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Co-design and assessment of mitigation practices in rice production systems: A case study in northern Vietnam

Azeem Tariq[a,b,d,*], Andreas de Neergaard[b,e], Lars Stoumann Jensen[b], Bjoern Ole Sander[c], Mai Van Trinh[d], Quynh Duong Vu[d], Reiner Wassmann[c], Stephane de Tourdonnet[a,*]

[a] Montpellier SupAgro-IRC, UMR 951 Innovation SupAgro-INRA-CIRAD, Montpellier, France
[b] Department of Plant and Environmental Sciences, University of Copenhagen, Denmark
[c] International Rice Research Institute (IRRI), Los Banos, Philippines
[d] Institute for Agricultural Environment, Vietnamese Academy of Agriculture Sciences, Sa Doi street, Phu Do, Tu Liem South, Ha Noi, Viet Nam
[e] Faculty of Social Sciences, University of Copenhagen, Øster Farimagsgade 5, DK-1353 Copenhagen C, Denmark

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ABSTRACT

Rice production systems are an important source of agricultural greenhouse gas (GHG) emissions. Mitigation techniques, such as alternate wetting and drying, have been developed but have often not taken into consideration the constraints imposed by the practices and preferences of farmers. Since GHG mitigation benefits are not obvious at smallholder farm level, it is essential to design site-specific mitigation technologies with the participation of local stakeholders. The purpose of the present study was to adapt a participatory approach to designing and assessing mitigation practices for the dissemination of climate-friendly rice production systems. To improve the hybridization of scientific and local knowledge, a participatory five-step approach to prototyping was applied: (i) diagnosis based on a literature review and survey of stakeholders, (ii) design of mitigation practices based on laboratory trial and local knowledge (that of farmers, agricultural advisors and regional stakeholders), (iii) testing in growth chambers, (iv) testing in farmers' fields and (v) dissemination and assessment. The study was conducted in An Luong village, Red River Delta, northern Vietnam. In the study area, rice residue burning is restricted and farmers have to incorporate residue into the soil. Current water management practices, *i.e.* conventional continuous flooding and adopted midseason drainage, are not enough to reduce GHG emissions from added residues. Two new water management practices (pre-planting plus midseason drainage and early plus midseason drainage) were designed in participation with local stakeholders, and subsequently tested in the laboratory and in the field with the participation of local farmers. Future mitigation practices were assessed based on the yield, GHG emissions reduction and feedbacks of local stakeholders. Early plus midseason drainage proved to be an effective and feasible mitigation option for rice production in the area. Here we show that participation of local stakeholders in co-designing process help to identify the feasible GHG mitigation options, further it facilitates smallholder rice farmers to implement mitigation practices in their fields.

1. Introduction

Rice farming is one of the most important sources of anthropogenic agricultural methane (CH_4) emissions. It is well known that modified water management practices (early season drainage, midseason drainage, intermittent irrigation, alternate wetting and drying) have considerable CH_4 mitigation potential without the need for any external investment or resulting in a loss of yield for farmers (Pandey et al., 2014; Searchinger et al., 2014). These water management practices have often been tested at research stations and in controlled conditions to accurately determine the greenhouse gas (GHG) mitigation potential of the specific management of added organic amendments (*e.g.* rice residues, compost or manure) (Bhattacharyya et al., 2013; Ly et al., 2015; Tariq et al., 2017a; Zou et al., 2005). The actual implementation of mitigation strategies in farmers' fields is often constrained by local conditions, management practices and preferences. However, the implementation of mitigation strategies into actual field practices is not possible without actively involving farmers and local stakeholders in the planning and testing process. There is an urgent need to combine local field and practice-oriented knowledge with scientific knowledge to design a site-specific low emission rice production system (Stoop et al., 2002; Wassmann et al., 2000). Therefore, an on-farm

* Corresponding authors at: Montpellier SupAgro-IRC, UMR 951 Innovation, SupAgro-INRA-CIRAD, Montpellier, France.
E-mail addresses: azeem@plen.ku.dk, azeem.tariq@cirad.fr (A. Tariq), Stephane.De-Tourdonnet@supagro.fr (S. de Tourdonnet).

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participatory approach, taking advantage of scientific results acquired in the laboratory and applying them to field and on-farm experiments, is required to define optimum mitigating rice production systems.

The co-design of innovative agricultural prototypes for sustainable farming has arisen as a discipline in recognition of the need to combine research and practical knowledge in order to develop complex production systems (Vereijken, 1997). The co-design of mitigation prototypes at field scale is a challenge since climate change mitigation is a global issue rather than a direct concern for farmers. A participatory approach to prototyping in interaction with local stakeholders, preferably including farmers, is beneficial since it allows the interaction of both local and scientific knowledge (Meynard et al., 2012). Rahman and Bulbul (2015) propose the active involvement of local stakeholders to enhance the implementation of mitigation practices in rice production systems.

