Nitrogen Budget on Township Scale in North China Plain

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Abstract

To find out the critical problems of reactive nitrogen (Nr) on township scale and ascertain Nr flows in basic agricultural farming unit, we carried out a research of Nr budget at the township scale in North China Plain (NCP). Results showed that chemical N fertilizer dominants the Nr imported into a town, which was concerning with complex economic, social and conventional issues. Low Nr using efficiency in cropland subsystem was found in ecotone of agriculture-animal husbandry due to natural condition dependent and meteorological changes adaptive crop. Environmental Nr loads mainly derived from cropland subsystem due to excessive N fertilizer application and irrational applying universally used in NCP. Thus, application rates of N fertilizer synchronized to demand of crop and alternatives of scientific and advanced application measurements were necessary. Huge losses of Nr during storage of human feaces and manure due to inaccessible to treatment facilities and ignoring the rational management on wastes should be given a priority consideration. The extension of new extensive technologies of livestock husbandry for achieving higher converting ratio of feed and provided with facilities of treating manure with great efforts seem necessity especially in ecotone of agriculture-animal husbandry.

Keywords

Nr flow, Nr transfer, Township scale, NCP

1. Introduction

Many studies on Nr flows, fluxes and transfers on national scale (Cui et al., 2013; Gu et al., 2015) or on province-scale (Ma et al., 2014) have been documented recently. They revealed Nr transfers and fluxes to provide administrators with good information for better managing Nr in agricultural farming in order to increase utilization efficiency and decrease impacts on environment. Although, we think that research of Nr flow at lower level scale, such as in representative typical townships in rural areas maybe more implications for comprehending current Nr flows reflecting situations of authentically flowing of Nr and better closed to true flows of Nr at different townships, because in which various Nr behaviors actually are running and therefore major challenges maybe be found and that is helpful to further solve it.

2. Method

We carried out a research from 2014 to 2015 at a scale of rural township, a basic administrative unit in China. We used the method of daily recording on agricultural practices and food consumption of typical and representative households. We randomly selected 40 households in Disituan township (DS) (36°20′N, 114°00′E, 37 m of altitude), a planting-oriented region with 39.62×10^3 rural populations and cropland of 5142 hm^{-2} in Quzhou county, Hebei proince in NCP. 30 households were chosen in Gaoshanbu township (GS) (41°46′N, 115°41′E, 1380 m of altitude) with about 10.416×10^3 populations and cultivated land of 2.584×10^3 ha, grazing land of 2.225×10^3 ha, and forest land of 2.199×10^3 ha. Nr flows and fluxes in different households were ascertained based on mass flow and law of conservations of matter. Investigations and local rural statistical data on township Nr flows and fluxes were further scaled in the two townships with setting up an Nr calculation model at township scale especially adaptive to rural administrative township in China for assessment.

3. Results and discussions

3.1. Nr fluxes and balance on township scale

Over the observing year more than 90.8% of Nr, a substantial share was imported in chemical fertilizer for crop farming in cropland subsystem from other systems in ST, which showed that chemical fertilizer was preferred and because fertilizer application is convenient and less time-consuming and less laborious and also a economical alternative for the price of organic fertilizer was much more expensive than chemical fertilizer due to on the later paid by subsidies (Zhang, *et al*., 2012; Sun *et al*., 2012; Li *et al*., 2013), which just like the results showed that 11.6% of exported Nr in manure would rather be conveyed to other system for unknown fates, and overuse of fertilizer in

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developed extensive agricultural production in ST was found in the investigation and in much documentation by other researches in NPC (Zhao *et al.*, 1997; Gao *et al.*, 1999; Zhao, *et al.*, 2006; Ju *et al.*, 2007; Ju *et al.*, 2009; Chen *et al.*, 2011). More than 62.2% of exported Nr in pollutants entering environment mainly from cropland subsystem due to irrational application of fertilizer such as surface-spreading of nitrogen (Ongley, *et al.*, 2010) and from human feaces and manure of livestock husbandry during storages due to lack of sound disposals and not having access to the facilities for treating manure.

Over the investigating year chemical fertilizer, feed and manure shared 44.9%, 18.7% and 24.4% of Nr respectively in GS which highlighted predominant husbandry in ecotone of agriculture-animal husbandry. About 90.1% of Nr produced (account for 55.8% of Nr in total input) entered the environment which suggested that the converting efficiency of Nr was very low and much of them predominantly were environmental pollutants in GS.

3.2. Nr fluxes, transfers and fates in cropland subsystem

We divided the whole township system into three subsystems in order to conveniently analyze the Nr fluxes and transfers in different sections through townships and trace flow of various Nr species.

