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An optimal regional nitrogen application threshold for wheat in the North China Plain considering yield and environmental effects

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ABSTRACT

North China Plain is the bread basket for Chinese. However, the over-use of N fertilizer has resulted serious environmental pollution and even threat the food security owing to the soil degradation in North China Plain. It is essential to develop a suit of optimal regional nitrogen application threshold. In this study, we attempted to build the threshold by using dataset of literature review and field experiments. Results showed that the optimal N fertilizer rate should be around 185 kg N ha^{-1} for the wheat cultivation with achieved yield at 7000 kg ha^{-1}. Both literatures reviewed and field experiments agreed well on this threshold. The wheat yield under this optimal N fertilizer rate was about 2% lower than the theory maximum achievable yield (7203 kg ha^{-1}) in this region; however, the N rate could be reduced by 25% compared to the N rate under the maximum yield. This threshold entailed decreases of 25.25%, 20.17%, 27.89% and 38.80% in nitrogen application rates, residual inorganic soil nitrogen (0–100 cm), nitrate leaching and ammonia volatilization, respectively, on the regional scale. In addition, reducing theory maximum achievable yield by 2% was not statistically significant and would not result in additional risks because fluctuations in wheat yields over time (−57.07% to 34.73%) and space (−23.78% to 33.07%) were higher than 2% in this area.

1. Introduction

Nitrogen is the most important essential element for crop growth and yield, and the use of nitrogen fertilizer has made outstanding contributions to the ability of agricultural production to meet the food demands of the seven billion people in the world (Erisman et al., 2008). Nitrogen fertilizer application has increased grain production more than 40% in developed countries (Malhi et al., 2001) and 55% in developing countries (Li et al., 2009). Currently, the global population is still growing, which means there is a large demand for cereals. To gain increasingly large crop yields, the rates of nitrogen application continue to increase each year, while nitrogen utilization efficiency continues to decrease (Liu et al., 2008; Cui et al., 2010). If excess nitrogen cannot be absorbed by plants, then it remains in the soil, volatilizes into the air in the form of ammonia and nitrous oxide, or enters bodies of water through leaching and runoff (Ju et al., 2009). Furthermore, under certain conditions, residual nitrogen in the soil causes environmental pollution in the form of volatilization or leaching (Cameron et al., 2013), leading to serious environmental risks or even direct contamination (Zhang et al., 1996; Howarth, 1998). Previous studies have shown that emissions from agricultural nitrogen application can result in climate warming, water deterioration and soil degradation (Bazaya et al., 2009; Shan et al., 2015; Vashisht et al., 2015).

Optimizing agricultural nitrogen application can reduce the likelihood of nitrogen pollution occurring from the source (Min et al., 2012; Ruidisch et al., 2013), which is the most cost-effective, least labor-intensive and easiest method for farmers to prevent and control nitrogen contamination (Wang et al., 2012). The area of farmland in China is very large but the individual acreage of single-family farms is relatively small. Under the effects of climate, topography, planting patterns, regional policies and many other factors, field nitrogen application rates vary in different regions

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