Ecological Indicators 40 (2014) 76–89

Contents lists available at ScienceDirect

Ecological Indicators

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

Cropping system intensification grading using an agro-environmental indicator set in northern Italy

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ARTICLE INFO

Article history:
Received 18 April 2013
Received in revised form
27 December 2013
Accepted 2 January 2014

Keywords:
Agro-environmental sustainability assessment
Environmental impact
Organic farming
Integrated farming
Conventional farming

ABSTRACT

The term agro-environmental sustainability in agriculture usually refers to farming intensity. Lower intensity farming can be managed by reducing chemical and energy inputs. Beyond ethical issues and having in mind only agronomic aspects, cropping systems are defined by regulations that classify them according to their different input levels as conventional (most intensive), integrated (intermediate intensity), and organic (least intensive).

Among organic cropping systems, it is expected that the most intense cropping level would be arable farms where there is a greater need to import input factors, and the least intense level would be livestock farms. This research aims to systematically grade conventional, integrated, and organic cropping systems using a set of 22 indicators of input and environmental pressure. The grading results will then be compared to regulation-defined intensities.

Eight cropping systems belonging to four intensification levels were analysed by an indicator set classified as driving force or pressure indicators per the DPSIR schema. Driving forces represented farmer management decisions; pressures represented stressors to the environment resulting from agricultural activities not directly modifiable by the farmer. The 22 indicators analyse five aspects of cropping system: land use, fertiliser use, pesticide use, energy use and gaseous emissions.

Study results showed that most indicators were able to accurately grade the cropping system intensities. Specific driving forces and pressures indicators that failed to grade the cropping systems as expected related to several explainable factors. For driving force indicators, conventional systems demonstrated the highest impact on the environment and arable organic cropping systems the lowest. For pressure indicators, conventional cropping system presented the highest impact, followed by integrated cropping systems. In this case the arable organic cropping system presented a higher impact than did the livestock organic system. This level of discrimination showed that pressure indicators performed better at grading system intensification than did driving force indicators.

As a consequence, the analysis showed that higher input levels do not always result in higher pressures on the environment. Therefore, the environment would be better served by regulations that set thresholds for pressures rather than system inputs. The results also underlined that practices such as manure use and meadow presence improve the environmental performances of cropping systems.

1. Introduction

Over the past 60 years, European agriculture has undergone a period of rapid intensification achieved through an increased application of chemical fertilisers and pesticides, combined with implementation of best management practices, mechanisation, irrigation, and with the use of improved seed varieties (Tilman et al., 2002). Today, the term “agro-environmental sustainability” has come to imply high dry matter (DM) yields and society’s expectation for ecological service while complying with European environmental programs (Cross-compliance 73/2009/EC (EC, 2009a), Water Framework Directive 60/2000/EC (EC, 2000), Sustainable use of pesticides Directive 128/2009/EC (EC, 2009b), Birds Directive 147/2009/EC (EC, 2009c), and Habitats Directive 43/1992/EEC (Council of the European Communities, 1992)). These changes have led public and scientific communities to turn their attention to alternative farming systems including, among others, integrated farming, precision farming, conservation agriculture, and organic farming.

All of the above distinguish themselves from intensive conventional systems in their improved resource use efficiencies, rather than on external inputs to maintain productivity and profitability (Liebman et al., 2008). Low external-input and organic cropping

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http://dx.doi.org/10.1016/j.ecolind.2014.01.004

systems could provide a good compromise between intensity (level of input used per unit of surface) and efficiency (quantity of product obtained per level of input used) (Alluvione et al., 2011; Michos et al., 2012; Pointereau et al., 2012).

Cropping system intensity is defined by European, national, and regional level regulations. This paper considers only the agronomic aspects, contained in the different regulations and do not consider the different ethical aspects that have led to them. Conventional cropping systems must satisfy statutory management requirements defined in the cross compliance system (73/2009/EC; EC, 2009a), which represent the minimum legal limits. In Italy, the regional Rural Development Program (RDP) determines regulations for integrated farming systems, whereas organic agriculture is governed by European regulations 834/2007/EC (EC, 2007) and 889/2008/EC (EC, 2008). Among low-input cropping systems, integrated agriculture has been promoted for its reduced environmental impact and increased sustainable resource use (Alluvione et al., 2011; Morris and Winter, 1999). Organic farming has also been advocated as more sustainable than conventional systems over the long-term (Pimentel et al., 2005), as it uses the fewest inputs and therefore, is the least intense. Banned chemical products, improved nutrient recycling, and "minimisation of the use of non-renewable resources and off-farm inputs" are keys to its sustainability (Regulation 834/2007/EC (EC, 2007)).