The aim of co-designing the low emissions rice cropping system was to mitigate the global warming potential (GWP) of rice production systems without having a negative impact on farmers' yields or livelihoods. Researchers have highlighted the importance of participatory methods in the design and implementation of climate-friendly agricultural production systems (Smith et al., 2007; Vignola et al., 2015). The transition of a prototype from small (field) scale to large (farm or regional) scale is difficult to achieve without the sufficient participation of farmers, local professionals and regional stakeholders (Le Bellec et al., 2012). It is important to understand the process of combining the local agricultural expertise and technical scientific knowledge, and then share it with the participants (Altieri and Koohafkan, 2008). Local stakeholders facilitate communication of the central objective and increase the efficiency of adoption by farmers (Pretty, 1995). Regional stakeholders provide suitable conditions for adopting the innovation techniques, for instance farmers may receive incentives for adopting new technologies. Farmers share their constraints and provide the basis for the possible modification of current practices (Meynard et al., 2012). Krupnik et al. (2012) have demonstrated that mutual learning by researchers and farmers could lead to the development of an innovative irrigated rice system, and could facilitate its adoption under local conditions. Le Bellec et al. (2012) have designed the DISCS method for multi-stakeholders' participatory design and assessment of innovative cropping system. DISCS is a prototyping method which allows multi-stakeholders participatory approach by implementing three progress loops, at experimental field, farm and regional scales. Three categories of professional stakeholders are involved: farmers, researchers, and agricultural advisers, who are collectively in charge of designing and testing the cropping system prototypes. In addition, local public stakeholders including representatives of state institutions are consulted. Progress is assessed using scale-specific sets of indicators. The DISCS method was applied to develop low- pesticide citrus cropping systems in Guadeloupe, French West Indies.

In this study, a participatory approach was used to design and test a mitigation practices for rice production system in the Red River Delta in northern Vietnam. On a national scale, rice straw burning is restricted and the government is encouraging farmers to manage straw sustainably to improve human health and society and to prevent the environmental pollution and global warming (Hai and Tuyet, 2010). Therefore, farmers have to dispose of a large amount of rice straw by incorporating it into the soil. Typically, farmers have no other straw management options available to them, since its use for livestock feed or bedding, composting or bioenergy production is considered unattractive due to absence of livestock facilities, labor shortage or cost issues. Incorporation of rice straw into soil is known to result in increased GWP, particularly due to increased CH_4 emissions under flooded rice conditions (Bossio et al., 1999; Romasanta et al., 2017; Searchinger et al., 2014). Meanwhile, there is growing concern about CH_4 emissions from rice paddies and societal demand for the implementation of agricultural mitigation practices in Vietnam, where rice farming contributes up to 50.5% of national agricultural GHG emissions and 16.3% of all national anthropogenic GHG emissions, of which CH_4 is a major share (MONRE, 2014). It is becoming increasingly important to reduce CH_4 emissions from flooded rice fields to reduce the overall GWP of rice production systems in Vietnam. In that sense, two environmental demands being made on rice farming (reductions in straw burning and in GHG emissions) are potentially in conflict with one another (Romasanta et al., 2017) since farmers' default response to legislation that prohibits burning is to incorporate the straw into the soil. Finally, GHG mitigation does not produce tangible benefits for the farmers, and hence their motivation to adopt such practices will be influenced considerably by external incentives or system constraints.

The objective of this study was to adapt the DISCS participatory approach of prototyping (Le Bellec et al., 2012) to design mitigation practices for rice production systems in a village in northern Vietnam, and to understand the potential benefits and possible constraints in the adoption of mitigation practices in the area in future. The prototyping method was improved by incorporating multi-scale scientific results – from microcosm to field and farm scale – in the participatory process. The main aim was not to design a completely new rice cropping system, but to modify current management practices with the involvement of local stakeholders to minimize GHG emissions without reducing grain yield.

2. Material and methods

2.1. Description of method

The participatory approach of Vereijken (1997) and Le Bellec et al. (2012) was followed, with some modifications, involving local stakeholders in each step of the designing process and incorporating multi-scales experiments (Fig. 1). Four categories of stakeholders were involved in the designing and subsequent assessment process: i) researchers, who provide the scientific knowledge and tools; ii) farmers, as key stakeholders involved in the survey, field experiments and workshops; iii) local agricultural advisors, who provide local technical knowledge and feedback during focus group discussions and workshops; and iv) regional stakeholders, who are engaged in agricultural as well as regional socioeconomic systems. All four categories were involved in all the workshops. The stakeholders' composition at each step is presented in Table 1.

The participatory approach was based on local and scientific-oriented knowledge (Fig. 2). The participatory approach of co-designing included the following five steps: (i) diagnosis, based on a literature review and a stakeholder survey, aimed at identifying possible technical options for GHG mitigation from rice fields and existing smallholders farm practices and constraints, (ii) design of mitigation practices based on initial laboratory tests of possible options and workshops with farmers, local agricultural advisors and regional stakeholders, (iii) testing in growth chambers to explore the technical mitigation potential of designed practices under fully controlled conditions, (iv) testing in farmers' fields to establish the actual mitigation efficiency of designed practices under farmers' variable conditions, and (v) dissemination and assessment, based on laboratory and field trials and the experiences and perceptions of local stakeholders.

2.2. Case study

This section describes the method used in the co-design and assessment of mitigation practices based on residue incorporation for a lowland rice-producing area on the Red River Delta in northern Vietnam. The methods adapted at each step depended on the specific context and need to address the complex issue of GHG mitigation with local stakeholders. The data that resulted from the innovative process of co-design and assessment of mitigation practices is presented in the Results and Discussion sections below.

The study was conducted at a local scale in An Luong Village, An