Balancing N inputs for China's green agricultural development

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Abstract

Using environmental threshold and meta-analyses, we identified 'ideal' N inputs for China. Nitrogen inputs required to achieve food security for China increased from 12 to 30 Tg N yr^{-1} during 1950 and 2015, while actual N inputs increased from 6 to 52 Tg N yr^{-1} during the same period, exceeding the required and critical inputs (28-35 Tg N yr^{-1}) after 1980. We show how 20 Tg N yr^{-1} reduction in N input can be achieved through integrated N management practices. Such a 'win-win' would improve environmental quality greatly but need systematic reforms on agricultural structure, technology-transfer mode, and environmental policies.

Keywords: historic change of N balance, required N input, critical N input, food security, environmental sustainability

Nitrogen (N) fertilizer has played a key role in feeding the increased global population since the invention of the Haber-Bosch process (Erisman et al., 2008). With the increasing population and living standards, China is facing a huge challenge on how to produce enough food to meet the future demand only using environmental-safe N input. This challenge needs urgent answer for green agricultural development, that is, meeting double targets of food security and environmental sustainability.

1. N budgets and food security

We systematically evaluated N input and output budgets in China in 1950, 1980, 2010 and 2015 (Fig. 1). Fertilizer N inputs showed dramstic increase from 0.1 Tg N (1950) and 9.4 Tg N (1980) to more than 22 Tg N in 2000 and 30 Tg N in 2015. Total N inputs were controlled mainly by fertilizer inputs. Annual N removal (4.3 to 21 Tg N) by harvested crops increased similarly but much lower than total N inputs during the same period. Therefore N surplus (sum of all kinds of N losses) showed huge increase especially after 1980, reflecting decreased N use efficiency (NUE).

2. Required and critical N inputs

We calculated the required N input (for food security) and the critical N input (for avoiding environmental harm) for China during 1950 and 2015 (Fig. 2), based on improved planetary boundaries (De Vries et al., 2013) and summarized literature data.

The required N input (including all sources such as N_{FER}, N_{OM} and N_{ENV}) to be 14, 22, 28, and 30 Tg N yr^{-1} in 1950, 1980, 2000 and 2015, respectively. The critical N input was calculated to be 35 and 28 Tg N yr^{-1} based on nitrate leaching and NH_3 emission thresholds, with average of 32 Tg N yr^{-1}. The actual N input was much lower than the required and critical N inputs in 1950 and close to those inputs in 1980 but substantially higher in 2000 and 2015 (Fig. 2).

3. Closing N gaps through integrated management

Using meta-analyses (Xia et al., 2017), we assessed a range of N saving potentials for crop production in China to close the N gaps between actual N input and critical N input.

We proposed a three-step strategy: (i) replacing fertilizer N by effectively recycled manure; (ii) reducing N fertilizer inputs based on the crop N demand, while accounting for all other non-fertilizer N sources; (iii) integrated soil-crop system management, including optimized N fertilization techniques (i.e. the '4R strategy') and optimized crop management (best cultivars; optimal rotations). We found that total N saving potentials combined by Steps 1 (4.8), 2 (9.3) and 3 (5.3) were approx. 20 Tg N yr^{-1}, together with substantially improved NUE in the food production system, suggesting the best managed N inputs (32.3 Tg N yr^{-1}) being within the abovementioned critical N inputs.

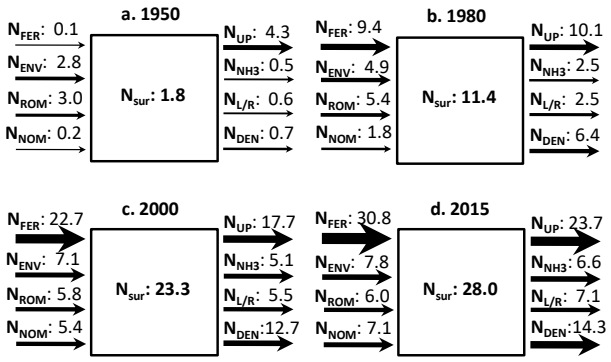

Fig. 1: Nitrogen budgets and N losses (Tg N yr^{-1}) to the environment in China's crop production systems.

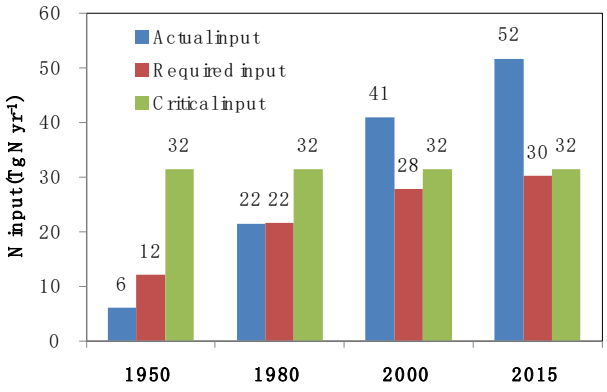

Fig. 2: Actual, required and critical N inputs (Tg N yr^{-1}) to China's food production in 1950, 1980, 2000 and 2015.

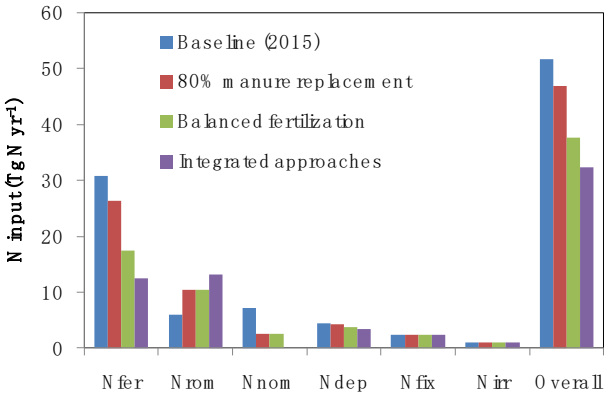

Fig. 3: Saving of N inputs by improved nutrient management practices (80% manure replacement, balanced fertilization, and integrated approaches) relative to baseline (2015).

To balance N inputs for green agricultural development, China requires a nationwide reform of its agricultural production systems via a substantial improvement in fertilizer products and management technology, nutrient policy and environmental regulations.

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