Keynote Speech

Nitrogen Management in Soil and Water for Our Future Earth

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Abstract
Although nitrogen (N) is an essential element for plants, it is one of the main contributor to eutrophication in closed water bodies such as lakes and inland sea. Beside, nitrous oxide gas (N_2O) derived from fertilizer and manure is one of the greenhouse gases. Humans can take in just 14% of fertilizer-N as protein for vegetation diets and 4% for carnivorous ones. Other remaining N is lost by N leaching or denitrification (N_2 and N_2O), or may be stored in soil as organic N. We emphasized excess application of manure compost caused N contamination of water by using natural abundances of ^{15}N. Nitrous oxide emissions can be reduced by controlling pH and decomposability of organic matter. Organic waste management should be well studied to establish sustainable agricultural systems in the future.

Keywords: Groundwater, Leaching, Nitrate, Nitrous oxide, Organic waste, Upland fields

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Introduction
Nitrogen, an essential element for plants, is one of the main contributor to eutrophication in closed water bodies such as lakes and inland sea. Nitrate that is the most oxidized form of N contaminates groundwater when excess N was applied to farmland. NO3 is easily leached out of the root zone because soil is usually negatively charged and cannot adsorb anions like $NO3^-$. In Japan, the percentage of groundwater containing nitrate exceeding a Japanese standard, 10 mg N L^{-1} peaked at 6.5% in 2003 and has decreased to 2.9% in 2013 (Ministry of the Environment, 2014) due to less application of N fertilizer and proper management of livestock manure after 2000. Many management practices have been proposed so far to reduce NO3 leaching losses in upland fields, based on scientific outcomes.

Nitrous oxide gas (N_2O), one of the greenhouse gases is derived from fertilizer and manure that were inputted to agricultural land. N_2O is of great importance because it can stand in the atmosphere for more than 114 years and has a global warming potential 298 times higher than CO_2 (Smith et al., 2007).

In this report, the author points out how N inputted to farmland affects soil and water environments and what we need for our future earth.

Nitrogen use efficiency
Crop production has increased greatly after the establishment of the Haber-Bosch process in 1911. N used as fertilizer will reach to 120 Mt all over the world by 2030, which is nearly equivalent to that of the N cycle on Earth prior to 1930 (Vance, 2001).

In addition to chemical fertilizer, we need to consider N from organic wastes. For example, a large amount of compost is produced from livestock wastes in Japan (7.7 Mt from cattle manure, 2.1 Mt from pig manure, and 2.1 Mt from chicken manure, Mishima et al., 2009). Livestock compost application to the farmland is very effective to increase soil organic matter and adjust soil pH as soil amendment. On the other hand, livestock compost contains lots of nutrients, which is slowly released to the soil over many months or sometimes years. This nutrient release, which cannot be controlled or predicted, would lead to unintended N leaching or N_2O emissions.

Figure 1 shows N use efficiencies of chemical fertilizer. Humans can take in just 14% of N as protein for vegetation diets and 4% for carnivorous ones. Other remaining N is lost by N leaching or denitrification (N_2 and N_2O), or may be stored in soil as organic N. The greatest loss occurs in crop production, where only 50% of N is absorbed by crops. Average Japanese requires 4 kg of N per year, and therefore ten times larger N, 40 kg of N must be applied to the farmland to produce foods for a Japanese (Maeda, 2007). Namely, 5.2 Mt of N is necessary for all Japanese people. However, the total use of fertilizer-N in Japan is only 1 Mt. This indicates that the remaining 4 Mt of N is used in other countries, where environmental problems may occur to foster Japanese people. This is a reason why Japanese should be responsible for N management in other counties as well as in Japan.

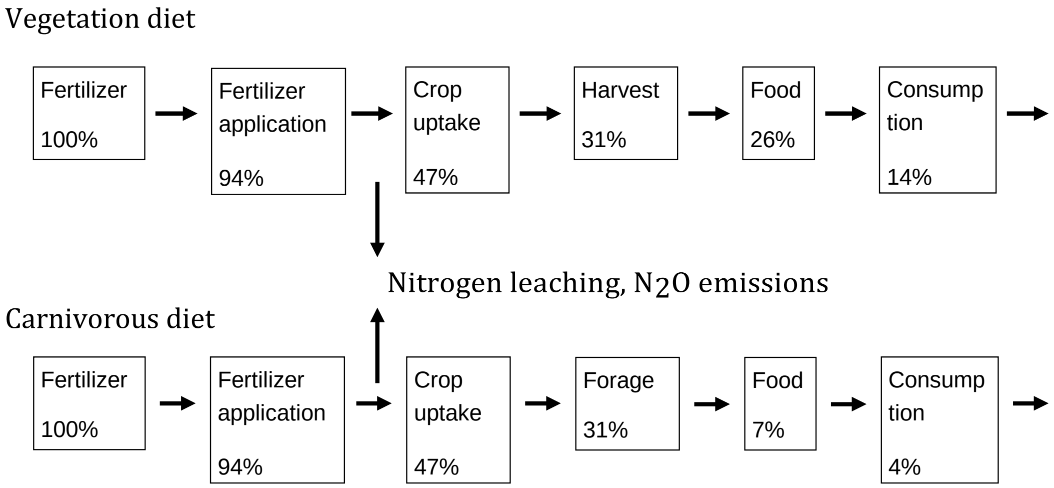

Fig. 1. Fates of chemical-fertilizer nitrogen for vegetarian and carnivorous diets.

