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Livestock Waste, Potential Manure Production and Its Use in Japan in 1980 and 2010

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ABSTRACT

The aim of this work is to quantify life cycle of nutrient elements for soil and crops, namely nitrogen (N), phosphorus (P), potassium (K), and carbon (C), from feed of livestock to potential of manure production via livestock waste, a potentially sustainable application of manure for farmland soils in Japan in 1980 and 2010. We also estimated real application to farmland from a questionnaire by setting several hypotheses to collect real proportion of farm households, because the questionnaire was intended for full-time farms, the proportion of which is minor within all farms. The questionnaire survey was conducted five times, from 1979 to 2003 for 5-year intervals, and one time from 2008 to 2013. These data were set for the years 1980 and 2010. As a result, the livestock feed became lower in P and K input, livestock got better nutrient use efficiency for livestock products, and waste production was reduced in 2010 than 1980. Potential of manure production was decreased in 2010 from what it was in 1980; however, estimated application of manure was also reduced from full to half of potential of manure production. Application level of manure in 1980 was higher than the amount that farmland received sustainably. This might be allowed for enhancing soil fertility; as such activity was also needed at that time. On the other hand, in 2010, application of manure was estimated to be less than half of that in 1980 and had not reached sustainable application level. From 1980 to 2010, manure application had been decreased, even though trends of manure application for crops per area were different in each crop. Although lack or surplus of manure might not always explain trend of soil fertility, we need continues survey of soil fertilities to check and monitor to grasp the trend of soil fertility indicated by total C and N, available N, P, and K, as well as estimate application of manure to farmland.

Introduction

Livestock manure is an important resource for food and feed production because it supplies measure nutrients such as nitrogen (N), phosphorus (P), and potassium (K). Carbon (C) is a carrier of these nutrients and is a source soil organic matter for improving soil's physical and chemical structure. However, too much application would cause negative impacts to surrounding environments and agricultural production, such as ground water pollution by N, damage to crop by P, and grass tetany to cattle by K.

Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan, established "Act for Promoting Proper and Use of Management of Livestock Manure" (later, Livestock Waste Management Act) in 1999 with 5 years moratorium, and then fully enforced it from 2004. During this moratorium, composting of sewage facilities was settled in most livestock husbandry farms and compost distribution centers in intensive livestock production area for enhancing use of livestock manure for crop husbandry farms. Under this Act, appropriate livestock waste processing, such as composting, slurry, sewage treatment, and burning, was enforced by MAFF. However, there is no quantitative verification between the use of manure and slurry by farms and amount of manure that can be produced from livestock wastes.

One of the problems in quantifying the use of livestock manure and slurry (later, we use "manure" as the word including slurry) could be that a systematic wide area survey had not been conducted for their quantification. A possible data source might be Basic Soil Environment Measuring Project - Station Monitoring (BSEMP-SM) from

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1979 to 2003 for five times and Soil Carbon Measurement Project (SCMP) from 2008 to 2012 for one time in Japan. The aim of these surveys is monitoring the change of soil fertility and its physical and chemical properties and carbon stock in farmland soil. Additionally, these surveys contain crop fertilization by mineral and organic fertilizers, farm household, and so on as extrinsic data. However, the survey was to be conducted at full-time or exemplary farms (Leon et al. 2013).

Here, we tried to estimate manure application in 1980 and 2010 from this extrinsic data of BSEMP-SM and SCMP. We also estimated potential of manure production in 1980 and 2010 considering the life cycle of nutrients from feed to manure in Japan. Then, we compared potential of manure production and estimated manure application in both years to inspect the effect of Livestock Waste Management Act. We also estimated farmland's sustainable manure accepting capacity in 2010, compared it with estimated manure application in 1980 and 2010, and then diagnosed lack and surplus of manure application in both years.

Materials and Methods

Estimation of Manure Use from Surveys

Data sources, estimating types of farms and their occupation within each crop group.

