Environmental sustainability of typical agro-food products: a scientifically sound and user friendly approach

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Abstract

The paper introduces an approach, developed in Agriculture & Quality programme, to evaluate the environmental sustainability of Apulian quality agro-food products that is integrated in the regional quality scheme "Quality Products". It highlights the methodological approach adopted, the sustainability themes identified and the indicators selected. Indicators measurable at the farm/firm level were selected in relation to the following environmental themes: biodiversity, land use and management, energy use and climate change, use of chemical inputs, and responsible management of by-products and waste. A scoring scale was developed for each indicator; going from 0 (unsustainable) to 10 (very sustainable) with 5 corresponding to the sustainability threshold or reference value. The presented approach is both robust and user friendly and is in line with the principle entailing continuous improvement; the key sustainability thresholds will be periodically reviewed and updated. It represents a practical and innovative way to develop an information scheme for typical agri-food products and can be, with some refinement and contextualisation, easily scaled up to other territories.

Keywords*: Environmental sustainability, Biodiversity, Quality agro-food products, Sustainability themes, Indicators.*

1. Introduction

Agriculture is facing an unprecedented confluence of environmental pressures and challenges such as land degradation, climate change, water scarcity and pollution, biodiversity loss (FAO, 2014a); and there are several interconnected and mutually reinforcing trends in food production and consumption (e.g. unhealthy and unsustainable diets, unbalanced supply chains), which pose serious challenges on the overall sustainability of food systems (Friedmann and Mcnair, 2008). Sustainable agri-food systems are needed to provide economic benefits for rural dwellers, to ensure socially appropriate solutions to the food and nutrition security challenges and also to limit the negative environmental effects of agriculture (FAO, 2014a; 2014b).

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In the complex socio-economic and environmental landscape in which food systems operate today, traditional local products present an interesting option for rural development to reverse negative environmental and socio-economic trends. A central issue is thus how to emerge local resources, which are little known or ill-utilised (Fonte, 2006). Many scholars recognise that it is critical that typical products reach the consumer embedded with information on their quality attributes, including indication of environmental performance and quality (Brunori *et al.*, 2016; Marsden, 2013; van der Ploeg *et al.*, 2009).

The environmental quality of typical products is strictly linked to the territorial context into which production and consumption activities are embedded – its natural geomorphologic, chemical, biological resources constitute an important part of the product 'typicality', while continuous reproduction and care for such resources is an important characteristic of the environmental quality of typical food production systems (van der Ploeg *et al.*, 2009).

One way to embed information about environmental quality and performance of food products is through environmental labels and information schemes (ELIS). The rationale behind such schemes is the belief that they can drive gradual market transformation by promoting food products whose production process respect the environment (UNEP, 2015; UNFSS, 2016). The environmental effectiveness of an ELIS is a function of (1) the stringency and quality of the standard being used, (2) its appropriateness for the production and supply chain, and (3) the level of its market uptake (Prag *et al.*, 2016). The stringency and quality of schemes depend on various characteristics (Gruère, 2013), including the methods of environmental assessment adopted.

Since the assessment of the environmental, economic and social sustainability of agriculture and agriculture products is crucial for transition towards sustainable agro-food systems (Chaudhary *et al.*, 2018; El Bilali, 2019; Poppe *et al.*, 2016), there are different holistic and non-holistic approaches and frameworks for the assessment of sustainability (FAO, 2013; Latruffe *et al.*, 2016; Talukder, 2016). Reytar *et al.* (2014) analysed the landscape of indicators and indices used in the assessment of environmental sustainability in agriculture and found that the most common agri-environmental themes are climate change (GHG emissions), water use, agriculture policies (e.g. agriculture subsidies). In their overview, Latruffe *et al.* (2016) confirm that a multitude of themes are covered in the assessment of environmental sustainability (e.g. climate change and GHG emissions; biodiversity; land/soil management; use of nutrients, pesticides and resources e.g. energy and water) and, consequently, a high indicators number. These findings confirm the complexity of environmental sustainability assessment in the agro-food arena.

A multitude of tools and models has been used to assess the environmental sustainability in the agro-food sector. These include methods based on Life Cycle Analysis (LCA) and Life Cycle Thinking (Brentrup *et al.*, 2004), such as Carbon footprint (Dubey and Lal, 2009), Water footprint (Mekonnen and Hoekstra, 2012), Ecological footprint analysis (Naderi Mahdei *et al.*, 2015), or other methods such as Environmental risk mapping (Delbaere and Nieto Serradilla, 2004), SALSA - Simulation Tool to Assess Ecological Sustainability of Agricultural Production (Eriksson *et al.*, 2005). However, their scientific soundness and user-friendliness are still critical issues (Talukder, 2016).

A further weakness of these tools for the assessment of environmental sustainability is that they are not easily integrated and usable in certification schemes. To fill this gap, the present paper introduces a robust, yet user friendly method, for the assessment of environmental sustainability of agro-food products in Apulia region (south-eastern Italy) that is integrated in the regional quality scheme and is suitable to communicate to stakeholders, primarily consumers and policy makers, the environmental performance and quality of these products.

2. Material and Methods

2.1. *Agriculture and Quality project of Apulia region: combining typicality, quality and sustainability*

Apulia is a peninsular region located in the south-east of Italy. It has a land area of 1,954,090 hectares (6.5% of the Italian territory) and a resident population of 4,050,072 inhabitants (6.7% of the Italian population); its rural areas amount to 97.1% of the regional area, within which resides 85.1% of the total population. A strong diversity of production characterizes the Apulian agriculture and its 272,000 farms (Apulia Region Authority, 2013). The Apulian economy is strongly linked to its typical agri-food products and the region gives important value to the traditions related to food and to the typicality of the products (Apulia Region, 2010; MiPAAF, 2013). According to the 19th edition of the list of Italian traditional food products (MiPAAFT, 2019), there are 285 traditional agro-food products in Apulia region: 13 alcoholic beverages, 24 meat products, 1 condiment, 17 cheeses, 1 fat, 107 plant products, 64 fresh pasta and cereal products, 45 gastronomy products, 9 fish preparations, and 4 animal products.

In the framework of Agriculture & Quality programme (A&Q) (2013-2015), *Regione Puglia* (Regional Government of Apulia) aimed to valorise and qualify regional typical and traditional food products through the creation of the quality scheme "*Prodotti di Qualità*" (Quality products, PdQ) aiming to ensure both origin and quality of food products by complying with the product technical specification approved by *Regione Puglia*. In this framework, the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM-Bari) – in collaboration with different Italian institutions namely the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), the Council for Agricultural Research and Economics (CREA), the National Research Council (CNR), the Forum on Mediterranean Food Cultures, the University of Bologna and the University of Naples Federico II – carried out a pilot project to assess and promote the sustainability of the products belonging to the quality scheme (Capone *et al.*, 2016). The aim is to ensure that the products adhering to the regional quality scheme satisfy not only the quality requirements, but also sustainability ones thanks to the development of a methodological approach and guidelines to assess the sustainability of Apulian quality typical products. The approach for the assessment of diets sustainability considers four pillars: environment, economy, society-culture and nutrition-health (Dernini *et al.*, 2013; Lacirignola *et al.*, 2012). According to this methodological approach, an agro-food product can be considered sustainable only if it is so for each pillar of sustainability: environmental, economic (Capone *et al.*, 2016), socio-cultural (Moscatelli *et al.*, 2017) and nutrition-health (Azzini *et al.*, 2018).

