3	1.8	2.3	2.4
02 UP	0.7	0.7	0.8	0.8	0.7
03 OC	0.6	0.6	0.7	0.8	0.8
04 MG	2.4	2.4	2.6	2.5	2.5

130 1) PD: paddy fields; UP: upland crop fields; OC: orchards; MG:
131 managed grasslands.

132
133 **Table B9. Rate of manure application to fields, unit: Mg C ha⁻¹ yr⁻¹.**

Land-use ¹⁾	1970	1980	1990	2000	2008
01 PD	0.8	0.7	0.5	0.4	0.4
02 UP	2.4	2.3	1.9	1.5	1.4
03 OC	1.0	0.9	0.8	1.2	1.1
04 MG	0.0	1.3	4.2	4.0	4.0

134 1) PD: paddy; UP: upland fields; OC: orchards; MG: managed grasslands.

135
136 **Table B10. Rate of overall input of organic carbon (sum of plant
137 residue, manure, slurry, and excreta) to fields, unit: Mg C ha⁻¹
138 yr⁻¹.**

Land-use ¹⁾	1970	1980	1990	2000	2008
01 PD	2.2	2.1	2.4	2.7	2.8
02 UP	3.1	3.1	2.7	2.3	2.1
03 OC	1.5	1.5	1.5	1.9	2.0
04 MG	2.5	3.8	6.8	6.6	6.6

139 1) PD: paddy fields; UP: upland crop fields; OC: orchards; MG:
140 managed grasslands.

141 **Supplementary Material C.** Equations used to estimate application rate of organic amendments in
 142 agricultural fields

143
 144 [Plant residues]

145 **Equations set C.1 (plant residue production for major crops and vegetables);**

146 Annual plant residue inputs to soils in different prefecture and year were estimated for each cropping group using
 147 the following equations;

148 **Equation C.1.1: for rice, wheat, sweet potato, beans, millet, and vegetables;**

$$RSC_{cg,pr,y} = \begin{cases} \sum_{c=1}^{nc_{cg}} (YFW_{c,pr,y}) \cdot YD2F_{cg} \cdot RS2Y_{cg} \cdot RSINC_{cg,rg,y} \cdot RSCC_{cg} \\ \sum_{c=1}^{nc_{cg}} (YFW_{c,pr,y} \cdot YD2F_c \cdot RS2Y_c) \cdot RSINC_{cg,rg,y} \cdot RSCC_{cg} \end{cases}$$

149 **Equation C1.2: for orchards, manure crops, and forage;**

$$RSC_{cg,pr,y} = \sum_{c=1}^{nc_{cg}} (RSCA_{c,y} \cdot CA_{c,pr,y}) \cdot RSINC_{cg,rg,y} \cdot RSCC_{cg}$$

150 Equation C1.2.1: orchards;

$$RSCA_{c,y} = const_c$$

151 Equation C1.2.2: manure crops;

152 for crops other than grass,

$$RSCA_{c,y} = BMCA_c$$

$$BMCA_c = YDWCA_c \cdot (1 + BG2Y_c)$$

$$YDWCA_c = const_c$$

153 for Italian ryegrass,

154 See Equation C1.2.3.

155 for grass excluding Italian ryegrass (including mixed seeding of *Poaceae* and *Fabaceae*),

156 See Equation C1.2.4.

157

158 Equation C1.2.3: forage of Italian ryegrass;

$$RSCA_{GRIR,y} = RSBGCA_{GRIR,y}$$

$$RSBGCA_{GRIR,y} = RSBGCA_{GRP,1982-84} \cdot \frac{YFW_{GR,y}}{YFW_{GR,1983}}$$