Nr conversion and loss The conversion ratio to total biomass of Nr was about 50.3% and to economic section (ie. edible parts for human food) was about 31.3%, a not too low use efficiency in ST and 32.3% and 21.3% respectively in GS. We found that nitrogen use efficiency in wheat-maize rotation in ST was averagely 31.8 kg/kg (yield per unit fertilizer N applied) due to area of wheat-maize rotation covering about more than 90% of cropland in ST while nitrogen fertilizer use efficiency was higher than 26 kg/kg (yield per unit fertilizer N applied) reported by Chen *et al*. (2011) in NCP for the yields of wheat and maize were the highest historically in ST possibly due to changed meteorological conditions suitable to cropping in the studied year. The conversion ratio of Nr in GS apparently was lower than that in ST probably due to low nitrogen using efficiency of hulless oat, fodder maize and flax that covered about 56.1% of cultivated area while for the crop production completely depended on nature precipitation and no any irrigation following ancient conventional farming resulting in low yield of the crop in GS. The results showed that in cropland subsystem more than 50.3% (in ST) and 68.6% (in GS) of imported Nr were lost among of which more than 70% volatilized in gaseous species of Nr due to predominantly surface addressing of nitrogen found in the investigation and also reported by others in NCP (Ongley, et al,. 2010; Zhang et al., 2013. Ju et al., 2014) and about 20.5 % of Nr imported in ST and about 30.1% of imported in GS in cropland subsystem accumulated in cropland soil mainly concerned with excessive use of fertilizer also reported by others in NPC (Zhao *et al*., 2009; Ju *et al*., 2014; Ju *et al*., 2009; Chen *et al*., 2011).

Utilizations and fates of output Nr About 73.2% of Nr in crop residues returned to the cropland in ST and 8.3% in GS, while only 2.6% were utilized as feed in ST and 63.6% as feed in GS， which highlights livestock husbandry in the agriculture farming construction of GS while planting-oriented in ST for economical and convenient fodder from crop residues is in much demand due to much herbivorous animal in livestock husbandry owned by GS and less fodder demand due to monogastric animals mainly feeded in ST as we found in the research. Other fates of crop residues mainly were used as firewood (10.4% of total Nr in residues) due to existing traditional cooking way in rural and as industrial raw materials (12.8% of the total Nr in residues) in ST and 26.1% and 0.1% respectively in GS and remain residues were abandoned to environment that were less than 1.8% of total crop residue Nr in the two townships. As result the ratio of crop residues recycled achieved more than 98.2% in two townships.

3.3. Fluxes, transfers and fates of Nr in livestock farming subsystem

Nr fluxes and budget About 31.4 t of Nr $yr^{-1}$was surplus in ST and 131.7 t $yr^{-1}$of Nr surplus in GS which were remarkable surplus in magnitude in two townships for the discharge coefficient of animal fecaluria referring to other reports maybe be lower than the actual value that we should have sampled and analyzed in-situ that actually was a laborious and time-consuming work, which was not our objects in the research. So we thought that the fluxes of Nr in manure at two sites probably be underestimated, notwithstanding that which didn't impede our understanding of Nr transform in livestock subsystem because we focus on feed utilization efficiency of transforming to animal product. The results clearly showed there was lower converting efficiency of feed in GS (10.6%) than that in ST (32.7%), which suggested that extensive breeding widely performed in ST, in which modern innovations and technologies were applied, had a high use efficiency of feed Nr and that correspondingly traditional and outdated scatter breeding had a low use efficiency in household currently adopted widely in GS.

Recycling and loss of manure More than 58.3% and 84.8% of total output Nr was in manure respectively in ST and in GS which in fact was very important and noticeable, nevertheless unfortunately about 32.4% of Nr in total manure in ST and nearly 27.0% of total manure Nr in GS were lost during storage due to shortage of facilities necessary for rational disposals for nearly all of the manure were found openly distributed outside of animal house and slurry running about on the ground and about 59.2% of total Nr in manure was sold out of the township in ST. So just 7.5% of total Nr in manure were returned to cropland and the results showed that farmers had a convention preferring chemical fertilizer to organic fertilizer just as we found that much of manure was lost in storage with ignored or exported out of the township and even a part of manure Nr were discarded casually as garbage (about 0.2% of total manure Nr) to environment such as ponds or ditches due to a laborious and time-consuming work of huge volume of manure and increasingly growing workforce price and less workforce, especially strong yang men in countryside due to labor migration to city for making more money to live in recent decades (Smith, et al., 2015).