The working group on environmental sustainability – including experts from ENEA, CREA and CIHEAM-Bari – identified and refined the selection of sustainability themes and indicators in accordance with the specificities of the region's typical products, the conceptual framework adopted as well as the requirements of the A&Q project that had in view the activation of a specific certification scheme to promote the transition of the Apulia food system toward a more sustainable one.

2.2. *Methodological approach for the selection of environmental themes and indicators*

The starting point of the adopted approach is a strategic, normative definition of sustainable food value chain (VC), as developed in FAO (2014c), which allows to tackle the question of food system transformation. This type of approach is conceptually different from descriptive/structural approaches in VC analysis, such as those deriving from commodity chain analysis and LCA-based indicators (Garnett, 2014; Stefanova & Iannetta, 2016). It is not simply a matter of how to do things better, but how to change toward production/consumption systems, which are able to deliver environmental and societal benefits. A further criterion for the selection of environmental indicators was their ability to inform the relation between the choice of the operators (cf. economic activities) and the ecological component of the territorial context.

The adopted methodological approach follows the guidelines for Sustainability Assessment of Food and Agricultural Systems (SAFA) of FAO (FAO, 2013) for the steps of definition of system boundaries, contextualisation and indicators selection:

1. System Boundary: The focus of the work is on products (and supply chains), participating in the scheme for quality typical products from Apulia region. Therefore, the definition of system boundary, spatial and temporal scales are those adopted by the A&Q project: regional boundary, year-based time boundaries, selecting a baseline year, compatible with the latest official statistical data on agri-food census. For each indicator, a selection of the benchmarks with which typical products are compared was performed.
2. Contextualisation: As suggested by SAFA, in order to select indicators, information should be gathered also about surrounding context of the value chains. In the framework of A&Q project, there have been detailed analyses focussing on the socio-economic conditions of the regional agri-food sector, positioning it in national and international perspectives, as well as environmental conditions and surveys were performed in order to understand which thematic areas are of particular importance for consumers (Capone *et al.*, 2017). This contextual information was used in order to select the environmental themes and sub-themes, the measurement units of indicators, as well as the sources of data and data collection methods.
3. Indicators can be integrated into indices in order to make easier comparisons, this implies weighting (e.g. equal weighting, differential weighting) and aggregating (e.g. arithmetic average, geometric average, setting a ‘knock-out’ threshold) the constituent indicators (Reytar *et al.*, 2014). For each indicator, a selection of the benchmark was performed with which typical products are compared, considering key sustainability thresholds to be reviewed (and updated) based on data periodically published by the national statistical authority (Istituto Nazionale di Statistica - ISTAT). The present environmental sustainability assessment approach considers the following indices: agriculture biodiversity management index; land management index; total energy use index; total chemical input consumption index; responsible management of production by-products and waste. It uses equal weighting (for indicators within indices/themes as well as among indices) and arithmetic average for aggregating both indicators and indices. A scoring system was developed for each indicator; from 0 (unsustainable) to 10 (very sustainable) with 5 corresponding to sustainability threshold or reference value. Actually, the scores of the indicators (not their effective values) are aggregated to obtain an overall score on the environmental performance/sustainability of a product.

3. Results and Discussion

3.1. *Environmental sustainability: guiding criteria and themes*

Environmental sustainability consists in the capacity to maintain over time the quality and reproducibility of natural resources (water, soil, biodiversity, climate resources, etc.) through their rational use as well as paying due attention to the negative impacts on the environmental resources. Therefore, the actors of the certified quality supply chain must commit to implementing an environmental management system aimed at a better use of resources (soil, biodiversity, energy, etc.) and, at the same time, pollution reduction (cf. reducing the use of production inputs such as fertilizers, pesticides, energy; waste management) through an approach based on the use of sustainable agricultural practices and a reorganization of production environments (firm, plants, etc.). To have products that are sustainable from the environmental point of view, the plant and animal production practices adopted by the companies that adhere to the regional scheme of *Quality products* (PdQ) must at least respect the guidelines and criteria of the integrated production (Dir.

2009/128/CE) and preferably be equivalent to those of organic farming (Reg. 848/2018/CE).

In this context, the working group on environmental sustainability has identified some key concepts behind ways of managing production processes that contribute to a greater sustainability of the agro-food system.

Special attention must be paid to certain guiding criteria such as:

- Preserving and increasing agro-biodiversity (e.g. plant varieties, local animal breeds, functional biodiversity, etc.) by adopting an ecosystem approach that takes into account the conservation of the agricultural landscape and support to production processes that derive from natural biodiversity (pollination, pest resistance, agricultural system resilience, etc.).
- Improving the efficiency of the use of resources, especially water resources and energy (both direct energy use as well as indirect energy use i.e. energy embedded in chemical inputs such as fertilizers, pesticides, etc.).
- Adopting sustainable practices that are necessary to reduce all types of degradation and depletion of soil, water and biodiversity (e.g. soil erosion, desertification, soil fertility reduction, water pollution, etc.).
- Reducing environmental pollution by decreasing the amount of chemical inputs used as well as the production of waste and by-products that should be managed responsibly and, where possible, enhanced through recovery, re-use and/or recycling processes.
- Promoting models of firm and supply chain organization that enable the reduction of losses along the food chain.

In compliance with the above-mentioned guiding criteria, and taking into consideration national and international literature, the following environmental sustainability themes were identified by the working group: biodiversity; land use and management; energy use and climate change; use of chemical inputs (fertilizers, soil conditioners/amendments, pesticides); responsible management of production waste and by-products. For each theme, a set of indicators, that meet the guiding criteria, has been identified.

