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Original Research Article

Using land-use management policies to reduce the environmental impacts of livestock farming

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ABSTRACT

The manure produced by livestock animals across all of Japan is approximately 90 million tonnes a year, which represents approximately 25% of the overall biomass of Japan's natural resources. In recent decades, the supply of the livestock animal compost has decreased due to various factors—a decrease in fodder, decrease in deserted cultivated land and increase in the importation of fodder—while the domestic animal manure portion of the livestock waste and associated increases have risen dramatically. Most of this manure leads to negative environmental effects by increasing nitrogen (N) loads in rainfall events and causing excess fertilisation, especially in agricultural areas. Animal manure accounts for approximately 23% of all categories of waste in Japan and 89% of all livestock waste in Japan. This 89% of livestock waste is generally utilised as compost or fertiliser. In Japan, the oversupply of fertiliser has already been identified as a problem in the field of agriculture. To address these issues, we assessed the two-dimensional (2D) concentration distribution of N in a water system to specifically analyse the effect of livestock contamination. From the results of this analysis, we observed that industrial factory wastewater creates a narrow localised impact, while the livestock industry creates a medium/broad impact. Therefore, this study provided a simultaneous representation of the total and specific impacts of both human and livestock activities under typical rural catchment conditions. The difference between the environmental impact index value of the current situation and the policy effect was quantitatively assessed. These results will contribute to the construction of a practical decision-making method. Additionally, reduced greenhouse gas emissions, a widely expanded network of protected areas and/or efforts to provide corridors to ease species movement may be necessary to achieve more globally sustainable practices.

1. Introduction

Human actions, including agricultural and livestock activities, have been targeted as key contributors to nitrogen (N) pollution in environmental and social contexts (Cooper, 1993; Laurance, 2001; Leip et al., 2011; Mobaied et al., 2012; Flaherty, 2014; Mouri, 2014). Runoff from agricultural areas within a catchment is a major source of N entering rivers, reservoirs and coastal waters (Carpenter et al., 1998). Livestock manures and chemical fertilisers are essential for agricultural production, but their excessive use may lead to environmental problems such as water and air pollution (Hantschel and Beese, 1997; Huaxiang et al., 2011). Pollution from livestock wastes has caused the deterioration of river water quality in recent years due to an increasing trend in intensive livestock farming, characterised by increased dependence on imported feed and the concentration of livestock in small areas (Schofield et al., 1990; Zebarth et al., 1999; Huaxiang et al., 2011). Studies have shown that higher N application rates lead to higher N surpluses in croplands than in grazing lands (Hatano et al., 2002; Pieterse et al., 2003; Britz and Hertel, 2011). In some cases, and depending on the soil type, gaseous N losses can represent a substantial fraction (≈50%) of total N losses (Jablouna et al., 2015). Not all N from fertilisers or manure are absorbed by the crops on which they are applied. Most of the residual or surplus N is discharged into groundwater through subsurface drainage (Hayashi and Hatano, 1999; McGrath et al., 2010; Sun and Huang, 2012).

To evaluate the impact of agricultural and livestock activities on the cycling of N at the catchment scale and on the degradation of

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water quality, N mass-balance approaches have been put into practice. The N mass-balance approach, based on a calculation of N flow associated with the production and consumption of food and feed, was developed and used to determine the impact of N cycling at the farm, community, regional and national levels (Barry et al., 1993; Zebarth et al., 1999; Mouri and Oki, 2010; Mouri et al., 2010; Mouri et al., 2012).

Livestock manure has caused serious pollution in rivers and soils worldwide (Cowling and Nilsson, 1995; Laurance, 2001; Laurance et al., 2011; James and Galloway, 1998; Reda, 1996; Thomann, 1963; Whitehead et al., 1979). Therefore, limiting the number of managed livestock has been developed as a measure to control the production and consumption of manure on farmlands (Ondersteijn et al., 2000; Jesper et al., 2006; Mouri et al., 2010). The global rate of increase in reactive N (Nr) creation by humans was relatively slow from 1860 to 1960. However, since 1960, the rate of production has accelerated sharply. Cultivation-induced Nr creation increased from approximately 15 teragrams (Tg) N per year in 1860 to approximately 33 Tg N per year in 2000. Nr creation through fossil fuel combustion increased from less than 1 Tg N per year in 1860 to approximately 25 Tg N per year in 2000. Production of Nr from Haber–Bosch agricultural activity processes went from 0 before 1910 to more than 100 Tg N per year in 2000, of which about 85% was used in the production of fertilisers. Therefore, between 1860 and 2000, the anthropogenic N creation rate increased from approximately 15 Tg N per year to approximately 165 Tg N per year, with about five times more Nr originating from food production than from energy production (Galloway, 1998; Galloway and Cowling, 2002; Watanabe and Ortega, 2011; Chen et al., 2013). Recent studies have shown that declining soil fertility is a serious threat to future crop and livestock productivity (Stoorvogel and Smaling, 1990; Stoorvogel et al., 1993; Bouwmana et al., 2013). Traditionally, crops and livestock have been operationally separated but functionally linked, and different production systems involving cattle, sheep and goats have developed in response to agroecological opportunities and the growing demand for livestock products. Hence, to better achieve a nutrient balance in production systems, the rate of movement of nutrients from soil to land to river and again back to the soil needs to be monitored, quantified and remedied.

