

Effects of human activities on nitrogen flow in the rural area of the Taihu watershed in China

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Abstract

In this study, to assess the nitrogen flux, efficiency and environmental load in the rural area of the Taihu watershed, China, a detailed quantification of systems was constructed. Material flow analysis method and the principle of conservation of mass were used. Results show nitrogen inputs in crop production and livestock breeding were high, 59~75.6 kg ha⁻¹ and 42.5~50.9 kg ha⁻¹, respectively. However, the nitrogen use efficiencies (NUE) were low. For livestock-breeding system, NUE was only 8.1% to 11.4%. Up to 56% of the nitrogen was lost to the environment in the rural area of the Taihu watershed. As for nitrogen load of atmosphere and water body, crop production was the key factor.

Key Words

Nitrogen flow, nitrogen use efficiency, rural area, Taihu watershed

Introduction

Nitrogen limits primary productivity in ecosystems. To overcome this limitation and maintain food security, densely populated agricultural regions in developing nations now use synthetic nitrogen fertilizers to boost yields. However, nitrogen saturation of aquatic ecosystems was observed here and there, i.e. Taihu Lake, Dianchi Lake and lots of rivers in the watershed. Human activities have more than doubled the annual amount of reactive nitrogen (Nr) entering terrestrial ecosystems since the preindustrial era (Galloway 1998). Increased gradually Nr emitted to the atmosphere resulting in the haze, greenhouse effects, acid rain and so on. In this study, we assessed the fate of Nr in the rural area of the Taihu watershed, China. A detailed quantification of Crop Production-Livestock Breeding System (CLS) was constructed in this study. Material flow analysis method and the principle of conservation of mass were used.

Methods

Description of the study area

The Taihu watershed is located in the lower reach of Yangze River. The humid climate and high GDP benefit the agriculture development. In the past century, due to the excessive population growth and the increasing demands for cultivable lands, the water coverage had been greatly reduced. For the cropping system, the paddy rice-wheat was dominant. The cropping varieties incremented cropping intensity and were more dependent on chemical fertilizer. Most farmlands are near to the rivers. The number of farm animals had also increased. The excreta were sold for the farmers as manure in their cultivated lands.

Crop Production-Livestock Breeding System

The nitrogen flow in the CLS system can be analyzed by the flow route as follows (Fig. 1).

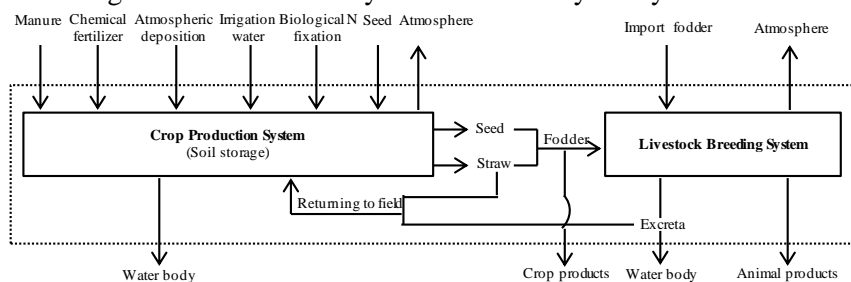


Figure 1. The nitrogen flow

(1) Crop production subsystem

For the Crop production subsystem (CPS), nitrogen inputs include chemical fertilizer, excreta, seed, straw returned to field, biological fixation, atmospheric deposition and irrigation water. Total nitrogen outputs include net nitrogen removal by harvesting crops (including straw), losses to air by ammonia emission, emissions of nitrogen oxides, nitrous oxide and di-nitrogen from nitrification and denitrification processes, losses to water by runoff and leaching and soil accumulation.

(2) Livestock breeding subsystem

For the Livestock breeding subsystem (LBS), nitrogen input items include nitrogen derived from fodder, kitchen waste, animal by-products and import fodder. Nitrogen outputs include nitrogen in meat, egg, milk, bone, by-products and excreta.

Data sources

Basic data (e.g. population, fertilizer use, crop yields, cultivated areas and animal numbers) were derived from governmental statistical yearbooks and bulletins (Changshu Statistical Bureau, 2000-2013). Crops category included wheat, paddy and vegetables. Farm animals were aggregated into seven animal categories (pig, dairy cattle, sheep, laying hen, broilers, duck and goose). Data about nitrogen content in crops and animal products, nitrogen excretion values and the partitioning of animal products into edible food were obtained from literature (Ma et al., 2012; Chinese Statistical Bureau, 2000-2013). Nitrogen loss parameters (i.e. fractions for ammonia emission, emissions of nitrogen oxides, nitrous oxide and di-nitrogen varying as a function of nitrogen inputs and fractions for leaching, runoff and discharge as a function of nitrogen surplus) were obtained from literature (IPCC, 1997; Ti et al., 2011; Ma et al., 2012) and surveys.