159 Equation C1.2.4: forage of grass excluding Italian ryegrass (including mixed seeding of *Poaceae* and
 160 *Fabaceae*);

$$RSCA_{GRNI,y} = (RSBGCA_{GR,y} + RSUGCA_{GR,y}) + \frac{BMCA_{GR,y}}{YRRE}$$

$$RSBGCA_{GR,y} = RSBGCA_{GRP,1982-84} \cdot \frac{YFWCA_{GR,1997-2005}}{YFWCA_{GRP,1997-2005}} \cdot \frac{YFWCA_{GR,y}}{YFWCA_{GR,1996}}$$

$$RSUGCA_{GR,y} = RSUGCA_{GRP,1982-84} \cdot \frac{YFWCA_{GR,1997-2005}}{YFWCA_{GRP,1997-2005}} \cdot \frac{YFWCA_{GR,y}}{YFWCA_{GR,1996}}$$

$$YFWCA_{GR,1997-2005} = \sum_{y=1997}^{2005} \left(\frac{YFWCA_{GRP,y} \cdot CA_{GRP,y} + YFWCA_{GRPF,y} \cdot CA_{GRPF,y}}{CA_{GRP,y} + CA_{GRPF,y}} \right) / 9$$

$$BMCA_{GR,y} = YDWCA_{GR,1996} \cdot (1 + BG2Y_{GR}) \cdot \frac{YFWCA_{GR,y}}{YFWCA_{GRPF,1996}}$$

$$YDWCA_{GR,1996} = \frac{YDWCA_{GRPF,1996} \cdot CA_{GRPF,1997-2005} + YDWCA_{GRP,1996} \cdot CA_{GRP,1997-2005}}{CA_{GRPF,1997-2005} + CA_{GRP,1997-2005}}$$

161

162 where,

163 RSC = mass of organic carbon in plant residue to be incorporated into soils in a year, Mg C yr⁻¹.

164 *c* = cropping type (e.g. tomato, two-row barley, Italian ryegrass, etc.).

165 *cg* = cropping group (e.g. paddy rice, wheat, vegetables, forage and manure crop, etc.).

166 *nc* = the number of cropping types in a cropping group (paddy rice (3); wheat (4); sweet potato (1); beans (4);

167 millet (1); vegetables (38); forage and manure crop (8); industrial crop (3); fruit and tea (2)).

168 *ncg* = the number of cropping groups in a land-use type (paddy fields (3); upland fields (7); orchards (1);

169 managed grasslands (1)).

170 *pr* = prefecture.

171 *rg* = region (group of prefectures).

172 *y* = year.

173 *const* = fixed constant taken from literatures.

174 YFW = yield in fresh weight, Mg yr⁻¹.

175 YD2F = proportion of dry weight against fresh weight of yield.

176 RS2Y = proportion of residues by weight against yield, dry weight basis.

177 RSINC = proportion of plant residues to be returned to soils against other usages or treatments such as bedding
 178 for live-stock, handicraft, incineration, and disposal.

179 RSCC = concentration of organic carbon in plant residue, dry matter basis, g g⁻¹.

180 CA = cropping area, ha.

181 RSCA = plant residue production per a unit cropping area in a year, Mg ha⁻¹ yr⁻¹.

182 BMCA = total biomass of grass including above and below ground biomass per unit cropping area, Mg ha⁻¹.
 183 YDWCA = yield per a unit cropping area in a year in dry weigh, Mg ha⁻¹ yr⁻¹.
 184 YFWCA = yield per a unit cropping area in a year in dry weigh, Mg ha⁻¹ yr⁻¹.
 185 BG2Y = proportion of below ground biomass against yield in dry weight.
 186 RSBGCA = below ground biomass residue input to soils per a unit cropping area in a year, Mg ha⁻¹ yr⁻¹.
 187 RSUGCA = upper ground biomass residue input to soils per a unit cropping area in a year, Mg ha⁻¹ yr⁻¹.
 188 YRRE = mean of number of years for renewal of grasslands.
 189 GR = grass.
 190 GRIR = Italian ryegrass.
 191 GRNI = grass excluding Italian ryegrass.
 192 GRP = grass of *Poaceae* family, e.g. Italian ryegrass.
 193 GRPF = grass with mixed seeding of *Poaceae* and *Fabaceae* families.

