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A cost-benefit analysis of rice field winter flooding for conservation purposes in Camargue, Southern France

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ABSTRACT

Rice plants have a high silica content, which prevents rice straw from being used as a compostable bi-product in the same way as that from wheat and many other crops. The most common post-harvest practice in rice fields in France is to burn and then plough the fields. Flooding harvested fields during winter may create agronomical and environmental advantages, but the economic profitability of the practice has not been adequately studied. We used a cost-benefit analysis to explore six possible agricultural scenarios during the rice intercrop period, at the scale of individual farms and of society as a whole. All scenarios were economically realistic for the farmer (benefits-to costs ratios > 1), except current burning-ploughing which was just below economic equilibrium (B/C = 0.93). The most beneficial however was harvesting rice in flooded fields, which saved irrigation pumping costs. Similar results existed at the society level, and burning-ploughing was again clearly unacceptable (B/C = 0.73), largely because of greenhouse gas emissions and the absence of ecosystem benefits made available by flooding fields. Harvesting rice in flooded conditions and maintaining water in the fields afterwards was the most profitable option, and remained so during our sensitivity analysis when a wide range of variable evaluations were simulated. More than burning and ploughing, flooding rice fields facilitates straw and weed seed decomposition and creates a range of environmental benefits including the provision of extensive foraging habitat to wintering waterfowl. Our results suggest that post-harvest flooding of rice fields in France is economically realistic for farmers and the most beneficial practice for society.

1. Introduction

Rice cultivation induces a range of constraints for farmers worldwide. First, the flooding of rice fields during growth creates favorable conditions for a diversity of pioneer weed species adapted to temporary wetland ecosystems, such as Cyperaceae (Baki et al., 2000; Oerke, 2006; Anders et al., 2008; Rodenburg and Johnson, 2009). Despite late winter field preparations, successive years of rice cultivation often induces rapid colonization of weeds and causes yields to suffer. This forces farmers to compromise between regular crop rotation and the heavy use of herbicides, which prevents them from switching to organic farming (Palvadeau et al., 2012). A second problem that rice farmers face is the high silica content of rice straw, which limits its use as a compostable bi-product, such as how wheat straw is used as livestock litter. Rice farmers must therefore dispose of straw using methods that lack secondary agronomic benefits. The simplest method for rice straw disposal is burning, which has been a historical and on-going practice in many rice-growing regions, particularly in France (Monier et al., 2009). However, greenhouse gas emissions, fine particulate air pollution, and heavy smoke created by burning fields have led to the ban of this technique in some areas such as California (e.g., California Rice Straw Burning Act 1991 in Anders et al., 2008), raising the need for alternative straw disposal methods.

Post-harvest flooding of rice fields is an efficient means of promoting rice straw decomposition, and is a recognized alternative to the burning-ploughing regime in the U.S. (review in Pernollet et al., 2015a). Some weed seeds also lose mass or viability more rapidly in flooded conditions, thereby potentially reducing the need for herbicides (Manley et al., 2005; Fogliatto et al., 2010). Finally, flooding rice fields after harvest creates vast areas of shallow wetlands, which, while artificial, provide very attractive

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grounds for a large number of wintering waterbirds (Eadie et al., 2008 for the U.S.; Pernollet et al., 2015b in Europe). The birds themselves could provide additional benefits, further promoting the decomposition of straw by trampling and dabbling (Bird et al., 2000 for the U.S.; Brogi et al., 2015 in Europe), as well as reducing weed seed stocks through foraging (van Groenigen et al., 2003; see however Brogi et al., 2015). All of this supports the idea that post-harvest winter flooding of rice fields would be a mutually beneficial strategy for farmers and the environment, whereby farmers benefit from agronomic and ecosystem services and wildlife conservation is promoted (review in Pernollet et al., 2015a). A preliminary analysis considering potential savings on direct costs suggested winter flooding would be economically beneficial (Manley, 1999; Manley et al., 2005), but to date a thorough economic evaluation of winter flooding considering costs of field flooding, tillage operations, savings on nitrogen and pesticides costs, financial incentives or income from hunting, ecotourism or other ecosystem services, has yet to be completed (Manley, 2008).