The crude data about kinds of manure application by full-time crop and livestock husbandry farms and those of part-time come from five surveys of BSEMP-SM done from 1979 to 1983, 1984 to 1988, 1989 to 1993, 1994 to 1998, and 1999 to 2003. In our study, we only use the first survey as the oldest survey. Then, we use SCMP from 2008 to 2012 by MAFF as the latest data. Total number of survey points were more than 22,000 on 1st year for BSEMP-SM and more than 3,000 farmlands with continues 5 years (>15,000 records) on SCMP. These data were adopted for 1980 and 2000, at every 5-year interval on BSEMP-SM and for 2010 on SCMP. Number of full-time and part-time farms, and that of crop husbandry and livestock husbandry farms in these years come from statistical year book (MAFF 1981a, 2011a). Farmland area cultivated by a cattle, swine, and poultry husbandry farm comes from "Cost of Livestock Products" (MAFF 1981b and 2011b).

Hypotheses to Dividing Farms as Basic Data for Farmland Cultivation Area by Types of Farms

Mishima, Kimura, Eguchi, and Shirato (2012) set seven hypotheses to estimate manure application from BSEMP-SM data, namely, 1) manure application rate is different between crop groups (they set seven groups), 2) manure application rate is different in districts, 3) manure application rate is different between full-time farm and part-time farm, 4) manure application rate is different between crop husbandry farm and livestock husbandry farm, 5) ratio of number of full-time to part-time farm is same within crop husbandry farm or livestock husbandry farm, 6) farmland area cultivated by a full-time farm and by a part-time farm is the same, and 7) farmland area cultivated by a crop husbandry farm and by a livestock husbandry farm is the same, except orchard, tea, forage, and fodder. We modified their seventh hypotheses, as farmland area cultivated by a crop husbandry farm and a livestock husbandry farm is different. Then we applied these seven hypotheses to our dataset to estimate manure application data to estimate manure application in designated years.

Estimating Cultivated Area by Types of Farms and Calculation of Manure Application Rate

From these statistical data, number of farms of four households (full-time livestock husbandry farm, full-time crop husbandry farm, part-time livestock husbandry farm, and part-time crop husbandry farm) and their cultivated area of seven crops (paddy rice, upland crop, vegetable, orchard, tea, forage, and fodder) was calculated. The BSEMP-SM data and SCMP data were divided into 28 groups (four farm households multiplied by seven crops), then average manure application is obtained in each group. Here, manure was categorized into six types, namely, cattle manure, swine manure, poultry manure, and those with saw dust. Total manure application was obtained by multiplying 28 crop areas with six types of manures, then summarizing into seven crop groups and six types of manures. This calculation was done in Japanese national scale and in seven districts in Japan.

Calculated manure application rate is fresh on weight basis. To convert amount of C, N, P, and K, concentration of water and these four elements were referenced from national scale surveys (MAFF [1982] for 1980 and Furuya [2005] for 2010).

Basic Unit of Livestock Waste Production and Potential of Manure Production in 1980 and 2010

Livestock waste production was calculated from kinds of feed consumption listed in the “Cost of Livestock Products” (MAFF 1981b and 2011b) and the “Feed Statistics Handbook” (Association of Agriculture and Forestry Statistics). Nutrient concentration in feed and fodder was according to the “Feed Composition Table” (Japan Livestock Industry Association 1981a, 1981b, 2011a, 2011b). Livestock waste N, P production was calculated by a calculation software made by Tsuiki and Harada (1997) and K production was calculated with Ikumo’s formula (Ikumo 2001). From N concentration, amount of C was calculated by C/N rate (Biomass Recycle Study for Agriculture, Forestry and Fisheries Systemize Sub-group, 2008). Total livestock waste production in national and district levels was calculated from number of kinds of livestock and the basic unit of kinds of livestock.

Nutrient loss after excretion to mature manure was estimated by a method of Mishima et al. (2008). Namely, the difference between C/P, N/P, or K/P ratio of excreted waste and those of manure counted as loss of N and K in mature manure, because P is stable during composting of livestock waste (Matsunami et al. 2006).