194
 195 **Equation C.1.3 (plant residue input to soil in different land-use types);**

$$RSCI_{lu,pr,y} = \sum_{cg=1}^{n_{cglu}} (RSC_{cg,pr,y}) / A_{lu,pr,y}$$

196 where,

197 RSCI = annual rate of plant residue organic carbon input to soils, Mg C ha⁻¹ yr⁻¹.
 198 *lu* = land-use type, including paddy fields, upland fields, orchards, and managed grasslands.
 199 *pr* = prefecture.
 200 *y* = year.
 201 *cg* = cropping group (e.g. paddy rice, wheat, vegetables, forage and manure crop, etc.).
 202 *n_{cglu}* = the number of cropping groups in a land-use type (paddy fields (3); upland fields (7); orchards (1);
 203 managed grasslands (1)).
 204 A = area of field in each land-use type, ha.

205
 206 **Table C1** List of parameters used for estimation for production and application of plant residues.

crop group	YD2F ¹⁾	RSCA ²⁾	RS2Y ³⁾	RSINC ⁴⁾	BMCA ⁵⁾	YRRE ⁶⁾	RSCC ⁷⁾
rice (1)			1.20	0.32-0.64-0.95			
straws							
husks	0.85		0.22	0-0.20-0.35			
roots & stables			0.27	1.0			
wheat (4)	0.85		0.97	0-0.63-1.0			
shoots			0.42	1.0			
roots & stables							
sweet potato (1)	0.30		0.50	0.46			0.4
beans (4)	0.85-0.90		0.9-1.0	0.75			
millet (1)	0.85		1.50	0.46			
vegetables (29)	0.05-0.25		0.2-5.0	0.46			
orchards (18)		1.0-15.4		1.0			
forage & manure crops (9)		3.6-15.9		1.0	5.6-17.2	10	

207 Two values separated with hyphen indicate minimum and maximum values, whereas three values separated with two hyphens indicate minimum,
 208 mean, and maximum values of parameter.

209 1) YD2F: proportion of dry weight against fresh weight of yield.

- 210 2) RSCA: proportion of residues by weight against yield, dry weight basis.
 211 3) RS2Y: proportion of residues by weight against yield, dry weight basis.
 212 4) RSINC: proportion of plant residues to be returned to soils against other usages or treatments such as bedding for live-stock, handicraft,
 213 incineration, and disposal.
 214 5) BMCA: total biomass including both above and below ground biomass per unit cropping area, Mg ha⁻¹.
 215 6) YRRE: mean of number of years for renewal of grasslands.
 216 7) RSCC: concentration of organic carbon in plant residue, dry matter basis, g g⁻¹. Parameter value was taken from Shirato et. al. (unpublished).

217

218

219 [Live-stock waste compost]

220 **Equation C.2.1 (Live-stock waste);**

$$LWFW_{ls,pr,y} = \sum_{lss=1}^{nlss_{ls}} (LSN_{lss,pr,y} \cdot LWE_{lss} \cdot DN_y)$$

221 where,

222 *ls* = live-stock type, including dairy cattle, beef cattle, swine, hen, and broiler.

223 *pr* = prefecture.

224 *y* = year.

225 LWFW = mass of live-stock waste produced in a year, in fresh weight, Mg y⁻¹

226 LSN = the number of head of live-stock

227 LWE = rate of emission of live-stock waste (excrement) in fresh weight per a head of live-stock, kg d⁻¹ head⁻¹

228 DN = the number of days in a year

229 *lss* = live-stock sub-category, based on class of age or utilization

230 *nlss* = the number of live-stock sub-category in different live-stock types (dairy cattle (3); beef cattle (3); swine
 231 (2); hen (2); broiler (1))

232

233 **Equation C.2.2 (Live-stock waste to be utilized for composting, in different type of live-stock);**

$$LW4LC_{ls,pr,y} = LWFW_{ls,pr,y} \cdot LWCOMP_{ls}$$

$$LW4SL_{ls,pr,y} = LWFW_{ls,pr,y} \cdot LWSL_{ls}$$

234 where,

235 LW4LC = mass of live-stock waste to be utilized for composting (to produce LWC)

236 LW4SL = mass of live-stock waste to be utilized for slurry production (to produce LWC)

237 *ls* = live-stock type, including dairy cattle, beef cattle, swine, hen, and broiler.

238 *pr* = prefecture.

239 *y* = year.

