Agriculture, Ecosystems and Environment 232 (2016) 312–325

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Assessing the role of agri-environmental measures to enhance the environment in the Veneto Region, Italy, with a model-based approach

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ARTICLE INFO

Article history:
Received 19 April 2016
Received in revised form 27 July 2016
Accepted 3 August 2016
Available online xxx

Keywords:
Agri-environmental measures
Decision support system
Environmental quality
Modelling
Nutrient cycling

ABSTRACT

Many efforts have been made in Europe to improve the environmental quality of agro-ecosystems. Since the 2000s, agri-environmental measures (AEMs) have been financed and implemented in EU countries, although their beneficial effects are still questioned due to poorly targeted environmental issues and a lack of site-specific payments. Indeed, estimates of AEM outcomes at the territorial level require considerable efforts to consider simultaneously multiple environmental objectives with multiple targets. As a result, a DAYCENT model-GIS platform was developed that integrates multiple types of pedo-climatic and land management information. The aim was to provide a decision support system for spatially evaluating and selecting the best AEMs in terms of soil, water and air quality, when compared with a standard scenario without any adopted measure. Our modelled results showed that in the Veneto Region, north-eastern Italy, the AEMs applied from 2007 to 2013 improved the environmental value of the agro-ecosystems, especially in terms of soil and water quality. Continuous soil cover, reduction of soil disturbance through grasslands, conservation agriculture and cover crops were the best simulated strategies to increase soil organic matter content (+25%) and reduce nitrogen leaching (−90%). These strategies were also able to sharply reduce soil water erosion (−86%) and as a consequence P loss, in particular in the steep hilly and mountain areas, although their application to arable lands in those landscapes is still rare. In contrast, care should be taken in the long-term regarding an increase in P leaching, since predictions up to +0.15 kg ha^{-1} y^{-1} are reached compared to the standard scenario. Finally, greenhouse gas (GHG) emissions (N_2O and CH_4) were reduced mainly due to increased fertilisation efficiency. The proposed method can be a flexible decision support tool for a result-oriented and scientifically-based evaluation of AEMs that may help policy makers to evaluate the most effective measures for increasing the environmental value of agro-ecosystems.

1. Introduction

Since the establishment of agri-environmental schemes in Europe, an attempt to reduce environmental risks of farming practices through preserving and maintaining the agro-ecosystems have been sustained on a voluntary basis following the "action-oriented" approach, meaning that farmers are not paid for the provision of production and outcomes, but for the adoption of land-management practices. Over the period 2007–2013, EU financial support for agri-environmental measures (AEMs) amounted to nearly 20 billion € (EC, 2014). In spite of the success of the approach, which led to *ca.* 22% of used agricultural area (UAA) in the EU-27 being under agri-environmental agreements (European Network for Rural Development, 2011), the ecological benefits have been largely questioned due, among other things, to poorly targeted environmental issues (Primdahl et al., 2010) and a lack of site-specific payments (ECA, 2011). In this context, a "result-oriented" adoption of agri-environmental schemes has recently been proposed to quantify the outcomes of EU environmental policies (Burton and Schwarz, 2013), with the aim of accompanying any agri-environmental measure with a scientifically based evaluation (Kleijn et al., 2001). Although the "result-oriented" scheme is still in its infancy, spatial targeting has already been identified as a key aspect for improving the cost-effectiveness of

Abbreviations: A, soil water erosion; AEMs, agri-environmental measures; GHG, greenhouse gas emission; N_{Leach}, nitrogen leaching; P_{Leach}, phosphorous leaching; P_{Loss}, phosphorous loss with water erosion; SOC, soil organic carbon.

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http://dx.doi.org/10.1016/j.agee.2016.08.010
0167-8809/

AEMs. As a result, the areas affected by site-specific environmental issues may benefit more from appropriate agri-environmental measures at lower costs (Uthes et al., 2010).

Several studies have recently highlighted the benefits provided by site-specific approaches. For instance, Desjeux et al. (2015) used a spatial econometric methodology to evaluate the agri-environmental benefits on biodiversity in the Netherlands and France, emphasising the effectiveness of spatial scale analysis to point out major discrepancies between the stated AEMs and their actual effects. Piorr et al. (2009) demonstrated that policy-driven land-use changes are affected by site-specific heterogeneity (fragmentation) at regional level as a result of climate and soil variability. While there are considerable amounts of data on socio-economic and policy-driven aspects as a result of managerial choices, most experimental studies did not integrate multiple site-specific measures at regional or national scales. Thus, only a few assessed environmental impacts and combined benefits on soil, water and greenhouse gas emissions at a fine spatial scale (*e.g.*, Deumlich et al., 2006; Ekholm et al., 2007), reflecting the complexity of combined methods to evaluate abiotic resources (Uthes and Matzdorf, 2013). Indeed, agri-environmental outcomes at the landscape level are affected by several factors, making a comparison between areas with and without agri-environmental scheme agreements quite difficult (Primdahl et al., 2003), although an overall assessment of AEM benefits requires that several environmental parameters are considered simultaneously. In this context, model-based studies that integrate spatial characteristics with agricultural management factors have demonstrated their suitability for comprehensive site-specific analyses (*e.g.*, Morari et al., 2004; Lugato et al., 2014), including multiple environmental indicators. Moreover, modelling predictions can be extended to cross-regional and cross-national scales, overtaking the spatial limitations of local empirical studies. This approach is fostered by huge amounts of highly-detailed management data that are available by local administrations, integrated with powerful hardware and software.

