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REVIEW

Estimation of Potential Supply of Livestock Waste Compost to Replace Chemical Fertilizer Use in Japan Based on 2000 Census of Agriculture

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Abstract

Legislation represented by the Livestock Waste Disposal Law and Compost Quality Control Law were enacted in order to reduce the excessive use of chemical fertilizer and disposal of untreated livestock waste. These laws encourage the replacement of chemical fertilizer use with livestock waste compost. The potential supply of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) from compost was estimated using computer software and prefectural and municipal data from the 2000 Census of Agriculture in Japan. Use of N, P_2O_5 and K_2O as chemical fertilizer in Japan was also estimated by the questionnaire data by the Ministry of Agriculture Forestry and Fisheries and the 2000 Census of Agriculture. The percent of chemical fertilizer replaceable with livestock waste compost was calculated by dividing the supply from compost by the use of chemical fertilizer on the basis of N, P_2O_5 and K_2O. Average and range of replaceable percent was 20.4% (106.9–7.1%), 21.8% (105.3–7.0%) and 31.5% (124.1–7.6%) in N, P_2O_5 and K_2O, respectively, among the 47 prefectures. The range in about 3,300 municipalities fluctuated between 2,047–0%, 3,762–0%, and 3,207–0% in N, P_2O_5 and K_2O, respectively. The significance of the data is discussed in the text.

Disciplines: Agricultural environment / Animal industry
Additional key words: animal industry, environment, nitrogen, phosphorus, potassium

Introduction

In 2000 the Japanese government enforced environmental laws[3] to encourage the use of livestock waste as an organic fertilizer, represented by the Livestock Waste Disposal Law, the Compost Quality Control Law, and the Sustainable Farming Law. Some of the environmental problems caused by untreated livestock waste in Japan are; (1) increasing nitrate concentration in ground water[1], (2) pathogenic microbes threatening human health, such as O-157, salmonella and cryptosporidium, (3) offensive smell, and (4) water pollution. As one of the effective means to treat these problems, especially to deal with increasing nitrate in ground water caused by excessive use of chemical fertilizer and disposal of poorly-treated livestock waste, the Japanese government encouraged the production of compost form livestock waste. The compost could then be applied to farmland replacing chemical fertilizer use. The potential supply of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) from livestock compost and use of N, P_2O_5 and K_2O as chemical fertilizer were estimated on regional basis in Japan to evaluate the percent of chemical fertilizer replaced by livestock waste compost.

Estimation of the percent of chemical fertilizer use replaceable by livestock waste compost (C)

The percent of chemical fertilizer use replaceable by animal waste compost (C) was calculated on the basis of prefectural and municipal data by the equation (1):

$$C(\%) = 100 \times A/B \qquad (1)$$

where A is the estimated supply of N, P_2O_5 and K_2O from livestock waste compost and B is the estimated use of chemical fertilizer in the chemical form of N, P_2O_5 and K_2O.

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1. Estimated supply of N, P_2O_5 and K_2O from livestock waste compost (A)

Yearly supply of N, P_2O_5 and K_2O from livestock waste compost was estimated as A of the equation (2):

A = (N, P_2O_5 and K_2O daily discharge from livestock waste per head) × 365 × (100 – loss of N, P_2O_5 and K_2O during composting process) × 0.01 × (Availability of N, P_2O_5 and K_2O in compost) × (number of livestock animals reared) (2)

In equation (2), yearly supply of N, P_2O_5 and K_2O from livestock waste compost was calculated by multiplying the daily discharge data by 365, (100 – loss(%)), 0.01, availability of nutrients and also by number of livestock animals reared in prefectures or municipalities reported in the 2000 Census of Agriculture[5].

(1) Daily discharge of N, P_2O_5 and K_2O from livestock waste

Daily discharge of N, P_2O_5 and K_2O from dairy cattle, beef cattle, pig, chicken and broiler excreta were calculated by computer software made by Tsuiki et al.[7] and are shown in Table 1.

(2) Loss of respective nutrients during the composting process

Loss of respective nutrients during the composting process was estimated and shown in (3):

Loss of N: 40%,
Loss of P_2O_5: 10%,
Loss of K_2O: 20% (3)

Loss of nitrogen was estimated to be 40% following the data by Ikeguchi et al.[2]. Since there were no data in reference to loss of P_2O_5 or K_2O, I arbitrarily estimated them to be 10 and 20%, respectively, assuming that loss of these two nutrients are lower than N which can be changed into a volatile form and lost mainly as ammonia. Most of the P compounds are less soluble than the K compounds and are considered to be more resistant to loss. The number of livestock animals reared in prefectures or municipalities was from the statistical data of the 2000 Census of Agriculture.

