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Long-term reduction of nitrogen fertilizer use through knowledge training in rice production in China

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ABSTRACT

Nitrogen (N) fertilizer has been excessively used in China's crop production, resulting in nonpoint pollution and significant greenhouse gas emissions. Previous studies show that farmers can reduce N-fertilizer upon receiving knowledge training. However, there is little evidence of the effectiveness of this effort in the long term. Based on an experimental study of site-specific nutrient management for rice production in China and a unique household dataset captured over seven years, this study shows that the traditional training approach has not been effective in reducing Chinese farmers' N-fertilizer use. Persistently reducing farmers' excessive use of N-fertilizer in the long term will require intensive in-field guidance – something that requires substantial investment and institutional innovation.

1. Introduction

Fertilizer has played an important role in China's crop production, but it has been excessively used for decades. According to Heisey and Norton (2007), China's fertilizer application per hectare (ha) in crop production grew rapidly after the 1960s, and in 1980 surpassed the average level of fertilizer application of industrialized countries. By 2000, China's average fertilizer application measured in element nutrients exceeded 200 kg/ha – a figure much higher than the average application in India (less than 100 kg/ha) and in industrialized countries (about 120 kg/ha). In 2006, China consumed 31 million tons of chemical nitrogen (N) fertilizer, accounting for about 32 percent of global N consumption (Heffer, 2009). Several studies have shown that in China, N-fertilizer use has been excessively used in grain production (Cai et al., 2002; Chen et al., 2006; Cui et al., 2008; Fan et al., 2007; Ma et al., 2008; Peng et al., 2002; Yan et al., 2012) and vegetable farming (Chen et al., 2004; He et al., 2009).

The excessive use of N-fertilizer has led to severe environmental problems and significant greenhouse gas (GHG) emissions. For example, the high rate of N-fertilizer use in China has led to large N losses in the form of ammonia volatilization and N leaching into groundwater and lakes (Zhu and Chen, 2002), as well as soil acidification, which could result in declines in agricultural productivity (Guo et al., 2010). Moreover, it has been estimated that agriculture and agrochemical industries account for at least 15 percent of China's total fossil energy use and nearly 20 percent of its total GHG emissions (SAIN, 2010). Emissions from N-fertilizer production, transportation, and application alone accounted for nearly 30 percent of GHG emissions in agriculture in 2007 – equivalent to 5 percent of China's total GHG emissions (SAIN, 2010). Thus, improved N management is of great importance to protecting the environment, creating sustainable agricultural production, and mitigating climate change in China.

The reasons for China's high rate of N-fertilizer use in agriculture have been debated; most tend to agree that farmers' lack of knowledge on efficient N-fertilizer use is a primary cause. For example, Huang et al. (2008, p. 165A) argue that "farmers [there] just do not know that they are overusing fertilizer. Many farmers in China learned to use chemical fertilizers when N-responsive varieties first came onto the market in the early years of the Green Revolution [during 1960–1980]. Since then, new varieties that are more responsive to chemical fertilizer applications have become more widely available and used in China." Chinese farmers have relied on their previous experience, which has told them that the use of more fertilizer leads to higher crop yields (Huang et al., 2008). Meanwhile, the poor performance of the public extension system has also constrained farmers' access to new knowledge of efficient fertilizer use, particularly as extension agents are largely engaged in commercial activities – including the sale of fertilizer – to balance their budget deficits (Hu et al., 2009). In addition, politically, ensuring food security through increased fertilizer use in

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crop production has been one of China's major achievements, giving the government pause in reducing N-fertilizer use, despite emerging evidence of its adverse environmental consequences (SAIN, 2010). Consequently, improving N-fertilizer use efficiency by reducing its excessive use has never been a mainstream or central task among public extension agents. Another contributor to the high rate of N-fertilizer use in China has been fertilizer subsidies. However, Huang et al. (2011) show that those subsidies are nondistorting, because they are not coupled with farmers' purchases of fertilizer.

A number of recent empirical studies have verified the effectiveness of knowledge training (of various approaches) on improving the efficiency of N-fertilizer application in China's agricultural production (IRRI, 2012; Hu et al., 2007; Huang et al., 2008, 2012; Jia et al., 2013; Peng et al., 2006; Xiang, 2012). For example, some studies show that, compared to a control group of farmers, farmers who partook in participatory training on the appropriate use of N-fertilizer saw their N-fertilizer use decrease by about 15–20 percent in rice production (Hu et al., 2007; Huang et al., 2008). Through more intensive in-field training and in-season guidance, farmers could reduce N-fertilizer use by more than 30 percent and increase rice yield by 5 percent. Similar short-term effects were also found in maize and wheat studies. For example, Huang et al. (2012) found that by partaking in a 1–2-hour training program on nutrient management, farmers in the North China Plain reduced N use by 22 percent in maize production. Following the same approach, Xiang (2012) found that knowledge training on improving N management could reduce N-fertilizer use in wheat production, although the rate of reduction was lower than that in maize production.

