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Agronomic and environmental causes of yield and nitrogen use efficiency gaps in Chinese rice farming systems

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ABSTRACT

Yield (YG) and nitrogen use efficiency (NUE) gap analysis is a key tool in addressing the sustainable intensification of agricultural systems. Distinguishing and quantifying the underlying agronomic and environmental causes of these gaps is as important as estimating their magnitude. We applied a field experimental framework that allowed us to partition YGs and NUE gaps due to crop management, climatic factors and/or inherent soil productivity. YG and NUE gaps were determined as the differences between yields and NUE under standard farm practices and the attainable yield and NUE using optimum management practices. In farmer's fields in China, the rice YG and NUE gap (expressed as the partial factor productivity of applied N, namely kg rice grain per kg fertilizer N applied, PFP_N) averaged 1900 kg ha^{-1} and 18 kg kg^{-1} respectively. However, both were subject to large variability within and across different rice farming systems in response to key agronomic and environmental variables, with larger gaps in moderate- and low-yielding fields and in single rice systems. Management practices such as optimizing N and water management and increasing rice transplanting density simultaneously narrowed the YG by 38% and the NUE gap by 39% on average. Climatic- (YG-C) and inherent soil productivity-based YGs (YG-S), which represented fractions of YG derived from climate and soil variability, accounted for on average 16% and 38% of the total YG across low- and moderate-yielding fields in single rice systems, and by 14% and 27% in early and 11% and 20% in late rice farming systems, respectively. Growing-degree days (GDD) for early rice and daily minimum temperature (T_{MIN}) for late rice were the best predictors of YG-C. For single rice in the Yangtze Delta, YG-C included multiple factors such as lower daily mean temperature and GDD, and higher daily maximum temperatures and precipitation during rice growing periods. Soil nutrient supplying capacity was partially responsible for YG-S in those under-performing fields. Significant and exploitable potential exists for increasing rice productivity with higher NUE, especially in moderate- and low-yielding fields. However, national and regional agricultural policies should place more emphasis on supporting good agronomy and soil management, thus moving towards a soil-climate smart management approach in rice farming systems.

1. Introduction

Rice (*Oryza sativa* L.) is the staple food of over three billion people and plays an important role in the national economy in many developing countries (Dat Van, 2001). China is the largest producer of rice, accounting for 19% of the global area sown and 29% of the total production of rice grain (FAO, 2013). Although rice consumption per capita may decline slightly in China as a result of overall economic development, further increases in rice production will be necessary to meet the demands of the growing population (Peng et al., 2009; Fan et al., 2012; Chen et al., 2014). This can only be achieved by increasing rice yields per unit area on the slowly declining planting area. Much effort has been spent in recent decades on genetic modification and the development of more effective management practices designed, to increase productivity through increasing the yield potential or decreasing the yield gap (YG), the difference between the yield under optimum

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