Land Use Policy 42 (2015) 131–140

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Multi-criteria and multi-stakeholder assessment of cropping systems for a result-oriented water quality preservation action programme

Clémence Ravier[a,b,*], Lorène Prost[c], Marie-Hélène Jeuffroy[a,b], Alexander Wezel[d], Laurette Paravano[e], Raymond Reau[a,b]

[a] INRA, UMR211 Agronomie, BP 01, 78850 Thiverval-Grignon, France
[b] AgroParisTech, UMR211 Agronomie, BP 01, 78850 Thiverval-Grignon, France
[c] INRA, UR1326 Sciences en Société, 77420 Champs-sur-Marne, France
[d] Department of Agroecology and Environment, ISARA Lyon (Member of the University of Lyon), 23 rue Jean Baldassini, 69364 Lyon Cedex 07, France
[e] Chambred'Agriculture de l'Yonne, 14 bis rue Guynemer, BP 50289, 89005 Auxerre Cedex, France

ARTICLE INFO

Article history:
Received 14 August 2013
Received in revised form 30 May 2014
Accepted 14 July 2014

Keywords:
Multi-criteria analysis
Local stakeholders
Water quality programme
Cropping systems design
Drinking water catchment

ABSTRACT

Water quality preservation programmes as currently proposed by public institutions are questionable with regards to efficient territorial development, yet necessary in catchment areas, and for the improvement of water quality. We provide a method based on a multi-criteria and multi-stakeholder analysis to assess cropping systems designed with farmers in a vulnerable drinking water catchment. Individual interviews with various stakeholders involved in the catchment improvement programme allowed us to gather a diversity of points of view on their preferences concerning various criteria describing cropping system sustainability and economic, social and environmental aspects. Five groups of stakeholders with different preferences were identified to define five scenarios of sustainability preferences. To support a result-oriented approach, achievable goals to improve water quality and contribute to sustainable development were chosen together with stakeholders. Then cropping systems designed with local farmers were assessed using the five scenarios of stakeholders' preferences to open discussions on the implementation of alternative cropping systems within the drinking water catchment. The method was able to identify some cropping systems that, although very diverse, might assure the required drinking water quality, and were judged as theoretically highly sustainable by all the stakeholder groups.

Introduction

Farming is responsible for diffuse water pollution, such as by nitrates and pesticides (Hénin, 1980; Panno and Kelly, 2004; Aubertot et al., 2005; Worrall et al., 2009). The European Water Framework Directive (WFD) states that all EU countries must reduce water pollution (Howarth, 2011). Member states have to delineate vulnerable zones within drinking water catchment areas and implement measures to conform to the WFD objective for water quality protection for the future (European Parliament, 2000). Farmers within these vulnerable zones are encouraged to implement practices that have less harmful environmental impacts (Laurent and Ruelland, 2011), and can be supported by public financial incentives to voluntarily adopt agro-environmental measures (AEMs). These measures are mostly action-oriented, as they rely on the implementation of recommended management practices. AEMs consist of a list of objectives concerning practices such as reduction of nitrogen fertilizer and pesticide use, guaranteeing a reward regardless of the results on water quality (Gerowitt and Bertke, 2003). However, these action-oriented measures, even when they are funded, are generally not sufficient to change farmers' practices in the long term and may fail to achieve the desired objectives (Matzdorf and Lorenz, 2010). They are not adopted widely enough by farmers (Kuhfuss et al., 2012) but also, in some cases, they are not effective enough to achieve the required drinking water quality (Barnes et al., 2009; Howarth, 2011), meaning that alternative approaches must be sought for building efficient action programmes promoting new cropping systems appropriate to the local context (Burton and Schwarz, 2013; Hasund, 2013). In this respect, "result-oriented" measures are an interesting alternative as the reward is based on the result. Based on an obligation to produce results independently from the management practices, they have already proven their efficiency (Gerowitt

* Corresponding author at: Avenue Lucien Brétignières, 78850 Thiverval-Grignon, France. Tel.: +33 1 30 81 52 95.
E-mail address: Clemence.ravier@grignon.inra.fr (C. Ravier).