3.2. *Indexes and indicator sets*

3.2.1. Agriculture biodiversity

Biodiversity is a resource or asset to be safeguarded and, as such is also an indicator of sustainability. The agricultural farm is therefore the physical place where the farmer's decisions interact with the specificities of the territory to reach a productive result. Each farmer inherits an environmental capital in terms of natural resources that he/she somehow manages to achieve a production and, therefore, a profit based on social and economic pressures and demands. Each farmer must deal with the specific structure of the territory and with particular structural conditions that, in turn, are determined by the context not only physical but also socio-economic (plots, climate, infrastructure, market, etc.); within these constraints he/she designs the organization and management of the firm. From this interaction between the choices of the farmer and the territories in which he/she operates, derives a wide variety of agricultural and cultural environments, which overall determine the quality of the landscape and the environment (Calabrese *et al.*, 2015; Calabrese *et al.*, 2013). Each rural area is, therefore, the complex result of local variations in climate, soil, economic relations, social structure and adaptive responses. In the agroecosystem hierarchy, the farm is the fundamental organization level and the functional unit of the territory (Caporali *et al.*, 2003).

If one takes into consideration the agricultural firm level, as the farm productive organization is the result of farmer's choices, by analysing the farm structural components that make up the system, it would be able to tackle in a global, holistic, systemic way, all the farmer's decisions concerning all the complex ecological and productive processes that can influence the state of the agro-ecosystem in relation to biodiversity.

As a result, the main areas of investigation in relation to the major biological and ecological processes going on at farm level are:

1. The plot: It is the smallest unit of the agro-ecosystem (agro-ecosystem unit), on which the farmer decides the type of crop, chooses the type of management (pest control

and management, soil fertility, etc.) and on which determines positive or negative effects on flora and fauna.

2. The farm: The farm is the smallest functional unit to be considered for sustainable management; at the level of which the farmer makes decisions and organizational choices according to the technical-economic context of the territory in which he operates in the context of the general economic policy.

3. Ecological infrastructures (or Ecological Focus Areas).

The Ecological Focus Areas can be present at plot and farm levels. Ecological focus area means any infrastructure on the farm or within 150 meters from it that has an ecological value for the farm (IOBC, 2004). The presence of ecological focus areas[1] on the farm is very important also for the purposes of the Common Agricultural Policy (Ecological Focus Area and set-aside area). They are used to ensure the presence of associated biodiversity on the farm in order to help support production processes through the provision of environmental and ecosystem services. The ecological focus areas are very diverse e.g. hedges, wildflower strips, strips managed without pesticides use (conservation headlands), grass strips, small ponds, dry stone walls, dirt roads, piles of stones or other materials. In addition to these semi-wild areas, even some of the productive areas may serve as ecological focus areas, such as pastures, meadows and orchards managed extensively and fallows, which contribute to the conservation of biodiversity on the farm.

For the analysis of environmental sustainability with reference to the impact on and the need to preserve agricultural biodiversity, qualitative and quantitative indicators have been proposed (Table 1; see also Supplementary material 1), which assess the sustainability of the choices made by agricultural entrepreneurs in relation to farm agronomic practices and spatial organization of production also in no directly productive areas.

3.2.2. Land use and management

Soil is subject to many threats whose main ones are water erosion, organic matter reduction, compaction, salinization, desertification, hydrogeological risk, biodiversity decrease, and punctual and widespread pollution.

Agricultural activity constitutes a factor of land defence from other uses that reduce its environmental value, but can also determine harmful effects, of physical and/or biological nature, on soil quality. The Communication of the European Commission COM(2006)231 on Thematic Strategy for Soil Protection (European Commission, 2006b) and the proposal for a directive establishing a framework for the protection of soil (European Commission, 2006a) set out common principles for protecting soils across the EU. They identify the risk of erosion as one of the main problems of European soils. The Soil Thematic Strategy was adopted in February 2012 and includes four pillars, namely awareness raising, research, integration, and legislation (European Commission, 2012). Moreover, rules for direct support schemes under the Common Agricultural Policy (CAP) contemplate erosion control as one of the main requirements for maintaining agricultural land in good agricultural and environmental conditions.

Water erosion of soils, an extremely complex and inevitable natural phenomenon, depends on the climatic conditions, the geological, ped-

[1] "Since 2015, every farmer in the European Union who claims a direct payment and has more than 15 hectares of arable land is obliged to have 5% of his arable land covered by ecological focus areas. These are areas which bring benefits for the environment, improve biodiversity and maintain attractive landscapes (such as landscape features, buffer strips, afforested areas, fallow land, areas with nitrogen-fixing crops, etc.). Some exceptions to this general rule apply, for example to farmers who have more than 75% of their area under grassland. The obligation to have 5% of land covered by ecological focus areas may be increased to 7% subject to a European Commission report in 2017 and a legislative proposal from the Commission. This obligation is one of three *'greening'* measures of the Common Agricultural Policy 2014-2020 – the others being the maintenance of permanent grassland and crop diversification." (European Commission, 2015).

ological, hydrological, morphological and vegetation characteristics of the territory; it can be accelerated by human activities, in particular by agro-silvo-pastoral activities (cultivation types, ploughing and cropping systems, forest management, grazing), up to determining the onset of serious economic and environmental problems. The content of organic matter in soils is influenced by the climatic conditions and cultivation techniques.

A phenomenon linked to soil degradation processes and in particular to surface erosion is soil compaction. The compaction of soils involves significant changes in the structural properties, reducing the drainage capacity of the soil and consequently increasing the superficial flow and the risk of erosion; it also causes changes in the hydraulic and thermal conductivity, the balance and characteristics of the liquid and gaseous phases of the soil itself and asphyxia phenomena. Soil compaction is favoured by natural phenomena (rain, swelling of the clays,…) and, above all, factors of anthropogenic origin linked to livestock farming (overgrazing) and cropping practices, such as the traffic of agricultural machinery. The risk of compaction is obviously higher where high loads (in terms of tractors / combine harvesters) are concentrated on treatable UAA of reduced size.

A useful element to evaluate the intensification of agricultural practices with respect to the national context is the consumption of mineral fertilizers. Another risk factor related to the intensification of agricultural practices, and relevant not only for the soil but also for the air and the safety of the agro-food products themselves, is the use of plant protection products. The use of fertilizers and pesticides can also have indirect effects on ecosystems, causing, for example, an impoverishment of soil biodiversity and a consequent degradation of soil structure and properties.

Environmental indicators relating to land use and management theme are reported in Table 1 (see also Supplementary material 2).

3.2.3. Energy use and climate change

The activities of agricultural companies cause both GHG emissions and alterations in the sequestration into and release of carbon from the soil. These can have positive or negative effects on the climate (Mackey *et al.*, 2013).

At farm level, direct GHG emissions are due to:

- Use of energy (in combustion processes, in mobile or fixed sources).
- Emissions from the soil (especially CO_2 due to the decomposition of organic matter and N_2O emissions due to nitrification and denitrification processes). These emissions are influenced by the application of mineral and organic fertilizers and by the intensity of cultivation operations as well as by soil and climatic conditions.
- Methane emissions due to enteric fermentation processes in ruminant production systems.
- Manure management and animal housing systems.

