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Research article

Effect of irrigation-drainage unit on phosphorus interception in paddy field system

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ABSTRACT

In lowland agriculture, paddy fields are present in the form of irrigation-drainage unit (IDU), which consists of paddy fields and natural ditches around the fields. Phosphorus (P) export from IDUs significantly impacts water quality in adjacent water bodies. In this study, we explored the characteristics and behavior of P in a typical IDU in Jianghan Plain, China. From 2012 to 2015, we measured P concentrations in different water components of the IDU, i.e., rainwater, irrigation water, field ponding water, runoff water and ditch water, and accounted for spatial and temporal variabilities of the P concentrations. Across the rice growing season, the highest total P (TP) concentration was observed in the field ponding water. Total P concentration in ditch water gradually declined and it reached 0.06 mg L^{-1} at the rice maturation stage. The concentration was lower than that of incoming irrigation water (0.13 mg L^{-1}) and rainwater (0.17 mg L^{-1}). Although both paddy soil and ditch sediment had low degree of P saturation, the ditch sediment had greater P binding energy (1.58 L mg^{-1}) and larger maximum P sorption (526 mg kg^{-1}) than the soil (0.88 L mg^{-1} and 455 mg kg^{-1}, respectively). The P mass balance for the rice season over the four consecutive years showed a net depletion of 3.36–8.11 kg P ha^{-1} yr^{-1}. Overall, IDUs substantially reduced the P concentrations in outputs from the IDUs as compared to inputs through irrigation and rainfall. The IDUs functioned for P retention by extending P settling time and natural degradation of P in the system. Optimizing the IDU management by controlling water discharge during fertilization and disturbance periods can be popularized for its cost saving and environmental benefits.

1. Introduction

Rice feeds over 50% of the world's population (Lampayan et al., 2015). The world rice cultivating area amounted to 160 million hectares in 2014, with a total grain production of 741 million tons (FAOSTAT, 2016). In China, paddy fields account for 27% of the national agricultural land area and they contribute approximately 23% of the world's total rice production (Xu et al., 2018). Rice paddy fields have also attracted worldwide attention as a valuable wetland ecosystem (Naftchali et al., 2017; Krupa et al., 2011; Yoshinaga et al., 2007). The growth of rice requires a large amount of water, and in China rice production consumes 60%–70% of the total agricultural irrigation water (Rice regional layout planning 2008–2015, Ministry of Agriculture). Paddy fields often discharge a large amount of water during a rice growing season (Ye et al., 2013). Meanwhile, paddy systems are closely related to water quality issues because of their natural connectivity with surface waters (Gitau et al., 2016; Guo et al., 2018a; Liu et al., 2018; Wang et al., 2018).

As a dominant nutrient limiting algal bloom in many aquatic systems (Sharma et al., 2017; Abell et al., 2010), P export from watersheds has received much attention because the export significantly affects the water quality of downstream rivers and lakes (Yan et al., 2017; Niraula et al., 2011Smith et al., 2001; Wang and Kalin, 2018). In paddy dominating watersheds, most of the P originating from the fields is transported downstream to primary surface water of concern and subject to interactions with water such as the drainage ditch networks and streams, which involve abiotic and biotic processes during delivery (Barlow et al., 2003). Agricultural fields and nutrient receiving waters are often linked by natural ditches (Ahiablame et al., 2010; Gitau et al., 2017; Guo et al., 2018b; Janse et al., 1998). Ditches could retain water and reduce the volume of run-off carrying nutrients. In addition to influencing runoff volume, ditches may also change P concentrations and

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