Results

Changes in nitrogen inputs and outputs

In 2012, the nitrogen inputs in the Yushan Town (31°31'58.2"N, 120°41'48.3"E) was 3327 ton yr⁻¹. The application of chemical nitrogen fertilizers accounted for 66-69.2% of the nitrogen inputs. The seed and returning straw contributed the minimum percent in total nitrogen inputs. Harvest (grain and straw) Nr content was 1510 ton yr⁻¹. Recycling Nr (returning straw, rations for fertilizer) amount was 89 ton yr⁻¹. Nr losses to the atmosphere, water and soil were 517, 1249 and 108 ton yr⁻¹, respectively. Among them, 568 and 623 ton yr⁻¹ of Nr were lost by the CPS system and the LBS system.

During 2000~2012, with the adjusted crop planting structure and intensive production level of farmland, harvest (grain and straw) Nr content in the Yushan Town ranged from 59 to 75.6 kg ha⁻¹. For the LBS system, the nitrogen input flux was within the range of 42.5~50.9 kg ha⁻¹. The amount of animal fodder was insufficient. 53%~68% of fodder were imported from outside. Environmental nitrogen load (not involved N₂) decreased from 60.5 to 24.2 kg ha⁻¹.

Nitrogen use efficiency and environmental losses

A low nitrogen flow efficiency of the CLS system was found from 2000 to 2012. Results showed that the utilization efficiency of nitrogen (22.5%~28.1%) was higher than that of nitrogen recycle (18.9%~21.2%) in the CPS system. For the LBS system, the utilization efficiency of nitrogen (8.1%~11.4%) was lower than that of nitrogen recycle (17.9%~18.3%). In the rural areas of Changshu City, fertilizer nitrogen applied to each crop (wheat 210, rice 327, vegetables 387 kg ha⁻¹, respectively) was far beyond the nitrogen demand of crop growth, restricting the utilization efficient of fertilizer nitrogen. As chemical fertilizer accounted for more than 66% of nitrogen input for the local farmland, its low utilization efficient caused low utilization efficient of nitrogen recycle.

The study area is in the water network region of the Taihu watershed. The rivers and ponds are near to the rural household and farmlands. Our results showed that 52% of total nitrogen losses from the CLS system entered into the water body. These may contribute to the higher nitrogen load of Taihu Lake. It was reported that 34% of non-point pollution of Taihu Lake derived from cultivated lands. During year 2000~2012, the CPS system and LBS system contributed 43% and 33%, respectively to the environmental nitrogen load. With the expansion of livestock farming and enhanced intensification level, animal products-derived nitrogen increased from 3.5 to 4.9 kg ha⁻¹. Meanwhile, a large number of manure from animals discharged freely, resulting in eutrophication and ammonia emission.

Influence of human activities on nitrogen flow

Since 21st century, urbanization rate increased from 36% to 52.8% resulting in the agricultural intensification and increase of nitrogen inputs pattern. Taking year 2012 as an example, chemical fertilizer application was 310.8 kg ha⁻¹, being 1.5 times the national level. We found a significant correlation ($R^2= 0.96$, $p< 0.01$) between water nitrogen load and fertilizer application to the cultivated lands, suggesting that excessive nitrogen application restricted the nitrogen utilization efficient and enhanced water nitrogen load. With the increased population growth, urbanization and economic growth, large numbers of waste discharge-derived nitrogen from people and animals aggravated the environmental nitrogen load. For year 2012, excreta - derived nitrogen in the study area was 61.1 kg ha⁻¹, being 3.2 times the national level.

Conclusion

To confront the severe eutrophication of aquatic ecosystem and reduce non-point source pollution radically in the Taihu watershed, China, the nitrogen flux, efficiency and environmental load in the village-scale were studied. Results showed that both amount of nitrogen inputs in crop production and livestock breeding was high, 59~75.6 kg ha⁻¹ and 42.5~50.9 kg ha⁻¹, respectively. However, the nitrogen use efficiency was low. Especially the LBS system, the utilization efficiency of nitrogen was only 8.1% to 11.4%. Up to 56% of the nitrogen was lost to the environment. As for nitrogen load of atmosphere and water body, crop production was the key factor. It was concluded that the demand for reasonable nitrogen management measures, such as balancing fertilization, increasing crop and animal production, and improving manure management was urgent.

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