(3) Availability of N, P_2O_5 and K_2O in compost

Availability of N, P_2O_5 and K_2O in compost is the bioavailability by agricultural plants of respective nutrients taking that of chemical fertilizers to be 100% and was estimated in (4):

Availability of N, P_2O_5 and K_2O in compost;
N: 40%, P_2O_5: 80%, K_2O: 90% (4)

N availability of cattle, pig and chicken compost was roughly estimated to be 10, 50 and 60%, respectively. Their average, 40%, was applied commonly to all kinds of compost as a temporary measure. A lot of information strongly indicates that the order of N availability among cattle, pig and chicken is chicken>pig>cattle, although the values are influenced by the conditions, such as period, temperature, kind of machines, aeration and so forth in composting. Availability depends on cultivation system as well. Availability of P_2O_5 and K_2O were estimated to be 80 and 90%, respectively, according to the data by Oyanagi[6].

2. Estimation of chemical fertilizer use as N, P_2O_5 and K_2O on a prefectural and municipal basis (B)

Use of chemical fertilizer as N, P_2O_5 and K_2O in Japanese prefectures and municipalities was estimated by the equation (5):

Table 1. Daily discharge of N, P_2O_5 and K_2O from livestock animals

	Dairy cattle	Beef cattle	Pig	Chicken	Broiler
N*	227.9	116.7	47.1	2.9	2.6
P_2O_5*	74.4	31.6	28.9	1.2	0.7
K_2O*	163.7	66.3	18.9	0.6	0.7

*g/day/head

Table 2. Kinds of farm produces applied for calculation of chemical fertilizer use

Crop	Vegetable	Others
Rice, Wheat, Barley, Buckwheat, Potato, Sweet potato, Soybean, Red bean, Corn, Kidney bean, Taro	Tomato, Cucumber, Chinese cabbage, Cabbage, Spinach, Onion, Carrot, Lettuce, Eggplant, Welsh onion, Pumpkin, Chinese radish, Sweet pepper	Strawberry, Melon, Water melon, Tobacco, Tea, Sugar beet, Sugar cane, Grass, Fruits

B = (Use of chemical fertilizer on farmland per year on the basis of farm produces (kg/10 a)) × (Cultivated farmland area per year on the basis of farm produces (×10 a)) (5)

where use of chemical fertilizer on farmland on the basis of crops was estimated according to questionnaire data authorized by a MAFF survey[4]. The crops produced included in the questionnaire are shown in Table 2. These crops are rice, wheat, barley, soybean, sweet corn, potato, tea-leaf, tomato, cucumber, water melon, forage, fruits, flowers and others covering almost all crops cultivated in Japan. Yearly cultivated farmland area on the basis of crops produced was obtained from the statistical data of 2000 Census of Agriculture. Use of chemical fertilizer (kg/10 a) as N, P_2O_5 and K_2O on the basis of crops is shown in Table 3.

Results and discussion

1. Calculation of the percent of chemical fertilizer use replaceable with livestock waste compost

(1) The percent of chemical fertilizer use replaceable with livestock waste compost

The percent of chemical fertilizer use replaceable with livestock waste compost as N, P_2O_5 and K_2O was calculated by equation (1) on the basis of prefectural and municipal data. The prefectural data is shown in Table 4. Average and range were 20.4% (106.9–7.1%), 21.8%

Table 3. Amount of chemical fertilizer use on farmland on the basis of farm produces

	N**	P_2O_5	K_2O
Rice*	7.8	10.7	8.6
Wheat	9	12	10
Sweet potato	6.1	14.6	14
Soybean	3.5	7.6	5
Tea	54.3	21.9	25.6
Tomato	23.7	32.5	21.8
Cucumber	50.3	40	40.3
Eggplant	56.3	42.2	45.1
Chinese cabbage	28.1	27.2	22.2
Strawberry	23	25.6	20.9
Water melon	13	19.9	12.2
Fruits	15.6	15.6	12
Forage	32	28	32

* The data of main farm produces are shown and others are omitted.
** kg/10 a of farmland.