To understand the nutrient balance, one must define the hydrologic, plant and livestock systems and determine how they operate in an environmental context. In an ecosystem, the processes of primary production, consumption, decomposition and nutrient cycling are largely self-contained (Cheng et al., 2013; Mouri et al., 2014b). However, when manure resources are managed, and human food production is one of the major objectives, nutrient transfers are influenced not only by the conditions and processes within the system, but also by circumstances and controlling forces outside the system. Nutrient assessments especially those in livestock systems—must account for flow from, and retention within, the soil, water, atmosphere and animal and human continuums (Wortmann and Kaizzi, 1998; Rego et al., 2003).

In Japan, approximately 1.53 million head of dairy cattle, 2.89 million head of beef cattle, 9.75 million head of swine and 180 million chickens were raised for consumption in 2007 (Fig. 1). The species distribution of livestock rearing has regional characteristics. For example, approximately 50% of the dairy cattle are in the Hokkaido region in Japan's north, approximately 40% of the beef cattle are in the Kyushu region of western Japan and approximately 60% of the country's pigs are raised in the Kyushu and Kanto regions, in both the west and east, respectively. The number of livestock per farmer has been increasing for most types of livestock over recent years. The total amount of manure waste generated amounts to approximately 90 million tonnes per year (SAFF, 2008).

Additionally, the amount of domestic animal waste related to biomass resource potential is very large. Food waste is estimated

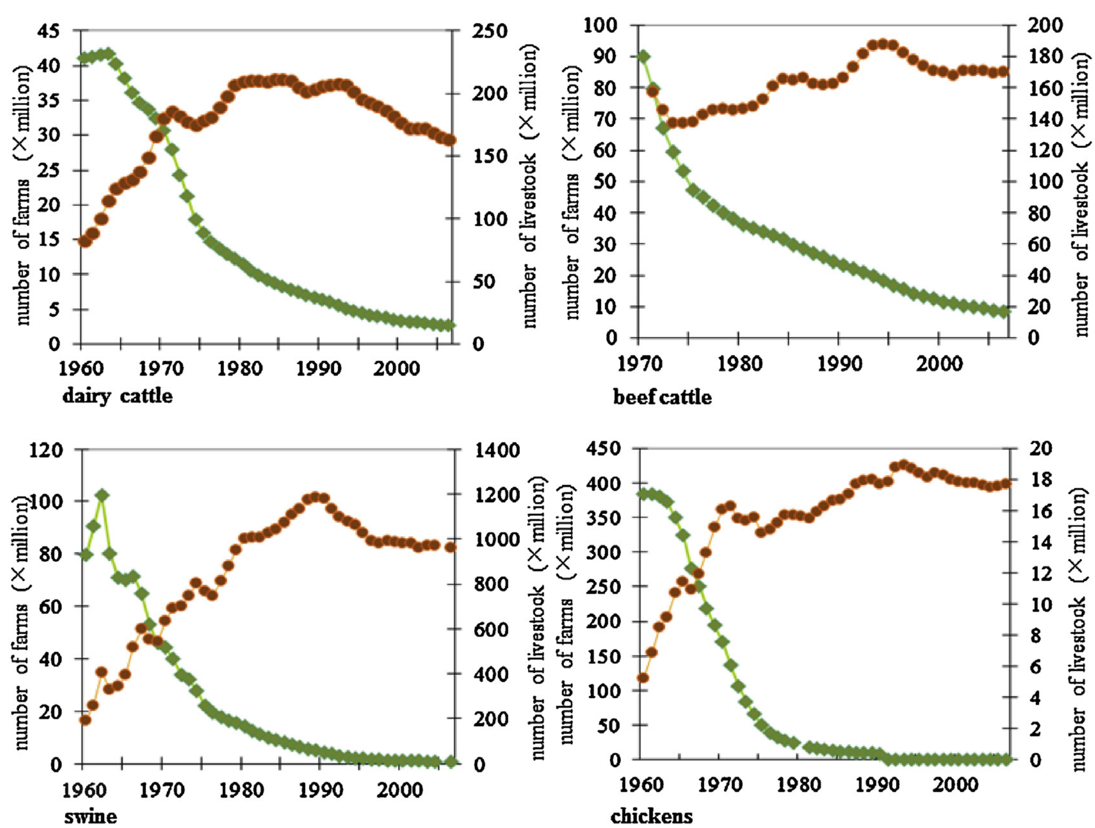

Fig. 1. Temporal variation in the relationship between the number of farms and the number of livestock such as dairy cattle, beef cattle, swine and chickens.