240 LWFW = mass of live-stock waste produced in a year, in fresh weight, Mg y⁻¹

241 LWCOMP = proportion of live-stock waste to be utilized for composting against other usages.

242 LWSL = proportion of live-stock waste to be utilized for slurry production against other usages.

243

244 **Equation C.2.3 (Live-stock waste to be utilized for composting, sum of all types of live-stock);**

$$\begin{aligned} \text{LWC}_{pr,y} &= \sum_{ls=1}^{nls} (\text{LW4LC}_{ls,pr,y} \cdot \text{LWD2F}_{ls} \cdot \text{LWDC}_{ls} \cdot \text{LWCC}_{ls}) \\ \text{SLC}_{pr,y} &= \sum_{ls=1}^{nls} (\text{LW4SL}_{ls,pr,y} \cdot \text{LWD2F}_{ls} \cdot \text{LWCC}_{ls}) \end{aligned}$$

245 where,

246 LWC = mass of organic carbon in live-stock waste compost derived from live-stock waste produced in a year in
247 dry weight, Mg C y⁻¹.

248 SLC = mass of organic carbon in slurry derived from live-stock waste produced in a year in dry weight, Mg C
249 y⁻¹.

250 *pr* = prefecture.

251 *y* = year.

252 *ls* = live-stock type, including dairy cattle, beef cattle, swine, hen, and broiler.

253 *nls* = number of live-stock types.

254 LW4LC = mass of live-stock waste to be utilized for composting (to produce LWC)

255 LW4SL = mass of live-stock waste to be utilized for slurry production (to produce LWC)

256 LWD2F = proportion of dry weight against fresh weight of live-stock waste (excrement)

257 LWDC = residual ratio of live-stock waste after decomposition during composting.

258 LWCC = concentration of organic carbon in live-stock waste in dry weigh basis, g g⁻¹.

259

260 **Equation C.2.4 (secondary materials to be utilized for live-stock waste compost production);**

$$\text{SMC}_{pr,y} = \sum_{sm=1}^{nsm} (\text{LWCOMP}_{pr,y} \cdot \text{SM2LW}_{sm} \cdot \text{SMD2F}_{sm} \cdot \text{SMDC}_{sm} \cdot \text{SMCC}_{sm})$$

261 where,

262 SMC = mass of organic carbon in live-stock waste compost derived from secondary materials produced in a
263 year, Mg C y⁻¹

264 *pr* = prefecture.

265 *y* = year.

266 *sm* = secondary material type, including straw, husks, saw-dust, and bark.

267 *nsm* = number of secondary materials to be used for composting live-stock waste.

268 LWCOMP = proportion of live-stock waste to be utilized for composting against other usages.

269 SM2LW = proportion of applied secondary materials against live-stock waste during composting, based on
270 survey data.

271 SMD2F = proportion of dry weight against fresh weight of secondary materials for live-stock waste
272 composting.

273 SMDC = residual ratio of secondary materials used for live-stock waste composting after decomposition during
274 composting.

275 SMCC = concentration of organic carbon in secondary materials, g g^{-1} .

276

277 **Equation C.2.5 (bedding materials for live-stock farming used for live-stock waste composting);**

$$\text{BDC}_{pr,y} = \sum_{bd=1}^{nbd} \left\{ \left(\sum_{ls=1}^{nls} \text{LSN}_{ls} \cdot \text{BD2LS}_{bd,ls} \right) \cdot \text{BDD2F}_{bd} \cdot \text{BDDC}_{bd} \cdot \text{BDCC}_{bd} \right\}$$

278 where,

279 BDC = mass of organic carbon in live-stock waste compost derived from bedding materials for live-stock, Mg
280 yr^{-1} .

281 bd = bedding materials for live-stocks, including rice-straw, saw-dust, wheat straw, dry grass, hey, and others.

282 nbd = number of bedding materials for live-stocks.

283 ls = type of live-stock, including dairy cattle, beef cattle, swine, hen, and broiler.

284 nls = number of types of live-stock

285 LSN = the number of head of live-stock.

286 BD2LS = mass of bedding materials to be applied per a head of live-stock, based on survey data, Mg head^{-1}
287 yr^{-1} .