Balance between Sustainable Manure Receiving Capacity, Manure Production Potential, and Manure Application

Mishima, Endo, and Kohyama (2009a) set amount of sustainable manure acceptance for lands for kinds of crop groups in prefectural scale in fresh weight basis. We employ their method and amount of manure acceptance in districts and method to getting different types of manures to one type of manure equivalent. Then, amount of sustainable manure acceptance in each district was compared with present manure application rate estimated in this study. Here, fresh weight of kinds of applied manures were calculated from fresh weight/P rate obtained from MAFF (1982) and Furuya (2005) for each kind of manure.

Manure application values were set as follows. Paddy rice field do not need additional manure application when all rice straw has been sown into paddy field (Shiga 1994). However, a part of rice straw is removed for bedding material for livestock or other industrial purposes. Therefore, we set manure application to the same amount as rice straw removal. Two districts (Hokkaido and Tohoku) and part of one district (Hokuriku, part of Hokuriku-Tokai) receive no manure, two districts (Kanto-Tozan and Kyushu) use 5.69 Mg FW ha^{-1} of livestock manure instead of rice straw produced at the field and the other two districts (Chugoku-Shikoku and Kyushu-Okinawa) and part of a district (Tokai indicated as Hokuriku–Tokai) use 2.85 Mg FW ha^{-1} as half of rice straw production (Mishima, Endo, and Kohyama 2009a). Yamaguchi, Harada, and Tsuiki (2000) set continues manure receiving capacity that would be 5–15 Mg FW ha^{-1} at upland fields, 5–10 Mg FW ha^{-1} at orchard, and around 20 Mg FW ha^{-1} at forage and fodder. Therefore, we set 10 Mg FW ha^{-1} for upland crop and vegetable, 7.5 Mg FW ha^{-1} for orchard and tea, and 20 Mg FW ha^{-1} for forage and fodder. These values are assumed to be of cattle manure. Swine and poultry manures have different characteristics, such as more rapid decomposition and higher nutrient efficiency. To correct this difference, we set 1 Mg of swine or poultry manure equivalent to 2 Mg and 2.63 Mg of cattle manure as the value of nutrient supply and decomposition rate, respectively (Yamaguchi 2000), and then the estimated manure application rate of three types of manure was integrated to cattle manure equivalent.

Results

Nutrients and Carbon Life Cycle from Feed to Manure in 1980 and 2010

Number of dairy cattle recorded a huge decrease from 1980 to 2010, but the increase of beef cattle compensated the decrease (table 1). Swine recorded slight decrease (1.6%, table 1). Layer was increased 16% and broiler slightly increased the shipment (table 1) because feeding condition and its composition have been changed from 1980 to 2010. Forage and fodder consumption increased, except K, and especially N and K increase in “Concentrated Feed” (figure 1). As the result, the basic unit of livestock waste for the kind of livestock, nutrients (C, N, P and K) were also changed, as shown in table 1. Increase of “Livestock Product” in 2010 was caused mainly by increase of milk production (6,489 Gg in 1980 to 7,631 Gg in 2010). Total livestock waste production was larger in

Table 1. Basic statistics of livestock number and basic unit of C, N, P, and K in livestock waste production.

			1980				2010			
Year	1980 Head	2010 Head	C	N	P	K	C	N	P	K
Dairy cattle	2,104,800	1,484,300	425.5	83.6	14.4	29.7	228.7	68.6	12.2	36.9
Beef Cattle	2,281,000	2,892,300	553.2	47.0	9.9	29.3	266.7	60.4	8.1	16.5
Swine	10,065,000	9,899,500	62.4	18.2	4.8	4.9	71.3	22.7	3.1	4.9
Layer	155,032,000	180,994,000	10769.5	890.6	135.4	235.9	15736.9	1040.3	117.0	213.2
Broiler shipment	624,150,000	633,799,000	2491.4	138.2	13.8	31.3	2385.9	152.1	22.2	32.4
Total waste production			7,473	690	131	234	8,038	785	107	210

Unit for cattle and swine: kg $head^{-1}$ yr^{-1}.
For layer: g $head^{-1}$ yr^{-1}.
For broiler: g $head^{-1}$ $shipment^{-1}$.
For total waste production: Gg.