Indirect emissions are due to the production, storage and transport of various inputs (fertilizers, pesticides, fuels, feed, lubricants, seeds, plastic material, machinery, etc.) used in agricultural production. Several LCA studies indicate that the contribution due to the production of mineral nitrogen fertilizers is significant in plant production, while there are few studies concerning contribution to climate impacts due to the use of pesticides and lubricants. In the livestock sector, indirect impacts are linked to the production and transport of feed. In fact, the import of feed causes high impacts on the climate not only due to their intensive production and related transport, but above all due to the change in the use of the soil associated with the production of soya, corn and other feed crops in other continents.

The most used indicators currently linked to climate change are aimed at accounting for direct and indirect GHG emissions due to different agricultural activities. Traditionally, these accounts do not include CO_2 emissions due to the decomposition of organic matter in soils. Only the most recent policies aim at accounting for changes in carbon stock in the soil.

For the accounting of GHG emissions, the chosen approach is based on the adoption of proxy indicators. Indicators for the dynamics of organic carbon in soils are not be considered since there are still few studies that allow to translate the multitude of complex interactions in soil-plant-atmosphere systems, resulting from various agricultural practices, into a simple score system that adequately represents their effects on the climate. For the same reasons, indicators concerning methane emissions due to fermentation in the gastric tracts of ruminants have been excluded from the analysis.

Therefore, in this phase, we consider it useful to consider direct and indirect consumption of combustible energy sources, as indicators for the processes responsible for GHG emissions in agriculture. These indicators are aggregated into a composite index, using the weighted arithmetic mean, which acts as a proxy for the impacts on climate change (Table 1; see also Supplementary material 3).

Direct energy consumption is calculated using final energy consumption indicator i.e. the energy consumed by the farms to meet their production needs. This energy is accounted for on the basis of production for the agri-food sector, but also on the basis of that destined for other sectors (such as feed, textiles, etc.).

Regarding indirect consumption, the following inputs, purchased by the agricultural firm, are considered: mineral fertilizers based on phosphorus and nitrogen, lubricants, pesticides, feed, and plastic materials. It should be noted that indirect consumption for self-produced inputs by the agricultural firm is already counted, as data collection takes place at firm level, and not for each single product. The energy required for the production of capital goods (e.g. agricultural infrastructure and machinery) was not taken into consideration. Potassium-based mineral fertilizers, micronutrient-based mineral products intended for crop nutrition, seeds purchased by the agricultural firm and pharmaceutical products administered to farm animals were also excluded. In addition, energy consumption due to the production of organic fertilizers purchased by the firm was excluded, both because of the lack of data and because their use brings benefits in terms of reintegration of the organic matter content of agricultural land, with consequent benefits in terms of carbon storage.

For individual indicators, some additional notes are included hereafter:

- Final consumption of direct energy: The indicator considers the oil products purchased by the agricultural firm mainly for the operation of agricultural machinery, natural gas for heat production and electricity purchased from the electricity distribution network. This limit is due to the availability of statistical data in Apulia region, which take into consideration only the energy sources listed above, while the biomass sources purchased by the firm from third parties are not taken into account.
- Energy content of fertilizers, pesticides, lubricants and plastic materials: These inputs require energy sources both for the production of energy used, for the corresponding production processes, and as primary materials (feedstock energy). For various reasons related to the lack of updated studies of the sector, it was decided to consider the whole energy embedded in inputs, assuming the existence of a correlation between the energy content itself and the climate impacts related to the agricultural activity of the examined companies.

3.2.4. Chemical input consumption

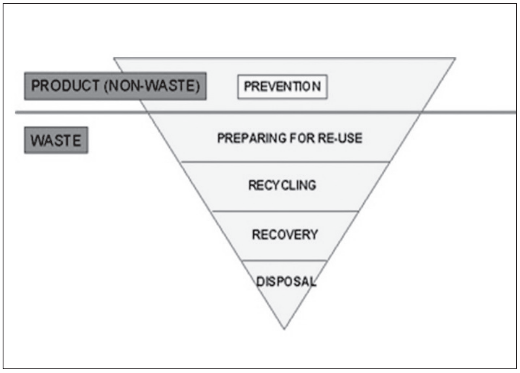
The use of chemical inputs at the level of primary production processes is undoubtedly a useful element in assessing the intensification of agricultural practices with respect to a national and regional context. The chemical inputs (fertilisers, fungicides, insecticides and acaricides, herbicides) in the present set of indicators (Table 1; see also Supplementary material 4) have been taken into consideration both in the case of soil/land management and energy use. However, in relation to this theme a specific reference is made instead to the quantities used to highlight the (un)sustainability of the use of these inputs with respect to the concrete risk of pollution of the agricultural system and, above all, of the environment.

The use of fertilizers, the most common of which are based on nitrogen and phosphorus, and of pesticides (fungicides, insecticides, acaricides and herbicides) can have different impacts depending on environmental contexts, crops, formulations and active ingredients used, as well as in relation to any additives or methods of administration and distribution. Another element of uncertainty in the environmental impact assessment, lies in the possibility of some molecules to persist for more or less long periods in the environment, to undergo modification processes and, therefore, to have a different fate and a different impact on natural resources and biodiversity. Currently, there are no exhaustive data on the use of chemical inputs by crop, territory and crop management system, even if many efforts are being made in this direction. On the other hand, it is useful to trace management choices and, if possible, direct them towards sustainability. A firm-level analysis that evaluates the agricultural entrepreneur's choices must necessarily be based on reference values linked to the Apulian territory, but which are not necessarily referring to management choices linked to specific agricultural production systems (integrated, organic and conventional). The idea is not to interfere 'ideologically' with the entrepreneur's choices, but to evaluate them in relation to what happens on the reference (regional) territory. Therefore, it was chosen to refer for the various indicators to the values of the statistical series reported in ISTAT publications; which may also be periodically reviewed in light of the change in the management of production processes traced precisely by ISTAT on a continuous and periodic basis.

3.2.5. *Responsible management of production by-products and waste*

The Framework Directive 2008/98/EC of the European Parliament and the Council of 19 November 2008 on waste (Waste Directive) defined a so-called "Waste hierarchy" (Figure 1). In fact, to better protect the environment and human health, Member States must take measures for the treatment of their waste in accordance with the following hierarchy, which applies in order of priority: prevention, preparation for re-use, recycling, recovery of other type (e.g. energy recovery), disposal. According to the Waste Directive, every producer or other waste holder must personally take care of it or deliver it to an entity or a firm.

Figure 1 - Waste management hierarchy according to the EU Waste Directive.



Source: European Commission (2016).

Also with regard to food losses and waste, a similar hierarchy has been defined by the High Level Panel of Experts on Food Security and Nutrition (HLPE). In fact, the HLPE invited to adopt measures to reduce food losses and waste (FLW), through a *food-use-not-waste* hierarchy, that is FLW prevention, reallocation of food as animal feed, food recycling for energy production through anaerobic digestion, food recovery for compost production, and ultimately, if no other solution is available, food disposal in landfills (HLPE, 2014).