Flooding rice fields during winter may be costly in some regions such as in France because of the energy required to pump the water. To overcome these costs subsidies are often given to farmers who undertake winter flooding (e.g. in California, The Nature Conservancy, 2014; in Spain, Pernollet et al., 2015b). In France rice is primarily grown in the Camargue, a vast delta created by the two branches of the Rhône River. Compared to other major waterbird winter quarters in Europe, the Camargue still has extensive areas of natural wetlands. To date only 9% of the Camargue rice fields are flooded in winter, compared to 62% in the Ebro delta and Albufera de Valencia, Spain. Post-harvest flooding is mostly practiced in the Camargue for hunting purposes, and Camargue farmers receive no financial incentives for winter flooding (Pernollet et al., 2015b). This may restrict the development of winter flooding of the Camargue rice fields, which is further limited by the fact that Camargue farmers have to pay pumping costs while in other areas (e.g. the Ebro Delta) the fields can be flooded by gravity and farmers receive financial incentives for doing so. The most common practice in the Camargue remains the rapid burning of straw after harvest, followed by ploughing of the dry fields during winter (75% of the residual rice straw still undergoes burning in Camargue, the remaining 25% mostly being chopped, Monier et al., 2009). Despite the potential agronomic and environmental benefits of post-harvest rice field flooding, this practice will only be implemented by farmers if it is financially sound. The aim of the present paper is to conduct a cost-benefit analysis of rice field winter flooding to determine whether this could be an economically feasible option for French rice farmers. We also compared the benefits-to-costs ratio with alternative farming practices during the non-growing season, including the current burning-ploughing practices (Monier et al., 2009). Beyond the individual farm, we analysed the potential costs and possible benefits to society and discussed whether financially supporting Camargue rice farmers to flood their fields during winter with public funds would be appropriate.

2. Methods

2.1. Study area

The Camargue delta (43°30′N, 04°30′E) covers about 145,000 ha, of which ca. 15,000 ha are currently cultivated in rice (Parc Naturel Régional de Camargue hereafter PNRC, 2013a). Water is pumped from the Rhône River through a network of canals and channels maintained by specific local organisations (Associations Syndicales Autorisées—ASAs). All farmers pay the ASAs for irrigation rights, except the farmers located along the river who may use private pumps to access the Rhône water supply directly. Flooding the high lands (1 m above sea level, 55% of the total agricultural area) requires farmers to use an additional private pump, either a tractor-held or electrical pump. To allow harvest in late September or early October fields are generally drained using a drainage network maintained by ASAs. Given that organic farming comprises less than 6% of the cultivated land (Palvadeau et al., 2012), our analysis was restricted to conventional farms. However, it is noted that straw management options are similar for both organic and conventional farms.

2.2. Economic evaluation

We relied on a cost-benefit analysis (CBA), which is based on economic efficiency criterion and measures whether the total benefits of a particular action are greater than the total costs (Hanley et al., 2009). Such analyses are becoming increasingly popular with policy-makers, and have been used in relation to conservation initiatives (Turner et al., 2000), conservation controversies (MacMillan et al., 2004), and in environmental impact assessments, such as for energy projects (Snyder and Kaiser, 2009). Compared to alternative approaches, such as cost-efficiency analysis or multicriteria analysis, the CBA has the advantage of considering costs and benefits in the same monetary unit (Pearce et al., 2006).

To identify the most common practices used in Camargue rice fields from harvest to the beginning of the next growing season we held interviews with the main stakeholders, such as agricultural engineers, agronomists, representatives of the rice farmers union, and farmers themselves. We also identified likely alternatives for field use after rice harvest, including winter flooding. For each scenario we listed all potential costs and benefits, separating those experienced by the individual farmer and those for society as a whole, including the farmer. We obtained quantitative estimators (expressed in €/ha) for each cost and benefit from literature searches and stakeholders. The geographic scale of analysis covered the total 11,390 ha of Camargue rice fields within the Camargue Natural Park in 2014 (France AgriMer, unpublished data). The temporal scale of analysis was limited to the period from harvest to straw incorporation into the soil, and all costs and benefits pertained to one single cultivation cycle. All monetary values listed in the following sections are given in 2014 Euros, with adjustments for inflation made where necessary (INSEE, 2014: www.insee.fr). A simple ratio of benefits to costs was then computed to evaluate each scenario compared to the current burning-ploughing practice. A sensitivity analysis was then conducted to determine the extent to which changes in the parameters would alter the evaluations of each scenario (for more methodological details and limits of cost-benefit analysis, refer to Hanley et al., 2009).

2.3. Agricultural scenarios

A total of six inter-crop management sequences (called scenarios hereafter) combining the various options available to farmers at each stage from harvest to the end of the winter were considered in the analysis (Table 1). In addition to winter flooding we tested only the most common current practices. Harvest was included because whether or not it is done on dry fields (as most often is the case) or in fields still flooded (practiced only in a few Camargue farms, but used widely in the U.S. and in Spain) it will profoundly affect the subsequent operations and costs. Straw can either be chopped during harvest, with the addition of a crusher onto the combine harvester itself, or concentrated into rows by the harvester and later burnt. Fields dry at harvest may or may not be subsequently flooded, then potentially drained again. The soil may either be worked deeply (ploughing, done only in dry fields) or