Table 4. Replaceable percent of chemical fertilizer with livestock waste compost on prefectural basis in Japan

Name of Prefecture	N: Replaceable (%)	P_2O_5: Replaceable (%)	K_2O: Replaceable (%)
Hokkaido	9.1	9.5	18.9
Iwate	31.7	27.4	56.4
Miyagi	28.0	24.2	44.4
Yamagata	13.6	13.2	20.7
Akita	8.8	9.0	12.2
Aomori	12.1	12.1	20.0
Fukushima	19.3	17.0	29.0
Ibaraki	25.8	30.7	35.4
Gunma	52.6	70.4	79.4
Saitama	34.9	39.8	40.7
Kanagawa	35.4	44.6	58.3
Chiba	40.5	45.8	55.9
Tokyo	9.4	11.7	18.2
Tochigi	32.2	29.4	48.8
Yamanashi	15.9	18.2	27.4
Nagano	15.9	17.0	29.2
Niigata	10.4	11.1	14.4
Ishikawa	12.8	12.1	16.4
Toyama	8.9	8.0	11.0
Fukui	9.0	7.1	10.1
Aichi	59.7	73.7	82.2
Gifu	49.6	51.3	64.0
Mie	24.5	29.0	31.9
Shizuoka	12.0	20.7	25.0
Kyoto	10.1	10.9	18.1
Shiga	13.4	11.1	19.1
Osaka	10.7	10.9	18.0
Nara	17.2	19.6	25.7
Hyogo	41.2	32.8	56.9
Wakayama	7.1	7.0	7.6
Okayama	26.3	21.7	42.4
Hiroshima	22.1	20.5	33.9
Yamaguchi	22.2	17.7	26.5
Tottori	25.4	23.5	38.9
Shimane	21.6	17.4	35.0
Ehime	30.2	36.3	39.3
Kagawa	47.7	44.4	52.7
Kochi	14.2	15.4	21.7
Tokushima	53.8	43.4	62.4
Fukuoka	17.6	17.0	24.8
Nagasaki	47.3	46.7	65.2
Oita	33.3	29.8	46.0
Kagoshima	45.4	53.6	63.8
Saga	27.6	21.0	34.0
Kumamoto	34.3	35.5	54.6
Miyazaki	106.9	105.3	124.1
Okinawa	20.3	33.1	37.6
Average	20.4	21.8	31.5

Table 5. Replaceable percent of chemical fertilizer with livestock waste compost on municipal basis in Miyazaki Prefecture

Name of municipalities	N: Replaceable (%)	P_2O_5: Replaceable (%)	K_2O: Replaceable (%)
Miyazaki	40.2	41.5	48.1
Miyakonojo	126.2	123.4	160.6
Nobeoka	71.7	76.9	99.2
Nichinan	167.0	217.5	225.7
Kobayashi	71.4	81.4	111.5
Hyuga	282.2	235.3	279.1
Kushima	46.5	37.1	54.1
Seito	46.2	37.4	58.1
Ebino	88.0	94.3	129.0
Kiyotake	18.6	14.2	27.3
Tano	12.5	9.0	15.9
Sadohara	30.1	24.0	46.8
Hokugyo	382.3	473.0	405.0
Nango	52.9	56.3	74.9
Mimata	107.7	101.7	143.3
Yamanokuchi	138.2	190.1	205.3
Takajo	176.2	187.0	200.2
Yamada	125.6	150.8	141.6
Takasaki	224.1	231.3	239.6
Takahara	72.1	72.5	101.4
Nojiri	128.8	127.2	152.8
Sukimura	89.6	79.7	109.3
Takaoka	92.9	88.4	110.8
Kokufu	32.2	30.6	38.0
Aya	91.1	127.0	136.7
Takanabe	128.8	128.8	120.8
Shintomi	134.4	136.6	132.1
Nishiyora	13.8	11.0	27.2
Kijo	147.7	143.7	170.7
Kawanami	162.0	208.1	191.7
Tono	101.5	92.5	110.7
Kadokawa	1,296.2	880.4	1,034.9
Togo	972.8	753.9	855.9
Nango	240.4	178.7	231.4
Saigo	27.3	26.4	34.7
Hokugo	25.8	29.5	43.5
Kitakata	70.1	59.1	107.2
Kitagawa	62.9	63.0	64.0
Kitaira	232.5	240.3	229.2
Morotsuka	89.6	128.3	143.2
Shiibamura	116.3	118.5	258.8
Takachiho	94.9	75.3	107.7
Hinokage	46.5	34.3	67.2
Gonose	25.7	29.4	44.4
Average	106.9	105.3	124.1