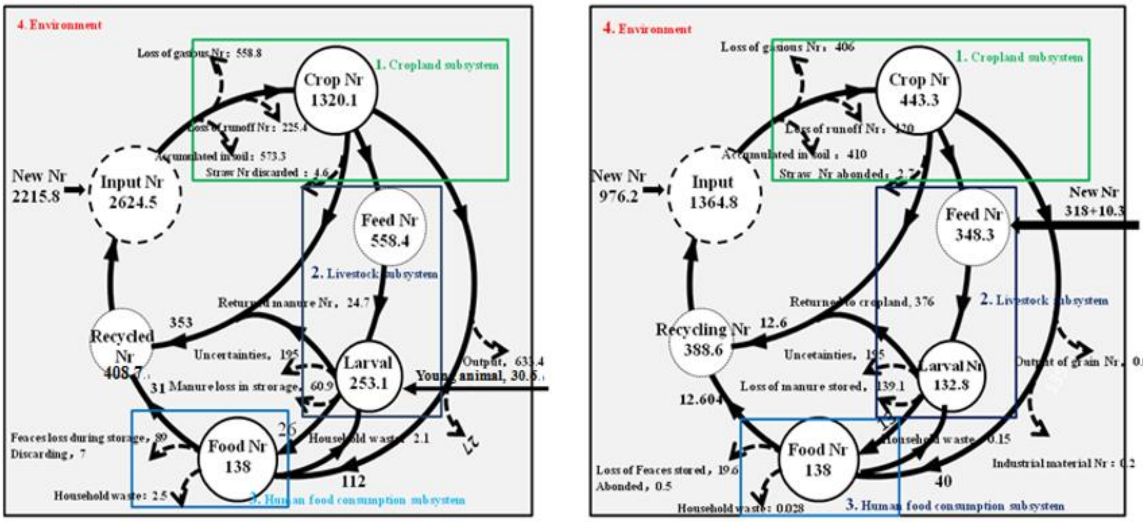

Fig. 1 Flows, fluxes and transfers of Nr in two different townships. The right fig. is for Nr flows in ST and the left for in GS. The edge and background in gray of the biggest rectangles means boundary and environment respectively of township system, and the other 3 rectangles in different edge colors indicate 3 subsystems. The sagittal curves indicate different Nr flows and the directions of sagittal arrows mean directions of Nr flows in system.The words and figures (in t/yr of unit) near the sagittal arrows mean Nr behaviors and corresponded fluxes respectively of the Nr flows meant by sagittal curves.

3.4. Nr fluxes, transfer and fate in human consumption subsystem

Nr fluxes and budget About 81.2% (in ST) and 74.9% (in GS) of imported Nr was derived from plant and remains were animal-derived food which indicated more animal-derived food were consumed in ecotone of agriculture-animal husbandry probably concerning with meat-eating habits there. The human faeces were possibly a major output in the subsystem accounting for 81.2% and 64.4% of total output Nr, the waste food produced during food processing such as chaff or bran with about 11.2% and 4.5% of total output Nr and the remains were food waste yielding from food consumption with nearly 3.1% 0.4% of total Nr in ST and in GS respectively which showed that people would like save more food from procession and consumption in GS related to long-term developed thrifty living habits just like we found during the investigation in GS maybe due to conservativeness of livings in underdeveloped regions.

Utilizations, fates of output Nr The Nr in human faeces were a huge magnitude in two townships while about 70.0% (in ST) and 59.9% (in GS) of total Nr in human faeces lost to environment during storage concerning with universal dry toilets used currently in NCP due to shortage of facilities for appropriate disposals and public health awareness. Just about 24.7% and 38.5% of Nr in human faeces returned to cropland, and that about 5.3% and 1.5% of Nr in human faeces were abandoned in ST and in GS respectively which shouldn't be ignored because of its strong impact on environment. So the loss of Nr in feaces storage was a major fates, a huge magnitude.

3.5. Food Nr production and environmental Nr loads

Various species of Nr derived from food production and consumption lastly released to environment would exert extensive impacts on it. The results showed that the environmental Nr loads (21.7 t N/km^2/yr, 39.3 t N per capita yr^{-1}) per area was lower in ST and inversely (15.6 t N/km^2/yr, 109.1 t N per capita yr^{-1}) for per capita in GS due to GS's scarcely populated area. Also we found that the cost for producing 1kg food Nr was about 4.89 kg Nr consumed which was about 1.94 times as much as that in ST while produced 4.36 kg environmental Nr pollutants in GS which was 2.40 times as much as that in ST, which suggested that more environmental Nr would be produced where more food was produced. The results shows that the environmental pollutants of Nr mainly derived from cropland (83.8% of total loads in ST and 82.5% in GS) which were primarily concerned with over-use of fertilizer and irrational applying measures in crop cultivation (has analyzed in other sections of the paper), secondly from livestock subsystem (David, *et al.*, 2015), thirdly from the food consumption and that prevailingly conveyed to atmosphere (50.9% of loads in ST and 53.1% in GS), notwithstanding the Nr loads from human consumption and livestock were not neglected in two townships due to lack of essential facilities and appropriate managing of human faeces and manure, otherwise the section to environment should have controlled well and decreased onto much lower level.

4. Conclusions and suggestions

Nr imported into township were mainly from chemical fertilizer especially in GS and more organic fertilizer would be used and improve recycling use ratio of agricultural waste was urgently essential for deceasing environment pressure. The environmental Nr loads mainly come from cropland subsystem which concern with excessive nitrogen fertilizer application and irrational applying such as surface application of fertilizer universally used, so decreasing application rates of nitrogen fertilizer and alternatives of scientific and advanced application measurements were necessary. The results highlight the huge losses of Nr during storage of human feaces and manure involved with lack of treating facilities and ignoring the rational management of the wastes, accordingly sewage treatment in rural new countryside construction and developing of flush toilets in dry region in NCP should given a priority consideration henceforth and extension of new extensive technologies of livestock husbandry for achieving higher converting ratio of feed and provided with facilities of treating manure with great efforts are all necessity especially in ecotone of agriculture-animal husbandry.

Acknowledgements

The research was financially supported by the National Basic Research Program of China (973 Program: 2014CB953800).

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