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# Assessing agro-environmental performance of dairy farms in northwest Italy based on aggregated results from indicators

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A B S T R A C T

Dairy farms control an important share of the agricultural area of Northern Italy. Zero grazing, large maize-cropped areas, high stocking densities, and high milk production make them intensive and prone to impact the environment. Currently, few published studies have proposed indicator sets able to describe the entire dairy farm system and their internal components.

This work had four aims: i) to propose a list of agro-environmental indicators to assess dairy farms; ii) to understand which indicators classify farms best; iii) to evaluate the dairy farms based on the proposed indicator list; iv) to link farmer decisions to the consequent environmental pressures.

Forty agro-environmental indicators selected for this study are described. Northern Italy dairy systems were analysed considering both farmer decision indicators (farm management) and the resulting pressure indicators that demonstrate environmental stress on the entire farming system, and its components: cropping system, livestock system, and milk production.

The correlations among single indicators identified redundant indicators. Principal Components Analysis distinguished which indicators provided meaningful information about each pressure indicator group. Analysis of the communalities and the correlations among indicators identified those that best represented farm variability: *Farm Gate N Balance*, *Greenhouse Gas Emission*, and *Net Energy* of the farm system; *Net Energy* and *Gross P Balance* of the cropping system component; *Energy Use Efficiency* and *Purchased Feed N Input* of the livestock system component; *N Eco-Efficiency* of the milk production component.

Farm evaluation, based on the complete list of selected indicators demonstrated organic farming resulted in uniformly high values, while farms with low milk-producing herds resulted in uniformly low values. Yet on other farms, the environmental quality varied greatly when different groups of pressure indicators were considered, which highlighted the importance of expanding environmental analysis to effects within the farm.

Statistical analysis demonstrated positive correlations between all farmer decision and pressure group indicators. Consumption of mineral fertiliser and pesticide negatively influenced the cropping system. Furthermore, stocking rate was found to correlate positively with the milk production component and negatively with the farm system.

This study provides baseline references for *ex ante* policy evaluation, and monitoring tools for analysis both *in itinere* and *ex post* environment policy implementation.



## 1. Introduction

The European Commission is employing many actions to get its Member States to reduce the environmental impact of agriculture across EU farmlands. Cross compliance, "green" additions to the Common Agricultural Policy (CAP) through the CAP Reform 2014–2020 (IEEP, 2011), and dissemination of Community Strategic Guidelines (CSG) (European Council, 2009, 61/2009/EC) applied via Rural Development Programme (RDP) national strategies on climate change, energy use, water management, biodiversity, and dairy restructuring (EC, No 74/2009) are just some of the most important efforts.

So many efforts demonstrate that the concept of what constitutes a high quality and sustainable agricultural system is

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continuously evolving. They also indicate the need to monitor the effect of policies *ex-ante*, *in itinere*, and *ex-post* with tools capable of holistic evaluation. Work had already been done in this direction. The European Councils of Cardiff and then Vienna (Presidency Conclusions, 1998a; 1998b) had emphasized the importance of developing environmental indicators to assess the impact of different economic sectors, including agriculture, and to monitor integration of environmental concerns into community policies. The European Council of Helsinki in its Presidency Conclusions (1999) had, in fact, taken action by creating a strategy to integrate the environmental dimension into its Common Agricultural Policy. Similarly, the Organisation for Economic Cooperation and Development (OECD), the European Environment Agency (EEA), the Directorate-General (DG) Environment, as well as the DG Agriculture and Rural Development, Joint Research Centre (JRC), and EUROSTAT were all developing Agro-Environmental Indicators (AEI) as part of agricultural policy reform. Hence, the IRENA operation (Indicator Reporting on the Integration of Environmental Concerns into Agriculture Policy) was launched to monitor the CAP (EEA, 2005). Agro-environmental indicators were being widely used both in Europe and outside Europe to assess agricultural sustainability (Bockstaller et al., 1997; Pacini et al., 2003; Bechini and Castoldi, 2009; Pacini et al., 2009; Gaudino et al., 2014; Bélanger et al., 2012).

Agro-environmental indicators must summarize, quantify, condense, and easily communicate the enormous complexity of the dynamic environment into a manageable amount of meaningful information (Bockstaller et al., 1997; Godfrey and Todd, 2001; Bélanger et al., 2012). An indicator is an alternative to describe a situation when direct measurement is impossible. It is a variable that reflects other variables that are difficult to illustrate (Bockstaller et al., 1997; Van der Werf and Petit, 2002). The impacts that agro-environmental indicators analyse generally relate to nutrient pollution, pesticide pollution, energy efficiency, gaseous emissions (greenhouse gases and ammonia emissions), biodiversity and productivity. Some indicators are specific to a geographic area and/or production sector for detailed analyses; others are more generic and allow situations to be compared. Some indicators are simple and account for only one aspect of a system while others are more complex.