(105.3–7.0%) and 31.5% (124.1–7.6%) in N, P_2O_5 and K_2O, respectively. Miyazaki Prefecture, where it is well known that there are a great number of pig, beef cattle, layer and broiler reared and that animal industry is one of the main industries, showed the biggest percent not only in replaceable N but also P_2O_5 and K_2O among the 47 prefectures. In contrast the smallest percent was obtained from Wakayama Prefecture, which is well known to have the biggest production of mandarin orange in Japan but have a very small number of all kinds of livestock animals reared. The percent of replaceable nutrients in municipalities of Miyazaki Prefecture is shown in Table 5. In Japan there are as many as about 3,300 municipalities. Therefore it is impossible to show all municipal data. The data for Miyazaki Prefecture with 47 municipalities was shown as the representative for the 47 prefectures in Japan. As shown in Table 5, for instance, in replaceable N, the percent fluctuated greatly from 1,296% to 12.5% with the average of 106.9%. Although the data is not shown, the percent in Japanese municipalities fluctuated between 2,047–0%, 3,762–0% and 3,207–0% in N, P_2O_5 and K_2O, respectively, with an average of 20.4, 21.8 and 31.5%, respectively.

(2) Mapping of the data in Table 4 and Table 5

For a better understanding of the percent data in Tables 4 and 5 through visual means, the data was processed into maps as shown in Fig. 1 and 2. The data was classified into 5 categories, i.e., (1) less than 10%, (2) 10–20%, (3) 20–30%, (4) 30–50% and (5) greater than 50% in Fig. 1, and (1) less than 30%, (2) 30–50%, (3) 50–100%, (4) 100–200% and (5) greater than 200% in Fig. 2.

(3) Evaluation of the data for practical application of livestock waste compost

The percent data, particularly that of the municipalities, should be useful for more practical application of livestock compost on Japanese farmland. How useful the data is depends on the attitude and effort of those concerned. The most positive attitude is seen in organic farming systems without any use of chemical fertilizer and is possible at many municipalities in Miyazaki Prefecture as shown in Fig. 2, where potential supply by compost exceeds 100%. In Japan, however, organic farming has not increased steadily because the cultivation system has high cost and low profitability because of very strict certification regulations. In contrast, many local governments encourage farmers to follow the environment-conscious farming to reduce both chemical fertilizer and pesticide to some extent, but not completely. A 30% reduction in N use seems to be possible. Approximately 20% N chemical fertilizer can be replaced by

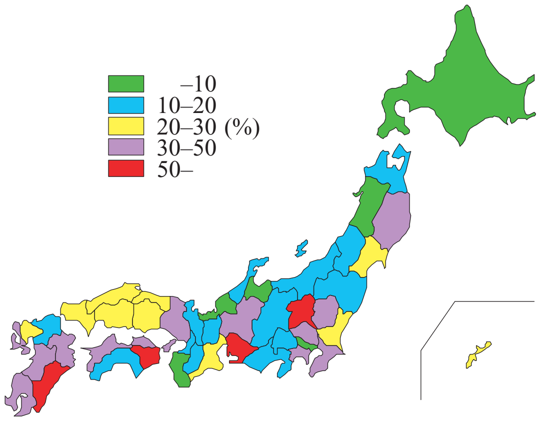

Fig. 1-1. N replaceable percent by compost
N replaceable percent was calculated by dividing the yearly supply of N from livestock waste compost by the yearly use of chemical fertilizer in the chemical form of N on the basis of prefecture.

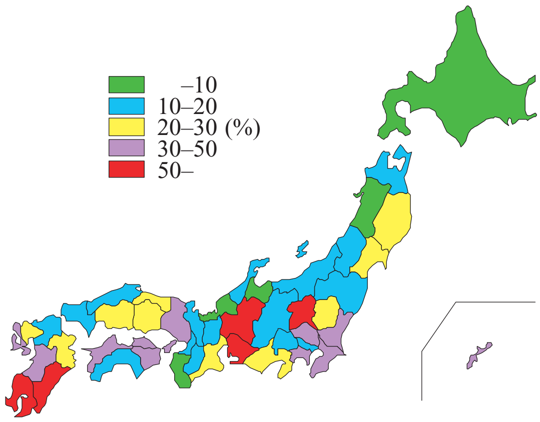

Fig. 1-2. P_2O_5 replaceable percent by compost
P_2O_5 replaceable percent was calculated by dividing the yearly supply of P_2O_5 from livestock waste compost by the yearly use of chemical fertilizer in the chemical form of P_2O_5 on the basis of prefecture.