2010 than in 1980 at all elements. This phenomenon would be caused by increase of N, P, and K in concentrated feed in 2010. Co-material, amended for bedding material for livestock and/or adjustment of water content in waste for composting, was a significant C source; however, decrease of N, P, and K would be a difference of co-material. In 1980, co-material mainly occupied rice straw and in 2010 was saw dust. Potential of livestock waste production calculated by the method of Mishima et al. (2008) with modification indicates slight decrease of C, as same as N and increase of P and K. Here, we set part of P (10% for 1980 according to Ikumo 2001, 7% for 2010 according to Matsunami et al. 2006) will leach with liquid

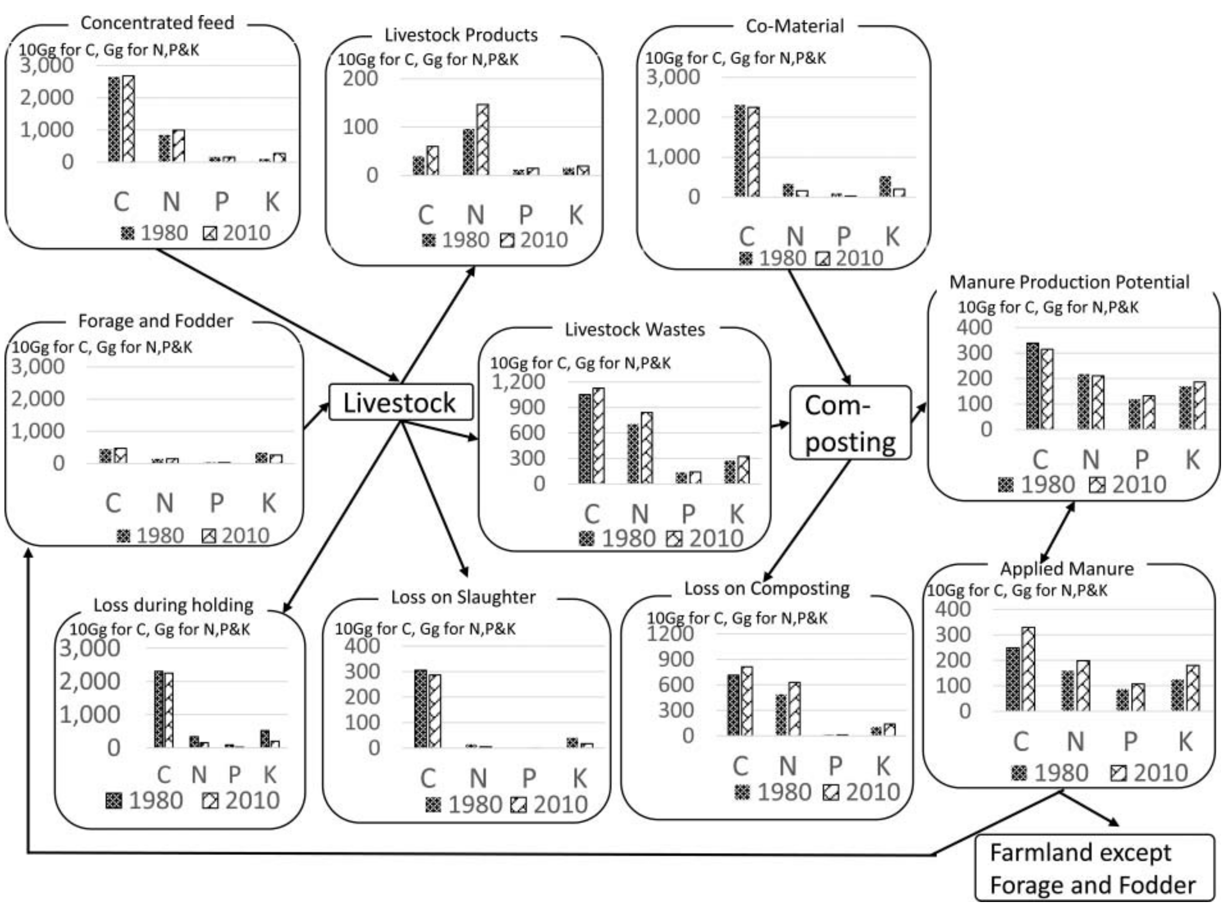

Figure 1. Life cycle of C, N, P, and K from feed to manure. Livestock feed is mostly occupied by imported concentrated feed. Most of C was lost during holding provably breezing and wastes. Waste was mixed with co-material, mainly straw in 1980 and sawdust in 2010. Except P, large amounts of C, N, and K were lost as gases or in manure effluent. Phosphorus was mostly kept in manure. In P basis, 68% of manure was used when compared with potential manure production and that of 2010 was 80%. Part of manure was returned to forage and feed production, but most of the manure was used for food crops.

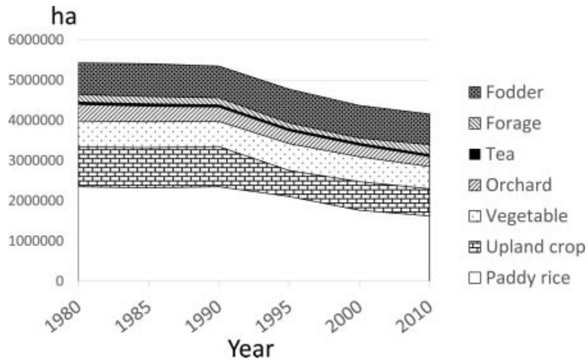

Figure 2. Changes of Japanese farmland area and its composition from 1980 to 2010. Farmland area had been continuously decreasing from 1980 to 2010. This caused total amount of sustainable manure application decrease.

produced during composting. Loss of C, N, and K was larger in 2010 than in 1980, because C/P, N/P, and K/P ratios were larger in 1980 than in 2010. Furuya (2005) indicated decrease of manure water content and increase of nutrient content. This tendency appeared in P and K, but there was no change in N in total (figure 1 "Manure Production Potential").

Estimated Kinds of Manure Application in 1980 and 2010 in Japan