http://dx.doi.org/10.1016/j.landusepol.2014.07.006
0264-8377/

and Bertke, 2003; Matzdorf and Lorenz, 2010; Sabatier et al., 2012; De Sainte Marie, 2014; Barataud et al., 2014). Result-oriented measures are probably relevant for water pollution issues since they allow a wider range of management strategies to be developed and implemented while relaxing constraints on management practices (Darradi et al., 2012; Sabatier et al., 2012). In addition, they seem to favour farmers' participation in building the water quality programmes and taking management initiatives more suited to local conditions and specific socio-economic contexts (Benoît and Kockmann, 2008; De Girolamo and Lo Porto, 2012). The WFD has introduced some elements intended to shift water governance towards integrated water resources management, requiring action to be based on public participation (De Stefano, 2010). To encourage result-oriented programmes and long-term territorial organization of agriculture to restrict water pollution, local stakeholders should be involved in the processes of changing farming practices (Schwarz et al., 2008; Garin and Barraqué, 2012). In fact, the consequences of changing practices or land use in catchment areas may affect a larger public than just the agricultural sector. Hence, various stakeholders playing various roles in these zones should be considered when designing new practices and building alternatives (Kerselaers et al., 2013). Yet, the question remains as to the most efficient way to involve the large variety of stakeholders with different knowledge, expectations and objectives regarding agricultural activities and their impacts on socio-economics and the environment. The many stakeholders in a drinking water catchment may propose various solutions and have conflicting interests (Parra-López et al., 2008), which can complicate the process of reaching a consensus on acceptable alternatives (Kerselaers et al., 2013). Also, these alternatives should be assessed as to their potential effects on water quality with simple, reliable, and easily monitored indicators, specified for local contexts (Melland et al., 2012; Hasund, 2013), and whether they suit the diverse objectives regarding the development of agricultural activities within a vulnerable area (De Stefano, 2010). In view of this diversity, a multi-stakeholder and multi-criteria assessment may be a way to address the complexity of the decision-making process for a particular region by identifying proposals able to satisfy the diversity of stakeholders' preferences (Arnette et al., 2010; Luyet et al., 2012). MASC® (Multi-attribute Assessment of the Sustainability of Cropping systems) is a tool able to carry out sustainability assessment of cropping systems, and is thus well suited to rank them for their estimated sustainability (Sadok et al., 2008, 2009). As the weights of the various criteria defining sustainability can be changed, this tool can be adapted to the various stakeholders' needs and requirements in a drinking water catchment.

The aim of this study was to analyze the possibility of identifying cropping systems at a water catchment scale, able to satisfy the differing requirements of the various stakeholders involved. We first identify the diversity of these requirements for the chosen catchment area. Then we assess the proposed cropping systems for the catchment area for their impact on water quality and sustainability. Finally we discuss the proposed approach to elicit stakeholders' priorities and assess alternatives to support decision makers within the water catchment area.

Materials and methods

The case study: the drinking water catchment of Brienon-sur-Armançon, France

Brienon-sur-Armançon is located in the province of Burgundy, north-eastern France. Brienon's drinking water catchment is one of the 507 priority catchments for water management in France. The 1700 ha of agricultural land in the drinking water catchment are currently dominated by annual field crops with very little livestock and only 2% of grassland (Agreste, 2010). Crop successions are mostly based on winter crops grown in short rotations, such as oilseed rape/cereals/cereals (Paravano, 2010). The water quality, analyzed monthly in the catchment, is characterized by high nitrate concentrations, sometimes up to the legal threshold of 50 mg l^{-1}, and pesticide residues whose concentrations occasionally exceed the legal maximum threshold (Duchenes, 2010).

Water quality issues concern many stakeholders in the catchment: fifty-eight farmers, three agricultural cooperatives, four local municipalities, citizens, a regional agricultural chamber, technical institutes, and one water services provider whose role is to ensure that water policies are implemented in the catchment area. Farmers in the catchment suggested an alternative to action-oriented agro-environmental measures, and proposed to take action by a means of a results-oriented programme. A steering group composed of local farmers, representatives from municipalities, technical institutes, chambers of agriculture, regional agencies, and the water services provider sought to devise a plan to assess a diversity of cropping systems regarding the need for water quality improvement and for sustainable development.

The cropping systems to be assessed

Two categories of cropping system were assessed: the current cropping systems, and alternative cropping systems designed to be adapted to the local water quality issues and to the local context.

Current cropping systems

Current practices are viewed as a baseline to assess farmers' proposals for alternative cropping systems in a local and water quality context. To investigate farmers' current practices, 18 interviews with farmers were carried out in the drinking water catchment (Paravano, 2010). The areas cultivated by these 18 farmers represent about 60% of the cultivated catchment area. From these interviews, eight cropping systems, considered as representative of the current situation, could be distinguished (A category in Table 1). They are based on three-year crop rotations (only winter crops) with high rates of nitrogen fertilization. We differentiated the crop rotations for two levels of pest control: intensive weed and pest control (A0), and intensive weed and integrated pest control (A1). This distinction allowed us to acknowledge the existing diversity of practices.

Alternative cropping systems

The second category (B) refers to the proposal of alternative cropping systems (Table 1). These were designed during a workshop involving farmers, agronomists, and technical advisors, according to the method proposed by Reau et al. (2012), with the aim of improving water quality in the catchment. Decreasing the intensity of pesticide use was expected with longer and more diversified rotations. Alternative cropping systems are based on 5-year crop rotations including a spring crop. We tripled the crop rotations with three different potential spring crops: pea (p), barley (b), or sunflower (s). To integrate the variability of farmers' practices for the alternative cropping systems, we distinguished intensive weed and integrated pest control (B1), and integrated weed and pest control (B2). Reduction of nitrogen leaching was expected due to (i) the systematic use of cover crops before each spring crop, and after winter oilseed rape and pea, and (ii) lower fertilization rates based on integration of higher nitrogen soil mineralization due to the presence of a catch crop, in the predictive balance-sheet method (Hébert, 1969) and to the introduction of a legume crop in the rotation.