Several complex tools have been developed, including the Integrated Assessment (IA) (Bezlepkina et al., 2011), Life cycle Assessment (LCA) (ISO 14040, 2006), Ecological Footprint (EF) (Rees, 2000), MOTIFS (Meul et al., 2008), DIALECT (Solagro, 2000), and FarmSmart (Tzilivakis and Lewis, 2004). Some researchers and institutions have selected from these sets. Others have proposed indicator sets specific to farm typology, targets, and scale (Freebairn and King, 2003), which limit the ability to compare situations. A standardised indicator set that describes all parts of a system with the same methodology and harmonized data collection methods is useful. To this end, a set of common AEIs were identified and described to compare the application effects of agro-environmental policy measures in Europe (European Commission, 2006; Oenema et al., 2011).

In Western Europe during the last decades, a progressive intensification process has largely increased crop and animal productivity both per unit of product and per unit of land. It followed from introduction of new technology, process specialization, large scale mechanization, and increased use of external inputs, such as feedstuffs, fertilisers, pesticides, and selected seeds (Bieleman, 1998; Thomassen and de Boer, 2005). The Italian Po Plain is intensively managed from an agricultural point of view, both for cropping and for animal husbandry (Bassanino et al., 2007; Bechini and Castoldi, 2009; Sacco et al., 2003). According to Bassanino et al. (2007) and Sacco et al. (2003), the dairy, pig, and beef farms of this area show the highest nutrient surpluses at the crop and farm scales; consequently, they have more potential to impact the environment. Dairy farms are characterised by the close relationship between their crop (grain and forage) and livestock systems (Van Calker et al., 2005) due to the complex equilibrium of nutrient and gaseous emissions of their livestock, crop, and manure storage systems (Van Evert et al., 2007; Bélanger et al., 2012). For this reason, dairy farms are a good fit for applying agro-environmental indicators to describe an intensive animal husbandry system that considers both the entire farm and its parts.

The overall goals of this work are to assess the environmental impacts of dairy systems and to identify which decisions by farmers most influence such impacts using a large set of agro-environmental indicators. The following details the specific aims of this work:

- to propose an organised list of agro-environmental indicators to assess dairy farms;
- to understand which indicators classify farms best;
- to evaluate the dairy farms based on the proposed indicator list;
- to correlate farmer decisions with their consequent environmental pressures, so that sound decisions to reduce the environmental impact of dairy farms may be formulated.

## 2. Materials and methods

### 2.1. Description of the area

The study was carried out in the Piemonte Region in the western part of the Po Plain (NW Italy). The climate is temperate subcontinental, characterised by rainy periods in spring and autumn, an annual mean precipitation of 850 mm, and an annual mean temperature of 11.8 °C. The soil types are Inceptisols, Entisols, and Alfisols, principally of silt-loam and silt textures with a normal or high content of both organic matter (2.24 ± 0.97%) and Olsen P (36.9 ± 30.4 ppm) (Bassanino et al., 2007). The utilised agricultural area (UAA) is approximately 996,000 ha of which 51% is arable (Regione Piemonte, 2010). The primary arable crops are maize (188,000 ha), meadow (128,000 ha), rice (121,000 ha), and wheat (86,000 ha), and the livestock sector includes 860,850 cattle, 991,450 pigs, and 8,487,263 poultry (ISTAT, 2012).

While professional dairy farms in Piemonte number about 1500 (Regione Piemonte, 2010), only 8% of them have adopted some official agro-environmental measures, and 1% are organic. Maize and meadows are irrigated. Crop yields and milk production are high. Animals are continuously housed in zero-grazing systems.

### 2.2. Description and survey of farming systems

The nine dairy farms selected for the study bred *Holstein-Friesian* cows and were representative of dairy farms in the Western Po Plain (NW Italy). Selection criteria included farm area size, herd size, type of crop rotation, and average yearly milk production per cow. Selected farms had to be representative of the dairy farm variability at the regional scale as reported in the available statistical database, and were selected by local experts in the most important milk-producing areas. Only farms where milk production provided most of the income were considered.

The principal farm characteristics are reported in Table 1. Maize (*Zea mays* L.) for grain or silage production was the main crop of the farms, with Italian ryegrass (*Lolium multiflorum* Lam.) intercropped during the winter before maize for silage. Grasslands yielded 4–5 hay or silage cuts per year and mainly included permanent meadows and lucerne (*Medicago sativa* L.). Winter wheat (*Triticum*