Veneto, a region located in north-eastern Italy, is affected by high anthropogenic pressures due to increasing conflicts over natural resources. Highly intensive and productive agriculture coexists with one of the most densely populated and industrialised areas of Italy, leading to increased environmental issues. Therefore, in the context of the Rural Development Plan (RDP, 2007–2013), the Veneto Region financed specific AEMs (*ca.* 22% of total rural development measures) with the aim of enhancing water quality, protecting soils from degradation and mitigating climate change.

With the aim of evaluating their effectiveness, an integrated model-GIS platform was developed. Following a holistic approach that included different biogeochemical cycles (*i.e.*, carbon, nitrogen and phosphorus), we evaluated the most effective measures to enhance soil and water quality as well as reduce greenhouse gas emissions.

2. Material and methods

2.1. Study area

The Veneto Region (north-eastern Italy) encompasses an area of about 18,400 km^2, of which 55% is occupied by the Venetian plain (Fig. 1a), an area of high population density. The elevation varies from sea level in the south up to *ca.* 3200 m on the Dolomites in the north. The plain, where most agricultural production is concentrated, is generally flat and rarely exceeds 100 m above sea level. The plain was formed by the depositional action of the Po and the Adige rivers (south-western part), Brenta river (middle-northern part) and Piave and Tagliamento rivers (north-eastern part). The area surrounding the Venice lagoon (1240 km^2) is even lower (around 2 m below sea level) and has been cultivated due to land reclamation since the 1st century BC.

Most of the low-lying plain in Veneto is covered by sandy and silty-clay deposits. According to the WRB classification (WRB, 2014), the major soils of the Venetian plain are Calcisols and Cambisols, characterised by medium natural fertility due to relatively low organic matter (around 15 g kg^{-1}) and cation exchange capacity from low (sandy) to high (silty-clay). Moving northward, hilly areas (15–300 m above sea level) are composed of calcareous, skeletal (25–47%) loam and clay loam soils (Luvisols and Cambisols). Mountain areas generally comprise sandy/clay

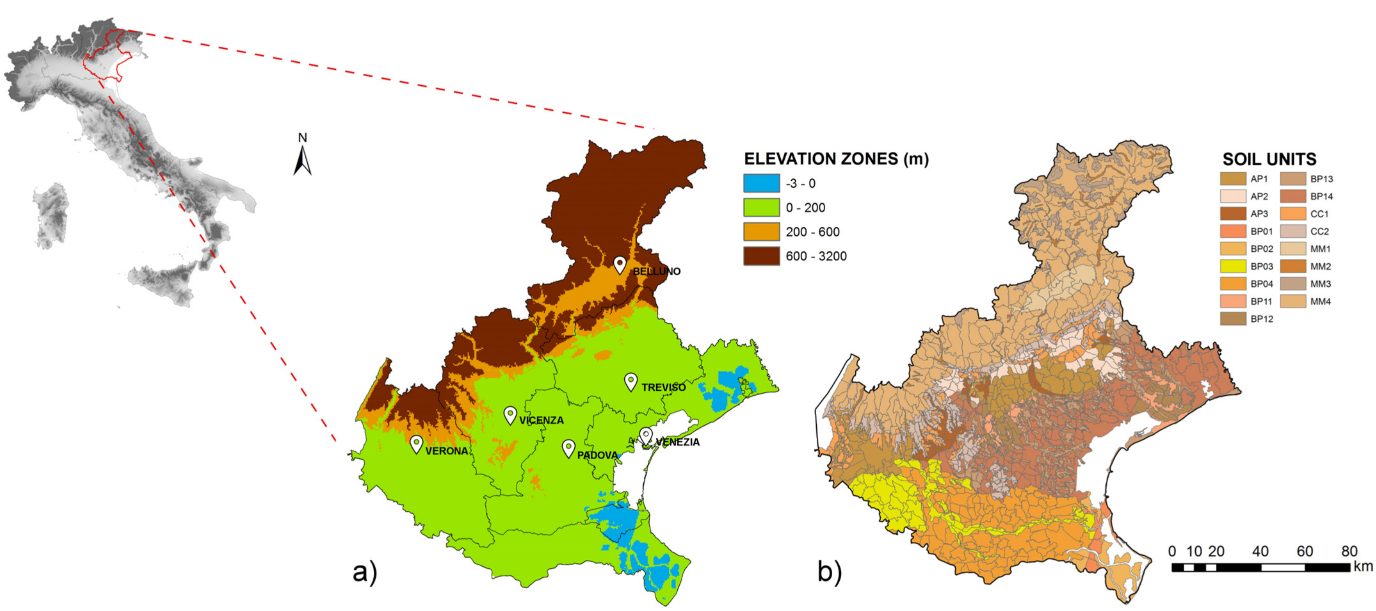

Fig. 1. Localisation of the Veneto Region study area and description of: a) elevation zones and provincial administrative centres; b) soil units.