Water pollution in agricultural areas

N and phosphorus concentrations have been reported to be high in the main drainage canals in the reclaimed areas of Kasaoka Bay, Japan, where livestock farming is the most common form of agriculture. Maeda et al. (2011) monitored water quality bimonthly from May 2009 to February 2010 and monthly from March to October 2010 at four or five sites in each of three branch canals running through farmland areas with different uses: (i) grassland, (ii) livestock and forage crops, and (iii) livestock, forage crops and horticulture. Concentrations of total N and P in water were higher for land use in the order of (ii) livestock and forage crops > (iii) livestock, forage crops and horticulture > (i) grassland. We also investigated the mechanism of N contamination by analyzing stable isotopes in drainage water, soil plots in all areas, and forage crops in area (ii). Abundances of natural fractions of ^{15}N ($\delta^{15}N$) and ^{18}O in nitrate-N indicated that N contamination in canals could be attributed to the high rate of manure compost application on fields of forage crops owned by livestock farmers in areas (ii) and (iii) and the fact that ammonia volatilization and/or denitrification occurred in the fields and/or in the canals. Further, ammonia volatilization from a cowshed was inferred based on significantly lower $\delta^{15}N$ values in orchard grass and soil in plots closer to the cowshed. In concluding, excess application of manure compost causes N contamination of water and ammonia volatilization from livestock affects soil N in reclaimed land.

Nitrogen leaching in upland fields with different fertilizer management

Fertilizer types affect NO_3 leaching in upland fields. Maeda et al. (2003) tested four N fertilizers (swine compost, coated urea, ammonium N, or no fertilizer) in a volcanic ash soil (Andisol) fields for 7 years. Sweet corn was grown in summer, followed by Chinese cabbage or cabbage in autumn each year. In chemical fertilizer plots (coated urea, ammonium N), NO_3 concentrations in soil water at 1-m depth increased markedly in the summer of the second year and fluctuated between 30 and 60 mg N L^{-1}. In the compost plot, NO3 concentration started increasing in the fourth year, reaching the same level as in the chemical fertilizer plots in the late period of the experiment. The potential NO_3 concentrations by an N and water balance equation satisfactorily predicted NO_3 concentration in the chemical fertilizer plots, but substantially overestimated that in the compost plot, presumably because a large portion of N from compost first accumulated in soil in the organic form. Our results indicate that excessive N from chemical fertilizers can cause substantial NO_3 leaching, while compost application is promising to establish high yields and low N leaching during a few years but would cause the same level of NO_3 leaching as in chemically fertilized plots over longer periods.

Nitrous oxide emissions from Asian soils

Denitrification is an important process to remove NO_3 from water, but the process may produce N_2O when soil is not enough reductive. Ha et al. (2015) compared three flooded soils (paddy soil from Vietnam, mangrove soil from Vietnam, and paddy soil from Japan). In Japanese paddy soil, N_2O and N_2 emissions were increased significantly by the addition of greater NO3 concentrations. However, N_2O and N_2 emissions from Vietnamese paddy and mangrove soils were increased by the addition of 0 to 5 mg N L^{-1}, but not by 5 to 10 mg N L^{-1}. At 10 mg N L^{-1}, N_2 emissions were greater in Japanese paddy soil (pH 7.0) than in Vietnamese paddy (pH 5.8) or mangrove (pH 4.3) soils, while N_2O emissions were higher in Vietnamese paddy and mangrove soils than in Japanese paddy soil. In Vietnamese mangrove soil, N_2O was the main product throughout the experiment. In conclusion, NO_3 concentration and soil pH affected N_2O and N_2 emissions from three flooded soils.

Nitrous oxide emissions in disinfestation, a good agricultural practice

Biological soil disinfestations are developed as alternatives to chemical fumigations. Reductive soil conditions produced by the application of easily decomposable organic matter, water irrigation and covering of soil with plastic mulch films suppress soil-borne pathogens during biological soil disinfestation at high temperature in the greenhouse. This method became popular as a good agricultural practice. However, N_2O may be more emitted as an intermediate product of denitrification during biological soil disinfestation. Maeda et al. (2015) determined the effects of different organic matter (rice bran, rice husk and dent corn) and mulch films on N2O emissions during biological soil disinfestation. Incorporation of organic matter increased N2O emissions compared with no organic matter addition at 50°C. Incorporation of rice bran and dent corn with easily decomposable C and low C:N ratios increased N_2O emissions for the first 12 h, but thereafter, available C supply from these amendments suppressed N_2O emissions. Permeability of mulch films increased at a higher temperature and was larger for polyvinyl chloride than for triple-layer polyolefin films. Our study indicated that rice husk should not be used for soil disinfestation and that application rates of organic matter must be determined based on their decomposability. Moreover, mulch film covering would not suppress N_2O emission in biological soil disinfestation because of high temperature.

Conclusion

The author showed how N management affect soil and water environments. Organic wastes are increasing in recent years. The management of organic wastes is a key to creating sustainable systems in agricultural and other sectors. All of us are important players responsible for our future earth.

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