The proposed qualitative indicator assesses the alignment of waste management practices at agricultural firm level with the waste management hierarchy with a particular reference to food losses and waste (Table 1; see also Supplementary material 5).

3.2.6. *Summary of themes, indices and indicators of environmental sustainability*

The environmental sustainability of a farm/firm is calculated as the arithmetic average of the scores of four indices (agricultural biodiversity management, land use and management, energy use and climate change, use of chemical inputs) and one indicator (responsible management of production by-products and waste) (Table 1). All the indices and indicators have the same weight. An agricultural farm/firm, and consequently any of its products, is considered sustainable from the environmental point of view if it has an overall score equal to or higher than 5.

Table 1 - Environmental indicators, themes and indices.

Indicators	*Themes*	*Environmental sustainability score component*	*Description*
Crop diversity (DC)	Biodiversity	Agriculture Biodiversity Management Index ABMI = (DC + NSAA + DCA + DCE + PCC + DCL + GA + SHS + DAV + DV) / 11	Synthetic index that assesses, through qualitative and quantitative indicators, the level of sustainability in the management of the biodiversity resource in relation to the agronomic practices of the agricultural firm and to the spatial organization choices of the productive and not directly productive areas at firm level.
Number of farm animal species (NSAA)			
Tree plant density (DCA)			
Herbaceous plant diversity (DCE)			
Presence of cover crops (PCC)			
Legume crop density (DCL)			
Plot average area (GA)			
Semi-natural habitat surface (SHS)			
Duration of rotations (DAV)			
Diversity of crop varieties and animal breeds (DVAB)			
Varietal diversity (DV)			
Application of soil conservation and improvement practices (SIP)	Land use and management	Land Management Index LMI = (SIP + SEP + NFI + PMI + SCM) / 5	Index to assess the sustainability in the use of the soil resource and in the agronomic practices related to it through qualitative and quantitative indicators
Soil erosion protection (SEP)			
Nitrogen fertilisers input (NFI)			
Input of plant protection products (PMI)			
Use of agricultural machinery (SCM)			
Final Energy Consumption (FEC)	Energy use and climate change	Energy Use Index EUI = (FEC + MFC + LC + PC + PMC + FC) / 6	Index that assesses GHG emissions at farm level
Mineral Fertilizers Consumption (MFC)			
Pesticide Consumption (PC)			
Lubricant Consumption (LC)			
Plastic Material Consumption (PMC)			
Use of off-farm animal feeds (FC)			
Nitrogen consumption (N-tot)	Use of chemical inputs (fertilisers, soil amendments, conditioners, plant protection products)	Total Chemical Input Consumption TCIC = (N-tot + P-tot + F-tot + Ins-tot + Herb-tot) / 5	Index that assesses the sustainability of the use of chemical inputs (fertilizers, pesticides, etc.) that end up in the soil, air and groundwater.
Use of total phosphorus pentoxide (P_2O_5) (P-tot)			
Use of fungicides (F-tot)			
Use of insecticides and acaricides (Ins-tot)			
Use of herbicides (Herb-tot)			
Methods for the management of production by-products and waste	Responsible management of production by-products and waste	Waste management (WM)	Qualitative indicator on sustainability in the management of production waste and by-products at the level of the agri-food firm
Environmental sustainability score = (ABMI + LMI + EUI + TCIC + WM) / 5			

3.3. *Discussion: From an environmental sustainability assessment approach to a sustainability certification scheme*

The methodological approach and set of indicators on agriculture environmental sustainability proposed in the present paper address three out of the five thematic areas (climate change, soil health, water, land conversion and its impacts on terrestrial ecosystems, and pollution) suggested by Reytar *et al.* (2014) namely climate change, soil health, and pollution (fertilisers, pesticides). As previously explained, the reason for it stays in the need for addressing main issues that matter at farm level, therefore, it can be argued that the impacts of land conversion are not as relevant in the Apulian context as it might be in other regions such as Latin America and South-East Asia, at least at the level of intervention focussed on by the certification scheme, where indicators on biodiversity address, at least indirectly, impacts of habitat conversion. The indicator set doesn't address water, and this can be a weakness of the approach that should be addressed given the central role of water in the Mediterranean context. The reason of this lack is in the impossibility to monitor in a really effective way, the rational use of water, as well as the causes impairing its quality, in relation to the specific requirements due to the different crops and microclimatic conditions of the Apulian companies. Nevertheless, referring to Reytar *et al.* (2014), the proposed approach also deals with waste management and expands the coverage of themes relating to pollution caused by agricultural activities and practices.

Besides, a growing challenge to sustainability is to balance benefits and trade-offs that result from agriculture (FAO, 2014a). The proposed approach, in order to consider possible trade-offs along the supply chain, addresses several phases of the life cycles of typical products. However, on the conceptual level, contrary to LCA-based methods, where the cradle phase is associated with mineral resources extraction, the focus is on the territorial agro-system environment as the cradle where farming takes place. The reason for such a choice is that environmental quality and performance of typical products depend on the linkage of the producers with the natural environment and on the quality of land-based resources (soils, biodiversity, water, climate).

It is increasingly being recognised that for environmental labels and information schemes (ELIS) to be effective in achieving the Sustainable Development Goals (SDGs), they need to address a product from a life-cycle approach (UNEP, 2015). From a methodological perspective, the adopted approach generalises and expands LCA as far as aggregation of indicators into composite indexes is concerned. In practice, many ELIS are based on LCA, a modelling methodology that still presents many criticalities in its accuracy and stringency aspects, especially when applied to food products; the modelling of LCA is based on Input/Output (I/O) analysis, which encodes an industrially-biased approach that is decoupled from limited territorial worldview of food systems (Stefanova & Iannetta, 2016). This makes such schemes conceptually not appropriate for communicating environmental performance of typical food products, which is rooted in their ability to use and conserve territorial natural resources. Moreover, various international efforts in the last 15-20 years to address biodiversity impacts and resources in LCA modelling framework have not yielded scientifically sound ways of doing so. On the other hand, it is increasingly recognised the functional role that biodiversity plays in provisioning of different levels and types of ecosystem services, which re-connect farmers in a close relation with local natural systems. Furthermore, LCA-based methods are more appropriate for production contexts, which can assure economy of scale, through which the cost of LCA consultancy services can be absorbed without compromising the quality of the food products. On the opposite, producers of typical products are often limited in scale, as they rely on local natural and social resources, and grow only when such territorial limits allow it (Fonte, 2006; van der Ploeg *et al.*, 2009).