Farmland area from 1980 to 2010 in Japan is shown in figure 2. Each crop had each movement; however, total crop planted area declined from 1980 to 2010, although forage recorded the largest planted area in 2010 during that period. The largest and second largest decrease in planted area was in paddy rice and in upland crop, respectively. Trends of manure C, N, P, and K application rate for seven crop groups in national scale are shown in table 2. The largest application of manure elements in paddy rice, upland crop, vegetable, and tea was recorded in 1980, then it declined in 2010, although application rate was lower in 2010 than in 1980. Manure application rate in 1980 was the largest in forage crop, then after vegetable and fodder, however, in 2010, vegetable was the largest user. Cattle manure was the most common, and the most widely used manure than swine or poultry manure; however, all kind of manure use was reduced concurrently from 1980 to 2010 (table 2).

Comparison of Sustainable and Estimated Manure Application in 1980 and 2010

Sustainable manure application was reduced by 18% from 1980 to 2010 (table 3). During this period, the farmland area declined, as shown in figure 2. However, Hokkaido and Hokuriku–Tokai increased sustainable application, and the other five districts reduced the application (table 3). The reason was increase of area for forage and fodder in Hokkaido and upland crop and vegetable in Hokuriku–Tokai. The other districts simply reduced farmland area.

Estimated application in cattle manure equivalent declined nationally by 65% and districts, except Hokuriku– Tokai (table 1) from 1980 to 2010. Decrease of application in cattle manure equivalent was especially large in Kyushu–Okinawa and Hokkaido.

Comparing sustainable and estimated application, estimated application was more than 50% larger in application in 1980, although more than 30% less on application in 2010 (table 3). Hokkaido and Kyushu–Okinawa are important livestock production areas in Japan. Hokkaido has a large number of livestock, especially dairy cattle, with extensive livestock farming. On the other hands, Kyushu–Okinawa has very intensive livestock production area with lack of fodder. In 1980, Hokkaido, Hokuriku–Tokai, and Chugoku–Shikoku

Table 2. Application of manure to kinds of crops.

