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Overcoming nitrogen fertilizer over-use through technical and advisory approaches: A case study from Shaanxi Province, northwest China

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ABSTRACT

Over-application and inefficient use of nitrogen (N) fertilizer is a serious issue throughout China, with adverse environmental and economic impacts. In this paper we present evidence of this in the wheat/maize double cropping system in the Guanzhong Plain in Shaanxi Province, northwest China. Results show the economic benefits of overcoming this problem are greatest for the lowest income farmers. We also outline new advisory approaches that could aid delivery of information to farmers. Evidence of excessive N fertilizer applications, and opportunities to maintain or even increase crop yields with lower rates of N, are presented from several sources. A survey of N applications to maize by 80–100 farmers showed that 77% were applying N at rates in excess of those recommended by the local advisory agencies. Experiments with maize and wheat at 120 sites, testing a range of N application rates, show remarkably small yield responses to applied N and high yields even when no N is applied. This is mainly because of large nitrate residues accumulated in the soil from past N fertilizer applications. Trials were conducted in 30 farmers' fields comparing the farmer's usual N rate with a lower rate based on a combination of local recommendations and measurements of nitrate in soil. On average, N rates to maize and wheat could be decreased by 70% and 20%, respectively, with no loss of yield and sometimes small increases. Economic assessments and household surveys showed the economic benefits for farmers of moving to more rational use of N fertilizer. Even a 30% reduction in N use would increase household income by 2–9%, and a 50% reduction by 4–15%. In all cases the poorest farmers benefit the most because fertilizer represents a larger percentage of their expenditure, so policies and practices leading to more rational N use are clearly pro-poor. Advisory approaches based on an N budget approach are outlined as an alternative to traditional approaches where farmers are simply given a recommended application rate. Simple in-field measurements of nitrate concentration in soil, using commercially available nitrate-sensitive strips giving a color reaction, may be a useful supplement for field-specific advisory work if the logistics at village level can be organised.

1. Introduction

The winter wheat–summer maize double cropping rotation is the principal cropping system in northern China, occupying around 16 Mha and the output accounting for about a quarter of total national food production (Yang et al., 2014). Excessive application of mineral nitrogen (N) fertilizer is a common problem in this system, with average N application rate of 553 kg N ha^{-1} annually to this system in Shandong province (Kou et al., 2005) and an N surplus of up to 526 kg N ha^{-1} in some cases (Zhen et al., 2007). N applications 30% greater than required for maximum crop yield

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have been noted for wheat, maize and other crops in this region (Norse et al., 2012). The issue has received less attention in northwest China compared to other areas, but there is also evidence of excessive N fertilizer use in this region, especially in the relatively intensive cropping of the Guanzhong Plain of Shaanxi Province (Zhang et al., 2000; Tong et al., 2004,b; Zhao et al., 2010a,b; Chang et al., 2014).

Excessive N fertilization results in low N use efficiency (NUE), increased production costs for farmers, and unnecessarily large losses of N causing serious environmental problems such as groundwater nitrate contamination (Zhang et al., 1996; Zhang et al., 1996), greenhouse gas emissions (Zhang et al., 2013a,b,b) and soil acidification (Guo et al., 2010). In the North China Plain (NCP) high rates of N fertilizer application are closely associated with high nitrate concentrations in groundwater and nitrate accumulation in the soil profile (Gao et al., 1999; Chen et al., 2000; Liu et al., 2003a; Ju et al., 2004).

Due to the huge food demand in China, there is resistance to suggestions to decrease N fertilizer use as this is seen as risking loss of production, despite considerable evidence to the contrary (Ju et al., 2004; Sun et al., 2012). A major goal for Chinese agriculture is to identify rational practices for N fertilizer management that combine the imperative to increase food production whilst decreasing N-related environmental pollution to an acceptable level. An approach that has been successful elsewhere in the world over several decades is a strategy based on measuring the quantity of mineral N in soil before planting and using this to guide N fertilizer applications (Soper and Huang, 1962; Wehrmann and Scharpf, 1979). Such measurements, generally termed soil N_{min}, may include the total of nitrate- plus ammonium-N or just nitrate as this is usually dominant. In the NCP, an in-season N management strategy based on the soil N_{min} test was developed for the winter wheat–summer maize rotation system under experimental conditions (Liu et al., 2003b; Chen et al., 2006). In this method, N fertilizer is applied in two or three splits during the growing season, with an optimum application rate being determined by comparing measured soil nitrate content in the root layer with predetermined target values at different