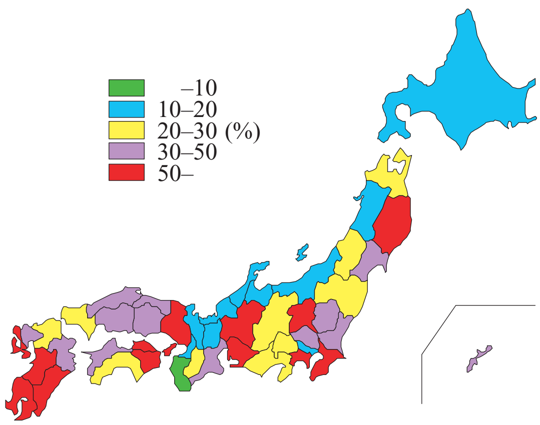

Fig. 1-3. K_2O replaceable percent by compost
K_2O replaceable percent was calculated by dividing the yearly supply of K_2O from livestock waste compost by the yearly use of chemical fertilizer in the chemical form of K_2O on the basis of prefecture.

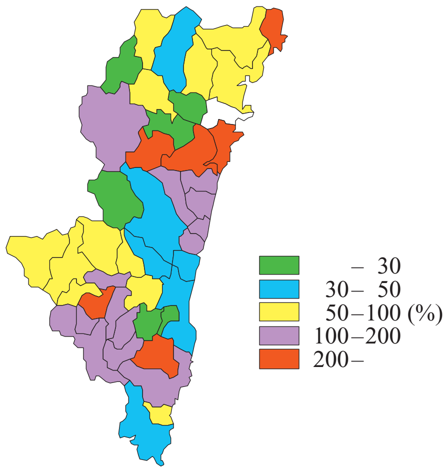

Fig. 2-1. Miyazaki Prefecture N Map
The percent data is N replaceable percent calculated by dividing the yearly supply of N from livestock waste compost by the yearly use of chemical fertilizer in the chemical form of N on the basis of municipality.

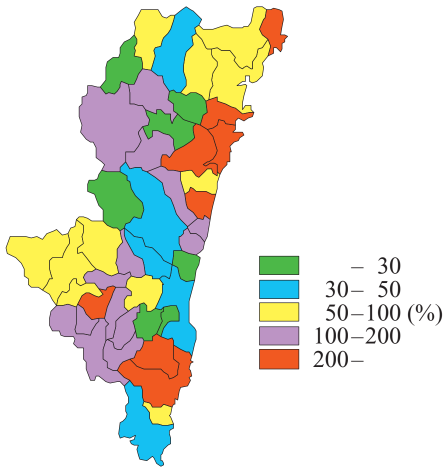

Fig. 2-2. Miyazaki Prefecture P Map
The percent data is P_2O_5 replaceable percent calculated by dividing the yearly supply of P_2O_5 from livestock waste compost by the yearly use of chemical fertilizer in the chemical form of P_2O_5 on the basis of municipality.

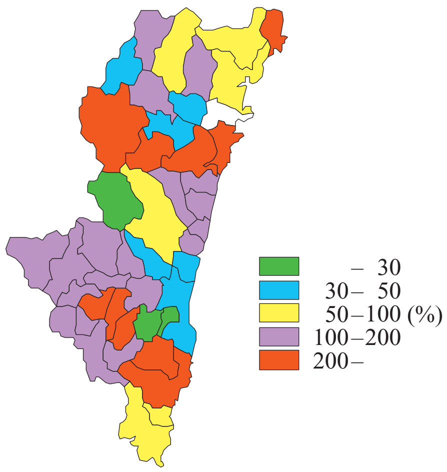

Fig. 2-3. Miyazaki Prefecture K Map
The percent data is K_2O replaceable percent calculated by dividing the yearly supply of K_2O from livestock waste compost by the yearly use of chemical fertilizer in the chemical form of K_2O on the basis of municipality.

compost, i.e., the average value in Japan of N in livestock compost. The difference of 10%, 30–20%, is possible to reduce because farmers tend to use more N chemical fertilizer than the necessary level.

In reality, however, even a 20% replacement of chemical fertilizer seems to be very impractical in many Japanese farms because they evaluate compost quality to be very variable and not reliable. Most farmers hesitate to use compost regularly, although they are conscious that compost application on their farmland is a "must" to maintain soil physical property in a good condition. Good soil property means persistent and good supply of water and nutrients from soil through the combined effect of well-organized air, liquid and solid layers, which can be formed by compost application. In order to extend livestock compost more widely in Japan, further research should be conducted, for instance, on the technology to evaluate compost quality speedily and efficiently and also to work out N availability value of compost compared to that of chemical fertilizer more accurately and more in detail. The area at the level of the municipality should be divided as small as possible to encourage transfer of compost from area to area more effectively according to its necessity.

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