	1980				2010			
	C	N	P	K	C	N	P	K
Paddy rice	1,078,879	67,511	37,461	64,477	983,177	53,458	27,123	48,926
Upland crop	1,300,509	89,785	55,174	83,114	709,857	39,089	20,310	35,613
Vegetable	940,669	73,393	49,689	66,110	845,899	50,830	30,768	45,489
Orchard	194,834	13,783	9,231	13,331	235,671	13,377	7,552	12,479
Tea	29,832	2,278	1,512	2,007	10,487	579	318	557
Forage	340,783	18,928	9,212	19,827	181,645	9,425	4,244	8,582
Fodder	860,226	49,930	25,857	50,946	613,447	31,505	13,774	28,639
Total	4,745,733	315,608	188,135	299,814	3,580,184	198,262	104,087	180,284

Unit: Mg.

Table 3. Comparison between amount of sustainable manure application as cattle manure and estimated manure application that converted to cattle manure equivalent in 1980 and 2010.

	Sustainable application		Estimated application	
	1980	2010	1980	2010
Japan	43,686	36,016	36,554	19,641
Hokkaido	15,598	15,755	11,016	5,161
Tohoku	4,503	4,013	5,028	4,321
Kanto-Tozan	7,905	5,203	7,305	3,055
Hokuriku–Tokai	2,164	2,619	961	1,392
Kinki	1,637	1,099	1,703	704
Chugoku-Shikoku	3,492	1,576	2,574	1,774
Kyushu-Okinawa	8,389	5,750	8,077	3,235

Gg FW.

had lower amount of estimated application than sustainable application. In 2010, Tohoku and Kyushu–Okinawa applied enough manure; however, the other districts lacked in application in cattle manure equivalent. The reason was change of applied manure. In 2010, cattle manure was mostly applied, swine and poultry manures were not used.

Discussions

Basic Unit, Livestock Waste Production, and Manure Production

There were several data about livestock waste production, although those were for estimating the capacity for composting facility, for sewage system (ex. Encyclopedia of Agricultural Technology - Livestock production - Measure of environmental problem 1999) and so on. Later, Tsuiki and Harada (1997) released a calculator for estimating livestock waste N, P, and fresh weight production from fed N and P amounts in forage, fodder, and concentrated feed, and Ikumo (2001) made an equation for livestock waste K production from amount of fed K. Using these formulae, basic unit of livestock waste N, P, and K production were set and were used for various way, such as estimation of regional or national nutrient budget (ex. Ikumo 2001). Source of livestock fertilization was referenced from Livestock Feeding Guideline formulated by MAFF with modifications, such as set 1.2 times of N and P amount than Livestock Feeding Guideline was fertilized (Tsuiki and Harada 1997). However, Livestock Feeding Guideline changed the nutrition for kinds of livestock and there are no verified data about livestock farms always keeping this guideline. Kohyama et al. (2006) referenced Livestock Production Cost (MAFF 2006) and Feed Composition Table (MAFF 2010) to estimate basic unit of livestock. These values would be more realistic than dependent on Livestock Fertilization Guideline (ex. MAFF 2006). In this study, we also used Livestock Production Cost (MAFF 1981b and 2011b) for consumption of kinds of feed fertilized, Feed Handbook (MAFF 1981c and 2011c) for getting composition of concentrated feed and Feed Composition Table (MAFF 1979, 2010) at 1980 and 2010 for estimation of kinds of livestock fertilizations to reflect difference of fertilizations and nutrients in wastes in those times. As a result, N and P in wastes were lower in 2010 than in 1980, except layer on N and broiler on P. These conditions reflected lower N and P fertilization by more use of concentrated feed, except poultry (layer + broiler) and better nutrient use efficiency by livestock, namely higher out of livestock product with lower input of feed in 2010 than in 1980 (figure 1). We cannot find C/N rate or other data about C concentration in forage, fodder, and concentrated feed; therefore, we cannot refer to C on livestock fertilization. We also found out C in wastes in each year. Therefore, we used the same C/N rate for wastes for 1980 and 2010.