288 BDD2F = proportion of dry weight against fresh weight of bedding materials.

289 BDDC = residual ratio of bedding materials after decomposition during composting.

290 BDCC = concentration of organic carbon in bedding materials, g g^{-1} .

291

292 **Equation C.2.6 (food waste to be utilized for composting);**

$$\text{FWC}_{pr,y} = \sum_{fi=1}^{nfi} \left(\text{FWCOMP}_{fi,jp,y} \cdot \frac{\text{PN}_{pr,y}}{\text{PN}_{jp,y}} \right) \cdot \text{FWD2F} \cdot \text{FWDC} \cdot \text{FWCC}$$

293 where,

294 FWC = mass of organic carbon in compost derived from food waste in a year, Mg yr^{-1} .

295 pr = prefecture.

296 y = year.

297 fi = food industry, including manufacturing, wholesale business, retailing, and foodservice.

298 nfi = number of food industry

299 jp = Japan.

300 FWCOMP = mass of food waste to be utilised for composting in fresh weight, Mg yr^{-1} .

301 PN = human population in a geographic administrative entity (prefecture or country).

302 FWD2F = proportion of dry weight of food waste against fresh weight.

303 FWDC = residual ratio of food waste after decomposition during composting.

304 FWCC = concentration of organic carbon in food waste, g g⁻¹.

305

306 **Equation C.2.7 (mass of organic carbon in live-stock waste compost produced in a year);**

$$LCC_{pr,y} = LWC_{pr,y} + SMC_{pr,y} + BDC_{pr,y} + FWC_{pr,y}$$

307 where,

308 LCC = mass of organic carbon in live-stock waste compost produced in a year, Mg yr⁻¹.

309 *pr* = prefecture.

310 *y* = year.

311 LWC = mass of organic carbon in live-stock waste compost derived from live-stock waste produced in a year in
312 dry weight, Mg C yr⁻¹.

313 SMC = mass of organic carbon in live-stock waste compost derived from secondary materials produced in a
314 year, Mg C yr⁻¹.

315 BDC = mass of organic carbon in live-stock waste compost derived from bedding materials for live-stock
316 produced in a year, Mg C yr⁻¹.

317 FWC = mass of organic carbon in live-stock waste compost derived from food waste produced in a year, Mg C
318 yr⁻¹.

319

320 **Equation C.2.8 (mass of live-stock waste compost applied to soils in different land-use in a year, except
321 managed grasslands);**

322

$$LCC_{lu,pr,y} = \sum_{cg=1}^{ncglu} (LCI_{cg,pr,y} \cdot CA_{cg,pr,y} \cdot FRT_{cg,lu} \cdot LCD2F \cdot LCCC)$$

323 where,

324 LCC = mass of organic carbon in live-stock waste compost applied to soils in all land-use types in a year, Mg C
325 yr⁻¹.

326 *lu* = land-use types, including paddy fields, upland fields, and orchards.

327 *pr* = prefecture.

328 *y* = year.

329 *cg* = cropping group.

330 *ncg* = number of cropping group.

331 LCI = rate of annual live-stock waste compost application to soil, based on questionnaire to farmer, in fresh
332 weight, Mg C ha⁻¹ yr⁻¹.

333 CA = cropping area, ha

334 FRT = fraction of cumulative cropping area in a year to field area (times of rotation in a year)

335 LCD2F = proportion of dry weight of live-stock waste compost against fresh weight.

336 LCCC = concentration of organic carbon in live-stock waste compost, g g⁻¹.

337

338 **Equation C.2.9 (mass of organic carbon in live-stock waste compost applied to soils in managed**
339 **grasslands);**

$$LCC_{MG,pr,y} = LCC_{pr,y} - \sum_{lu=1}^{nlu} LCC_{lu,pr,y}$$

340 where,

341 LCC_{MG} = mass of organic carbon in live-stock waste compost applied to soils in managed grasslands, Mg C yr⁻¹.

342 *pr* = prefecture.

343 *y* = year.

344 *lu* = land-use types, including paddy fields, upland fields, and orchards.

345 *nlu* = number of land-use types, including paddy fields, upland fields, and orchards.

346

347 **Equation C.2.10 (input of live-stock waste compost to soils);**

$$LCCI_{lu,pr,y} = LCC_{lu,pr,y}/A_{lu,pr,y}$$

348 where,

349 LCCI = rate of application of organic carbon in live-stock waste compost to soils per unit area of fields, Mg C

350 ha⁻¹ yr⁻¹.