The methodological approach and the related scoring system presented in this paper allow expressing in a simple, objective and numerical way the environmental sustainability of a product and/or the performance of the firm produc-

Figure 2 - Sustainability logo.

ing it. The main objective of the approach for the assessment of environmental performance of Apulian agricultural companies and agro-food products is to draft guidelines on the sustainability of typical products that serve for developing a sustainability certification scheme at regional level; with a *sustainability standard* and a *sustainability logo* (Figure 2) approved by the Apulia Region Authority. The rationale behind the planned product sustainability certification scheme is trifold:

4. In the short term, it is intended to inform consumers on environmental performances of the supply chains. Despite information on negative impacts on the environment (and their potential reductions through lower numeric values calculated as environmental footprints), consumers require also information on producers who add value to the environment in which they operate, through practices that protect soil, local biodiversity and landscape, avoid the use of substances with negative effects on both ecosystems and human health, limit negative effects on climate and on the use of non-renewable resources.

5. In the mid-term, since the introduction of a sustainability management system in an agri-food chain is only a starting point, it is important to envisage continual improvement; this means launching a virtuous process leading to an overall approach to sustainability for the Apulian agri-food firms applying the methodological approach outlined in this paper. The defined sustainability criteria and themes, following the principle of continual improvement, are continuously monitored to enable the assessment of the *benchmark* values. Sustainability benchmark and reference values defined in the *sustainability standard* will be updated every five years.

6. In the long term, its main function is to serve as a basis for the implementation of environmental management system, which informs value chain actors on the environmental performances of their activities as well as on the root causes of underperformances, in such a way that such information could be used in triggering collective action for achieving scaling up of positive impacts.

4. Conclusions

The paper presents an approach for the assessment of the environmental performance of the Apulian typical products. The presented approach has several strengths; basic indicators are measurable and simple, indicators are aggregated into composite indices that consider the specificities of the environmental pillar of sustainability, indicator benchmarks are dynamic. The approach is also both robust and user friendly. It is based on the last scientific developments regarding the assessment of environmental sustainability in agriculture and food systems. It is also user friendly as it allows farmers to assess the sustainability of their own farms and products using a straightforward 10-point scoring scale. This also allows an easy communication on environmental performance to consumers and policy makers alike. Another strength of the approach described in the paper is that it is linked to the regional quality scheme thus allowing to connect quality and sustainability. The proposed approach can be used standalone or integrated with economic, socio-cultural and nutrition-health indicators to get a holistic model for the assessment of agro-food products sustainability. For all the above-mentioned reasons, the approach has the potential to be used also on non-typical agro-food products in Apulia and Italy and, with due adjustments of thresholds/benchmarks and scoring scales, to be replicated in other territories in the Mediterranean area and beyond. Nevertheless, further work is needed to refine the approach especially regarding the values of sustainability thresholds and benchmarks in order to contribute to a continuous improvement in Apulian farms that is, eventually, leading to a genuine transition towards sustainability in the regional agro-food system. Further consideration is also needed to improve the coverage of the approach especially in relation to the management of water resources in Apulian farms and agricultural companies. Additional research will be required to better understand whether the proposed information on environmental sustainability will be also salient to future consumers.

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Supplementary materials

Supplementary material 1 - Indicators relating to agriculture biodiversity theme.

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th>Calculation methods (if applicable), thresholds and scoring scales</th></tr>
<tr><td rowspan="4">Biodiversity</td><td>Crop diversity (DC)</td><td>This indicator, referring to the number of cultivated plant species, aims to assess on-farm crop diversification practices, meant as a sustainable alternative to mono-cropping</td><td>Number of plant species grown on the farm.
DC = 1 i.e. monoculture.
Scoring scale:
<table>
<tr><td>DC</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>>10</td></tr>
<tr><td>Score</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>10</td></tr>
</table></td></tr>
<tr><td>Number of farm animal species (NSAA)</td><td>This indicator aims to assess the diversification of on-farm bred species, which enable the optimisation of production processes, the upgrading of by-products, and the improvement of biodiversity associated with production processes.</td><td>Number of animal species reared on the farm for production purposes.
Scoring scale:
<table>
<tr><td>DC</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>>10</td></tr>
<tr><td>Score</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>10</td></tr>
</table></td></tr>
<tr><td>Tree plant density (DCA)</td><td>Ratio of the number of plots grown with tree plants (UAA_{arb}) to the farm utilized agricultural area (UAA_{tot})</td><td>$DCA = UAA_{arb}\ x\ UAA_{tot}^{-1}$
Scoring scale:
<table>
<tr><td>DCA (%)</td><td>Score</td></tr>
<tr><td>DCA < 10</td><td>1</td></tr>
<tr><td>10 < DCA < 20</td><td>3</td></tr>
<tr><td>20 < DCA < 30</td><td>5</td></tr>
<tr><td>30 < DCA < 40</td><td>8</td></tr>
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<tr><td>60 < DCA < 70</td><td>8</td></tr>
<tr><td>70 < DCA < 80</td><td>7</td></tr>
<tr><td>80 < DCA < 90</td><td>6</td></tr>
<tr><td>90 < DCA < 100</td><td>5</td></tr>
</table></td></tr>
<tr><td>Herbaceous plant diversity (DCE)</td><td>Ratio of the number of plots grown with herbaceous plants (UAA_{erb}) within the farm to the utilized agricultural area (UAA_{tot})</td><td>$DCE = UAA_{erb}\ x\ UAA_{tot}^{-1}$
Scoring scale:
<table>
<tr><td>DCE (%)</td><td>Score</td></tr>
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<tr><td>20 < DCE < 30</td><td>8</td></tr>
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<tr><td>90 < DCE < 100</td><td>1</td></tr>
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</table>