Produced wastes were mixed with co-material to adjust water content in wastes and/or bedding material. Kohyama et al. (2006) referred co-material was a significant source of nutrients for manure; however, on our estimation, the amount of N, P, and K was several percent of livestock wastes, except C. Main component of co-material had been changed from rice straw in 1980 to sawdust in 2010 (MAFF 1981b, 2011). This change of composition of co-material might affect whether co-material became a significant N, P, and K source or not, because C/N ratio was more than 10 times higher in sawdust than rice straw (Biomass Recycle Study for Agriculture, Forestry and Fisheries Systemize Sub-Group 2008).

When P is set as a trace element, because of its very low mobility and loss on composting, we set the difference of C/P, N/P, and K/P ratios between livestock waste (dairy cattle, beef cattle, swine, layer, or broiler) plus co-material (sawdust or other) and composted manures with or without sawdust was thought as loss of C, N, and K during composting. In this calculation, lower P fertilization caused lower P waste production, then potential of manure production lower in 2010 than 1980. The other reason might be decrease of daily cattle that has the highest waste P producer, although beef cattle was increased instead. For the other livestock, swine in 1980 was almost the same as in 2010, and layer and broiler (shipment number) increased from 1980 to 2010. However, waste P reduction per head recorded more rapid decrease.

Planted Area, Estimated Application from 1980 to 2010, and Manure Use for Crops

We categorized 70 crops in 1980 and 100 crops in 2010 into seven crop groups. Paddy rice is the most dominant crop on the planted area, indicating the largest decrease of planted area, although the other crop was not indicating such large decrease (figure 2). This large decrease of paddy rice is caused by decrease of consumption of rice (MAFF 2014).

Estimated manure application in total amount from 1980 to 2010 indicated large reduction (table 1). Cattle manure was more popular manure than the others and crop husbandry farmers wished to use it (Yamaguchi 2000). In 1980, Mishima (2001a) indicated that in almost all of cattle, swine, and poultry manures, N was utilized, then its use reduced in 1995. He estimated the manure application with the other methods, namely, head number of livestock from statistics and basic unit of waste N production (Tsuiki and Harada 1997) with waste use ratio listed on Livestock Production Cost (MAFF 1981b, 1986, 1991, 1996). These statistics list how much waste was produced and how much waste was used in an averaged livestock husbandry farm for all kinds of livestock. He set utilization rate as utilized manure divided by total produced manure. Even in his method, about 90% of total livestock waste N was utilized in 1980, then utilization was reduced in 1995. The decreasing trend by Mishima (2001a) might be the same as this study, but reduction is more rapid in this study. For example, Livestock Production Cost (MAFF 2011a) indicates that 72% of dairy cattle waste, 42% of beef cattle waste, and 14% of swine waste was utilized in 2010. On the other hand, only 50% of cattle manure and 10% of swine manure was utilized in this study (from figure 1 data). Greenhouse Gas Inventory Office (2015) set 85% of broiler waste was composted then amended to farmland. Our estimate was that only 12% of poultry waste was utilized. In most cases, our result might lower manure use than the other studies. This difference could come from estimation methods, namely, built up national manure use from data about manure application from each type of farm, or estimated national resource budget, then multiplied with percentage of use or not. The Livestock Waste Management Act that was fully enforced from 2004 requires adequate processing of livestock waste, such as composting, sewage treatment, burning, and so on. Hopeful aim of this Act would be composting and adequate application to farmland, combined with Sustainable Agriculture Act that was set at the same time and that requires adequate use of manure and chemical fertilizer than willing to sustain agricultural production with enhance soil fertility. Our data would indicate these Acts might be still lagging far behind in grappling with willing of these Acts. During the moratorium of Livestock Waste Management Act, MAFF funded most farms for setting composting facilities, sewage system, and regional compost distributing centers. Some succeeding prefectures built manure information system (ex. Chiba Prefecture). However, there were few data about inspection or verification of quantitative manure distribution through these systems.