Nevertheless, nearly all these findings vis-à-vis knowledge training and reductions in farmers' N-fertilizer use were based on evidence gathered immediately following the knowledge training or interventions. It is not clear whether the effectiveness of various training programs can be retained in the long term. It could be argued that the farmers who participated in the experiments might have felt embarrassed about disregarding the researchers' advice; likewise, when the training was finished, they might have renewed their previous N-fertilizer application practices, thinking that the persistent reduction of N-fertilizer use in the long term could reduce the total N supply in the soil and adversely affect crop yield. In such cases, they might renew the use of conventional practices by using even more N-fertilizer in the long term. As a result, questions arise regarding whether different training approaches are sufficient in introducing fertilizer-saving technologies to smallholder farmers, and whether the reduction of N-fertilizer use reduces crop yield in the long term.[1]

The answers to the above questions are of great interest to policymakers, the fertilizer industry, and farmers. The findings of the current study have important policy implications – and not just in terms of nonpoint pollution, GHG emissions, and food security, but also in terms of food consumption and production, and N-fertilizer trade in China. Having an understanding of the long-term effects of various training approaches (e.g., one-time training vs. intensive, in-field guidance training) may thus help in designing future extension programs that encourage farmers to adopt sustainable-agriculture technologies, in China and in other developing countries.

The overall goal of this study is to examine the long-term effects of farmers' knowledge training on improved N management with respect to rice production in China. Specifically, it compares the effectiveness of different knowledge training approaches on long-term N-fertilizer use, and examines whether reductions in N-fertilizer use have resulted in diminished rice yields.

The remainder of this paper is organized as follows. Section 2 discusses the study's research design and data collection methods. Section 3 provides descriptive analyses of N-fertilizer use among farmers participating in various training approaches. Section 4 examines the impact of these training approaches on farmers' use of N-fertilizer, by using multivariate analysis. The final section concludes by discussing policy implications.

2. Research design and data

2.1. Experimental trials of training approaches

The technology addressed by this study and which was introduced to farmers through knowledge training is the site-specific nutrient management (SSNM) for rice production in China; it is a technology that was developed by the International Rice Research Institute (IRRI) and its collaborators in China in the early 2000s (IRRI, 2012; Peng et al., 2006; Wang et al., 2001). In essence, SSNM is a technology based on the site-specific conditions of rice production; it enables farmers to tailor nutrient management to the specific conditions of their own fields and improve efficiency or achieve reductions (in the case of excessive use) of N-fertilizer use without affecting rice yield (Buresh, 2009). However, farmers usually modify SSNM technology to fit their own demographic characteristics (Byerlee and de Polanco, 1986). Regarding N management, Khanna (2001) found that farmers adopted SSNM technologies sequentially and only partially. More recent empirical evidence from China shows that after farmers in Shandong attended a knowledge training seminar on improved N management, they followed the recommendation of reducing overall fertilizer use in maize production (Jia et al., 2013). Nevertheless, the recommendation of balanced N use – namely, reducing N-fertilizer use in the early vegetative season and increasing N-fertilizer use at later stages – was not followed due to the related increase in labor demand. Site-specific technologies, once put into practice, were always modified and adapted by farmers.

To examine the impacts of SSNM technology as distributed through various training approaches, the research team conducted field experiments in rice production in the selected villages over the 2003–2005 period (details of the sampling approach are discussed in the next subsection). The fieldwork was run by a team comprising economists, agronomists, and soil scientists, along with extension staff from local township extension stations. First, the research team randomly sent out flyers to a group of farmers (about 20–30 farmers) in each village and invited them to take part in a participatory knowledge training workshop on SSNM technology within a few days. Most of them accepted the invitation and came to the workshop; only a few were not available and did not join the workshop. During the workshop, farmers were asked to discuss soil conditions and their fertilizer-application practices for rice production; those practices included application timing, and the types and amounts of various fertilizers used during the entire rice growing season. Based on these discussions, the agronomists and soil scientists of this project team, together with the farmers, explored an appropriate package of SSNM technology that was then recommended to the village farmers. As the aim of distributing this technology was to reduce N-fertilizer use without lowering rice yield, and was introduced by scientists, there was no resistance from the participating farmers. Second, within this group of farmers, we invited about 10 farmers (ranging from eight to 12 among the villages studied) to experiment with the SSNM technology in their own rice fields. We divided these farmers into two groups (as shown in

[1] It is known that crop yield is related to crop N uptake which depends on N available in the soil and by fertilizers. Therefore, when knowing the N available in the soil, the required N fertilizer can be calculated for maintaining the yield. A number of field experiments has shown that the conventional practice in rice production in China overused N fertilizer and the moderate reduction of N fertilizer use would not adversely affect crop yield (IRRI, 2012; Peng et al., 2006).