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th>Calculation methods (if applicable), thresholds and scoring scales</th></tr>
<tr><td rowspan="3">Biodiversity</td><td>Presence of cover crops (PCC)</td><td>Weighted average of cover crops as related to the UAA, excluding the set-aside area</td><td>The duration of the presence of cover crops in the field (t) is calculated referring to one year (e.g. days / 365; months / 12) and weighted on the basis of the agricultural area (e.g. $UAA_{cover\ crop}$ / UAA_{tot}).
$PCC = \sum_{i=1}^{n} \frac{SAUcov\ crop}{SAUtot} t_i$
Scoring scale:
<table>
<tr><td>PCC (%)</td><td>Score</td></tr>
<tr><td>No cover crop</td><td>1</td></tr>
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<tr><td>45 < PCC < 55</td><td>7</td></tr>
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<tr><td>70 < PCC < 85</td><td>9</td></tr>
<tr><td>85 < PCC < 100</td><td>100</td></tr>
</table></td></tr>
<tr><td>Legume crop density (DCL)</td><td>Ratio of the number of plots with legumes (UAA_{leg}) to the farm utilized agricultural area (UAA_{tot})</td><td>$DCL = UAA_{leg} \times UAA_{tot}^{-1}$
Scoring scale:
<table>
<tr><td>DCL (%)</td><td>Score</td></tr>
<tr><td>DCL < 10</td><td>5</td></tr>
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<tr><td>20 < DCL < 30</td><td>8</td></tr>
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<tr><td>70 < DCL < 80</td><td>5</td></tr>
<tr><td>80 < DCL < 90</td><td>2</td></tr>
<tr><td>90 < DCL < 100</td><td>1</td></tr>
</table></td></tr>
<tr><td>Plot average area (GA)</td><td>Mean size of farm plots</td><td>$GA = \frac{UAAtot}{Number\ of\ plots}$
Scoring scale:
<table>
<tr><td>GA (ha)</td><td>Score</td></tr>
<tr><td>GA < 1</td><td>1</td></tr>
<tr><td>GA = 1</td><td>5</td></tr>
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<tr><td>GA > 7</td><td>1</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th>Calculation methods (if applicable), thresholds and scoring scales</th></tr>
<tr><td rowspan="3">Biodiversity</td><td>Semi-natural habitat surface (SHS or EFAs)</td><td>Percentage of semi-natural habitat surface (SUP_{SHS}) or ecological focus areas (EFAs) over the total farm area (TFA)</td><td>$SHS = \frac{\sum_{i=1}^{n} SUP_{SHS}}{TFA}$
Scoring scale:
<table>
<tr><th>SHS (%)</th><th>Score</th></tr>
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<tr><td>40 < SHS < 50</td><td>5</td></tr>
<tr><td>50 < SHS < 60</td><td>6</td></tr>
<tr><td>60 < SHS < 70</td><td>7</td></tr>
<tr><td>70 < SHS < 80</td><td>8</td></tr>
<tr><td>80 < SHS < 90</td><td>9</td></tr>
<tr><td>90 < SHS < 100</td><td>10</td></tr>
</table></td></tr>
<tr><td>Duration of rotations (DAV)</td><td>Number of years of the rotation of existing farm crops, excluding set-aside area</td><td>Weighted average of the number of years of rotation on arable land plots, excluding set-aside areas.
The presence of crops in the plot (t) is calculated referring to one year (e.g. days / 365; months / 12) and weighted on the basis of the land area (e.g. UAAcrop / UAA_{tot}).
$DAV = \sum_{i=1}^{n} t_i \frac{SAUi}{SAUtot}$
Scoring scale:
<table>
<tr><th>DAV (%)</th><th>Score</th></tr>
<tr><td>No rotation / monoculture</td><td>1</td></tr>
<tr><td>DAV < 6 months</td><td>2</td></tr>
<tr><td>6 months < DAV < 9 months</td><td>3</td></tr>
<tr><td>9 months < DAV < 1 year</td><td>4</td></tr>
<tr><td>1 year < DAV < 18 months</td><td>5</td></tr>
<tr><td>18 months < DAV < 2 years</td><td>6</td></tr>
<tr><td>2 years < DAV < 3 years</td><td>7</td></tr>
<tr><td>3 years < DAV < 4 years</td><td>8</td></tr>
<tr><td>4 years < DAV < 5 years</td><td>9</td></tr>
<tr><td>DAV > 5 years</td><td>10</td></tr>
</table></td></tr>
<tr><td>Diversity of varieties and animal breeds (DVR)</td><td>Number of on-farm plant varieties (DV) and animal breeds raised for production (NRAA)</td><td>DVR = DV + NRAA
Benchmark: DVR = 2
In the case of DV = 1, it is clearly matter about monoculture (mono-varietal cropping system) or one-breed animal husbandry.
Scoring scale:
<table>
<tr><td>DRV</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td>Score</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td></tr>
</table></td></tr>
</table>

Supplementary material 2 - Environmental indicators on land use and management.

Theme	*Indicators*	*Description of indicators*	*Calculation methods, thresholds and scoring scales*
Land use and management	Application of soil conservation practices	Quantitative indicator to evaluate the on-farm application of practices directed towards the conservation/improvement of the chemico-physical and biological properties of the agricultural soil	Share of farm's UAA on which soil conservation practices are applied. The following are intended as practices that allow conserving and/or improving the chemical, physical and biological properties of the agricultural soil: • Application of organic fertilizers (e.g. compost, manure...); • Application of soil improvers (to improve soil physical characteristics) and conditioners (to improve soil chemical characteristics); • Improving drainage to reduce water stagnation. Scoring scale: 0 (no application) to 10 (application on 100% of UAA).
	Soil erosion protection	Quantitative indicator to evaluate the on-farm application of practices to reduce the risk of wind and water erosion	Share of farm's UAA on which practices for soil protection against water and wind erosion are applied. The following are considered as practices of soil protection against erosion: crop rotation (including cover crops, fallow, forages), hedges as windbreaks, mulching and grassing, agro-forestation, terracing, strip cropping, protective grassy strips, drainage channels. Scoring scale: 0 (no application) to 10 (application on 100% of UAA).
	Input of nitrogen fertilisers	It provides an estimate of the rate of application of nitrogen-based products in the fertilisable UAA (UAA usually fertilised)	This indicator considers the total amount of mineral fertilizers distributed on the farm (ammonium sulphate, calcium cyanamide, ammonium and calcium nitrate, agricultural urea) in quintals. This amount is compared to the treated area (i.e. UAA - permanent meadows and pastures) in ha. Scoring scale: The consumption classes can be aggregated as follows: - High: > 1.5 (score: 0-3); - Medium: 1-1.5 (score: 4-6); - Low: < 1 (score: 7-10).
	Input of plant protection products	It provides an estimate of the rate of application of plant protection products in the treatable UAA	The indicator considers the total amount of plant protection products distributed on the farm, expressed in kg per year, regardless of toxicity classes. The amount is compared to the treated area (i.e. UAA - permanent meadows and pastures) in ha. Scoring scale: The classes of plant protection products use can be aggregated as follows: - High: > 10 kg / year (score: 0-3); - Medium: 5-10 kg / year (score: 4-6); - Low: < 5 kg / year (score: 7-10).

Theme	*Indicators*	*Description of indicators*	*Calculation methods, thresholds and scoring scales*
Land use and management	Use of agricultural machinery	It provides an estimate of agricultural machines trafficking intensity in the normally mechanized UAA for cultural operations (planting, preparatory and field works, weed control and plant protection treatments, harvest operations) and an indirect assessment of the deteriorating action caused to the soil physical properties	The composition of the machinery park, including machines number and average power, is determined from the firm survey. From these data, the number and average power in kW of tractors and combine harvesters are extracted. These values are multiplied by the average weight per kW of power of the machines (set indicatively at 0.50 q/kW) and by the number of passes in the field (ploughing, seedbed preparation, fertilization, weeding, phytosanitary treatments, for an indicative total of 5). The obtained value is compared to the treatable area (arable land, forage crops, trees) in ha. Scoring scale: The classes of machinery use can be aggregated as follows: - High: > 5.0 (score: 0-3); - Medium: 2.5 to 5.0 (score: 4-6); - Low: < 2.5 (score: 7-10).