When livestock production systems are paired with organic systems, further efficiency and sustainability is achieved. Regulation 834/2007/EC has defined livestock production as "fundamental to organization of agricultural production..." because it can provide organic nutrients to the cropping system through within-the-farm recycling, and allows for partitioning between low sustainability/externally- and high sustainability/internally-produced inputs (Nemecek et al., 2011). From this follows that in organic farms the highest intensification level should be on arable ones because they require more imported inputs; conversely, the lowest intensification level should be on livestock organic farms as they utilise nutrient recycling to meet many of their input needs.

Several authors have confirmed the relationship between lower intensification level and lower environmental pressures (i.e. Flessa et al., 2002; Kramer et al., 2006; Liu et al., 2007). Environmental pressures, however, have not always corroborated the expectations associated with the intensification levels described above, with organic cropping systems being less sustainable than conventional systems (Kirchmann and Bergström, 2001; Eltun et al., 2002; Basset-Mens and van der Werf, 2005). Finally, van der Werf et al. (2007), comparing many assessment methods applied to farms producing crops and pigs, found that the rank between organic and conventional farms depends on the assessment method applied and on the aspect analysed.

Field experiments and farm measures are two ways to evaluate directly the agro-environmental sustainability of different cropping systems, however, these methodologies are time-consuming when many aspects are analysed. "Indicators are an alternative when it is not possible to carry out direct measurements" (Bockstaller et al., 1997). They not only allow an understanding of complex systems (Mitchell et al., 1995), but also compare different situations, two characteristics that make them highly useful in the analysis of agricultural managements and their environmental pressures.

Different authorities — at both the European and worldwide scales — have created lists of indicators. Among them there are: EU Agro-Environmental indicators AEI (COM (2006) 508 (EC, 2006)), OECD agro-environmental indicators (OECD, 1999), and FAO agro-environmental indicators (FAO, 2012). At the European level indicators are also used to evaluate environmental policy effects. Some indicators are suitable to analyse different levels of complexities, such as Input Output Account (IOA) (Halberg et al., 2005), the Life Cycle Assessment (LCA) (ISO, 2006), and the Ecological Footprint (EF) (Rees, 2000). The IOA has been applied to different sustainability aspects, but in particular, to nutrient balances (Bassanino et al., 2007; Oenema et al., 2003; Schröder and Neeteson, 2008) and energy balances (Alluvione et al., 2011; Meul et al., 2007). In the case of the LCA and EF, they analyse the sustainability of the entire production system via pressure category assessment. Analysis of specific pressures related to different agricultural managements is most useful when performed by single indicators or indicator sets.

This work analyses different cropping systems at various intensification levels (conventional, integrated, and organic) using an agro-environmental indicator set built of different indicators derived from literature. The investigation aims to grade these cropping systems on both input level and environmental pressures; thereafter, the results will be compared to the expected grade derived from the intensification levels as defined by regulation.

2. Materials and methods

2.1. Description of the area

The study was carried out in the western Po Valley (Piemonte Region, NW Italy). The climate is temperate sub-continental, characterised by two main rain periods in spring and autumn, with an annual mean precipitation of 850 mm and an annual mean temperature of 11.8 °C. The soil types are Inceptisols, Entisols and Alfisols (Bassanino et al., 2007), mainly characterized by silt-loam and silt texture.

According to the regional administrative database (Regione Piemonte, 2010), arable and livestock farms cover most of the Utilized Agricultural Area (UAA). Conventional arable farms are in the majority (94.5%) while integrated and organic farms represent just 4.9% and 0.6%, respectively. The main arable farm crops were maize (*Zea mays* L.), winter cereals (*Triticum aestivum* L., *Hordeum vulgare* L.), soybean (*Glycine max* (L.) Merr.), and meadows (Sacco et al., 2003). Livestock farms bred principally bovine and swine. Bovine livestock farms fell into one of three breeding types: beef, dairy cows, or suckling cows (Bassanino et al., 2007), with suckling cows comprising the largest share at 47%, of which 1.2% were organic farms. Bovine livestock farm main crops included maize (for grain and silage production), winter cereals, lucerne (*Medicago sativa* L.), Italian ryegrass (*Lolium multiflorum* Lam.), and hay-producing meadows (mixed grasses and legumes).

2.2. Farm types

Conventional, integrated, and organic cropping systems of farms were considered in this study. Organic farms were further divided into arable organic farms and livestock organic farms according to their external input levels, which created four different farm intensification groups:

- conventional arable farms (CONV)
- integrated arable farms (INT)
- organic arable farms (ORG)
- organic livestock farms (LIV)

Two farms were selected at each intensification level, to represent the variability of farm managements and input use levels. Organic livestock farms were selected from the suckling cow breeding type. We further focused our work on cropping systems alone. From conventional and integrated farms, only those that applied mineral fertiliser were chosen to represent typical farmer behaviour in the area.