351 *lu* = land-use types, including paddy fields, upland fields, orchards, and managed grasslands.

352 *pr* = prefecture.

353 *y* = year.

354 LCC = mass of organic carbon in live-stock waste compost applied to soils, Mg C yr⁻¹.

355 A = area of fields, ha.

356

357 **Supplementary Material D. Soil inventories**

358 Some details on the soil inventories in Japan used in this study are described below;

359

360 D1. Soil inventories

361 1. '*Chiryoku hozen kihon chousa*' (in Japanese; i.e. basic survey for soil fertility conservation), conducted in year
362 1959-1978, that had been conducted to compile soil map for agricultural lands and collected data on
363 attributes of soil horizons from ca. 20,000-25,000 soil profiles throughout Japan. A sub-set called '*Kanni*
364 *danmen chousa*' (in Japanese; i.e. simple soil profile survey) contains data on attributes of surface and
365 sub-surface soil layers from ca. 25,000 sampling sites, except Kyoto and Wakayama prefecture, whereas
366 another sub-set called '*Daihyou danmen chousa*' (in Japanese; i.e. representative soil profile survey) contains
367 data on attributes of soil horizons from ca. 20,000 soil profiles (Nihon Dojo Kyoukai, 2002).

368 2. '*Dojo kankyo kiso chousa, Teiten chousa*' (in Japanese; basic soil environment monitoring project, stationary
369 monitoring), conducted during year 1979-1998 with a series of 4 waves with interval of 4-5 years had
370 collected soil samples from ca. 20,000 survey points in agricultural lands (Agricultural Production Bureau,
371 Ministry of Agriculture Forestry and Fisheries, 2008).

372 3. '*Dojou tanso chousa jigyou*' (in Japanese; soil carbon survey project), having been conducted since year 2008,
373 monitoring changes in SOC stock with annual interval, in about 3,000 survey points (Ondanka taisaku
374 dojou kinou chousa kyougikai, 2013). Inclusion of managed grasslands in monitoring sites setup is a
375 feature of this survey as the managed grasslands were either not explicitly surveyed or included only a few in
376 the above listed past soil survey 1 and 2, respectively.

377

378 D2. Methodology of the measurement of SOC concentration in existing soil inventories

379 With regard to methodology of the measurement of SOC concentration in above mentioned datasets, we can
380 indicate the followings based on some document-based evidences, observations and knowledge of experts;

381 A) In the soil survey in year 1959-1977, it is considered that wet oxidation methods (e.g. known as Tyurin
382 method or Walkley Black method) were used as major analytical procedures, while including some possibility for

383 a use of dry combustion method in later stage. A document-based, immediate reference on methodology is not
384 available (i.e. at least not attached with the dataset). Conducting a survey through old domestic reports might find
385 some relevant information on the methodology, however, will not be enough to fully elucidate it as many
386 different laboratories conducted the analysis.

387 B) In the stationary monitoring in year 1979-1998, operation manual for soil chemical analysis did specify to
388 use either dry or wet combustion methods and not to use wet-oxidation methods. However, no record on selection
389 of the method exists in the dataset.

390 As to methodologies used to determine SOC concentration in these datasets, it is considered wet-oxidation
391 methods (e.g. known as Tyurin method or Walkley and Black method) were used as a major methodology in the
392 soil survey for compiling soil map. No records or document-based evidence on which methodology has been
393 used are attached to this dataset. Whereas in the stationary monitoring, either dry or wet combustion methods
394 were used. Although, no record on selection of the method exists in this dataset.

395

396 **References**

397

398 Agricultural Production Bureau, Ministry of Agriculture Forestry and Fisheries: Dojou hozen chousa jigyou
399 seisekisyo., 2008.

400 Nihon Dojo Kyokai: Chiryoku hozen dojouzu de-ta CD-ROM (Zenkoku-ban), 2002.

401 Ondanka taisaku dojou kinou chousa kyougikai: Dojou yurai onsitsu kouka gas dojou tanso chousa jigyou
402 houkokusyo, heisei 24 nendo, 2013.

403