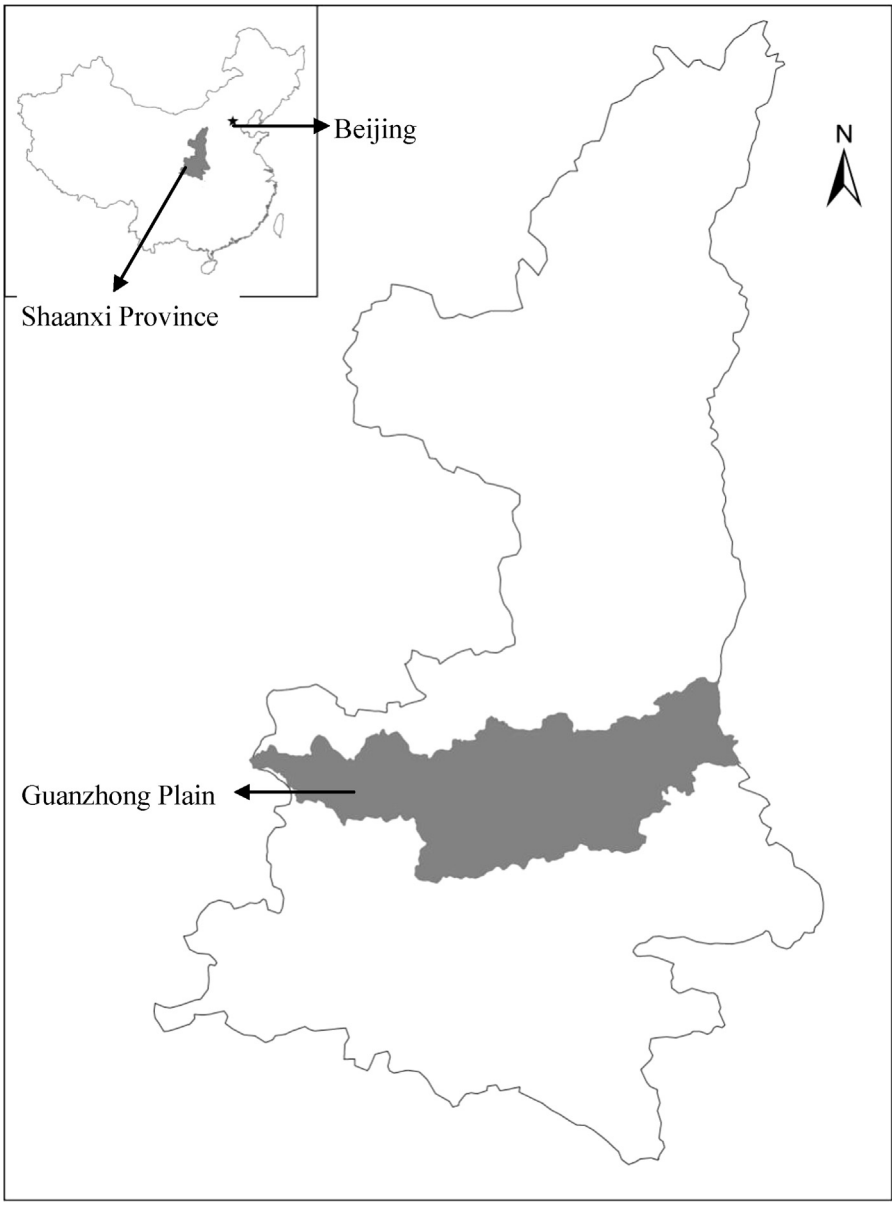

Fig. 1. Location of Guanzhong Plain in Shaanxi Province, northwest China.

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