Although the reason of increase of application for upland crop is not clear, vegetable and orchard are cash crops, so a farmer can pay more labor for manure application. Full enforcement of “Livestock Waste Act” that promotes more use or substitute use of manure with chemical fertilizer and “Sustainable Crop Production Act” also promote use of manure. These “Acts” would affect application condition of livestock manure. However, concentrated livestock farming area could consume all manure within the district is still doubtful as pointing out by Mishima et al. (2009b). In a recent movement in Japan, the difference between 1980 and 2010 is livestock waste use except conventional utilization style. For example, Nangoku Kosan Corporation and Miyazaki Biomass Recycle in Miyazaki prefecture use poultry waste as fuel then get water vapor for rendering or electricity, namely, thermal recovery. The ash after incineration is very rich in P and calcium. So, ash is commercially sold to various corporations. Kobayashi city in Miyazaki prefecture set phosphorus recovery plant from swine waste.

Sustainable Manure Receiving Capacity and Manure Application

On C and nutrient use through manure, almost all manure was utilized in 1980, then it became less than half in 2010, as shown in figure 1. If most of the manure was utilized, it would be favorable on condition from livestock husbandry farm side, because waste did not stagnate going away and utilized crop and livestock farms. However, if the application amount exceeded farmland's manure receiving capacity, it would cause problems in the farmland soil and surrounding environment (ex. Nishio 2001).

In 1980, at national scale, manure application was more than 1.5 times larger than sustainable application level that was thought as applying manure every year (table 3). This might be due to misgivings of negative environmental impact. If we could think optimistically, there were wide low soil fertility farmlands at that time. For example, Yoshiike (1983) summarized soil fertility measurement done by MAFF, and wide Japanese farmland soil needed more soil fertility on P. Therefore, large input of manure might be needed or might be permitted in 1980.

In 2010, decrease of farmland area as 75% of 1980, amount of sustainable manure application reduced to 82% of 1980. Because decrease of farmland was mainly at paddy rice that cannot receive such large amount of manure compared with the other crops, decrease rate of paddy rice was not smaller on manure application than farmland decrease. Applied manure was 55% of that of 1980 and 67% of sustainable application (table 3). In all districts, except Kinki, manure application was smaller than sustainable application in 2010 and was smaller than estimated manure application in 1980. Although Mishima, Endo, and Kohyama (2009a) indicated large surplus or deficiency on nutrient balance that equals chemical fertilizer plus manure minus crop harvesting, manure application level did not affect nutrient store in soil surface layer from 1980 to 2000. Obara and Nakai (2004) indicated that accumulation of P and K had occurred in farmland soils, but total C and N had reduced (by analyzing first to fifth survey of BSEMP-SM). Japan could produce twice the amount of applied manure (figure 1). Application of manure to all farmlands might be difficult, partly because of lack or too much of manure production at local scale (ex. Mishima 2001b). More manure might be needed to apply to farmland soils.

Conclusion

Uneven distribution of manure inside Japan and prefectures made it difficult to promote livestock manure use, mainly for crop husbandry farms. It is partly due to lack of information, such as from where will crop husbandry farm get livestock manure, lack of labor to apply manure to farmland, and difficulty of planning soil and crop fertilization. Livestock Waste Management Act was expected as promotion of manure use by setting composting facility in livestock husbandry farm and setting center for integrated manure and raw waste processing. However, our result of estimated manure application in 2010 against that in 1980 indicated an overall increase. However, this increase is largely dependent on cattle manure use. Use of swine and poultry manures was rather decreased. Lack of manure application was thought to be reduction of soil fertility that is measured with total C and N and available N, P, and K concentrations in soil. Promotion of manure application in recent years might be the first-order requirement. However, regarding soil fertility, sustainability, and/or soil health, application of manure with simple or easy idea might not realize balance of C, N, P, and K in soils. When Livestock Waste Management Act is combined with Sustainable Agriculture Act, we should think manure application as well as inorganic fertilizers for optimizing crops' needs of nutrients and balanced soil fertility. Future needs would be building up the system to make prescription for optimum fertilization with easy soil testing, and then deciding suitable application of manure and inorganic fertilizers, as well as local uneven distribution of livestock husbandry area.

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