Supplementary material 3 - Environmental indicators: Energy use and climate change theme.

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th>Calculation methods, benchmarks and scoring scales</th></tr>
<tr><td>Energy use and climate change</td><td>Final Energy Consumption (FEC)</td><td>This indicator monitors the use of direct energy at the farm level and measures the energy spent for cultural operations, heating, irrigation and different agricultural activities (drying, milling, pressing, cheese-making, slaughtering, etc.)</td><td>The indicator is calculated based on the consumption of:
a) Petroleum fuels: purchase of fuels (gasoline, oil, diesel, LPG, etc.), used for agricultural machinery and equipment.
b) Electricity consumed for agricultural activity, excluding the energy consumed by the holder’s family.
c) Fuels: solid fuels (wood, peat, coal, etc.), liquid fuels (fuel oil, gasoline, diesel oil, etc.) and gaseous fuels (methane, etc.) not used for firm vehicles, machinery and equipment, but for heating, refrigeration, corporate lighting, etc.
The whole energy consumption is related to the farm area (UAA).
The energy contained in electricity and fuel is expressed in MJ / kg or MJ / l (using LHV of fuels).
Benchmark (FEC_B) = 8.73 GJ/ha UAA
The benchmark is calculated as the average value of the indicator for the agricultural sector in Apulia based on data from ENEA, ISTAT and the information system of Apulia region (Bellini, Lipizzi, Consentino, & Giordano, 2013; ENEA-UTEE, 2011).
Scoring scale:
<table>
<tr><td>FEC</td><td>Score</td></tr>
<tr><td>FEC > 200% FEC_B</td><td>1</td></tr>
<tr><td>FEC ∈ [175%* FEC_B, 200%* FEC_B]</td><td>2</td></tr>
<tr><td>FEC ∈ [150%* FEC_B, 175%* FEC_B]</td><td>3</td></tr>
<tr><td>FEC ∈ [125%* FEC_B, 50%* FEC_B]</td><td>4</td></tr>
<tr><td>FEC ∈ [+25%*FEC_B, -25%* FEC_B]</td><td>5 (benchmark)</td></tr>
<tr><td>FEC ∈ [50%*FEC_B, 75%*FEC_B]</td><td>6</td></tr>
<tr><td>FEC ∈ [25%* FEC_B, 50%* FEC_B]</td><td>7</td></tr>
<tr><td>FEC ∈ [0, 25%*FEC_B] or the firm uses only biomass as combustible energy source that is purchased from third parties for at least 80%</td><td>8</td></tr>
<tr><td>FEC = 0 (the only source of combustible energy used by the firm is bioenergy with a maximum quota purchased from third parties of 20%).</td><td>9</td></tr>
<tr><td>FEC = 0 (no combustible energy source)</td><td>10</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th>Calculation methods, benchmarks and scoring scales</th></tr>
<tr><td>Energy use and climate change</td><td>Mineral Fertilizers Consumption (MFC)</td><td>This indicator assesses the consumption of the primary energy contained in mineral fertilisers used in the farm</td><td>The indicator is calculated by converting (through coefficients) the quantities of mineral fertilizers, expressed as kg of N and P (P2O5), into energy.
Fertilizer quantities are converted into MJ / ha UAA as follows (Eurostat, 2015):
• 58.17 MJ per kg N
• 14.16 MJ per kg P
The average consumption of nitrogen and phosphate fertilizers, calculated from the ISTAT data for Apulia region for 2012 (ISTAT, 2014, 2019a) are:
• 42 kg N / ha UAA
• 12 kg P2O5 / ha UAA
In energy terms, the benchmarks are:
• MFC-N: 2.44 GJ N / ha UAA
• MFC-P: 0.171 GJ P2O5 / ha UAA
• MFC_B = 2.92 GJ / ha UAA
Scoring scale:
<table>
<tr><td>MFC</td><td>Score</td></tr>
<tr><td>$MFC > 200\% MFC_B$</td><td>1</td></tr>
<tr><td>$MFC \in [175\%*MFC_B, 200\%*MFC_B]$</td><td>2</td></tr>
<tr><td>$MFC \in [150\%*MFC_B, 175\%*MFC_B]$</td><td>3</td></tr>
<tr><td>$MFC \in [125\%*MFC_B, 150\%*MFC_B]$</td><td>4</td></tr>
<tr><td>$MFC \in [+25\%*MFC_B, -25\%*MFC_B]$</td><td>5 (benchmark)</td></tr>
<tr><td>$MFC \in [50\%*MFC_B, 75\%*MFC_B)$</td><td>6</td></tr>
<tr><td>$MFC \in [25\%*MFC_B, 50\%*MFC_B)$</td><td>7</td></tr>
<tr><td>$MFC \in [0, 25\%*MFC_B]$</td><td>8</td></tr>
<tr><td>MFC = 0 (exclusive consumption of organic fertilizers, purchased from third parties for at least 80%)</td><td>9</td></tr>
<tr><td>MFC = 0 (exclusive consumption of organic fertilizers, self-produced in the firm for at least 80%)</td><td>10</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th>Calculation methods, benchmarks and scoring scales</th></tr>
<tr><td>Energy use and climate change</td><td>Pesticide Consumption (PC)</td><td>This indicator is aimed to monitor the consumption of fuel energy used to produce the plant protection products or fossil energy sources belonging to the primary feedstock of the plant protection products used in the farm</td><td>The indicator is calculated by converting (through coefficients) the quantities of pesticides (expressed in kg) into energy.
The quantities of pesticides are converted into MJ / ha UAA as follows (Ecoinvent, 2014): 182.91 MJ per kg of generic pesticide available on the market.
The benchmark (PC_B) is 1.80 GJ / ha UAA and was calculated using the average quantity of pesticides per ha of UAA distributed in 2012 in Apulia i.e. 9.88 kg / ha UAA (ISTAT, 2019b) multiplying it by the average energy content estimated by the Ecoinvent database (Ecoinvent, 2014).
Scoring scale:
<table>
<tr><td>PC</td><td>Score</td></tr>
<tr><td>$PC > 200\% PC_B$</td><td>1</td></tr>
<tr><td>$PC \in [175\%*PC_B, 200\%*PC_B]$</td><td>2</td></tr>
<tr><td>$PC \in [150\%*PC_B, 175\%*PC_B]$</td><td>3</td></tr>
<tr><td>$PC \in [125\%*PC_B, 150\%*PC_B]$</td><td>4</td></tr>
<tr><td>$PC \in [+25\%*PC_B, -25\%*PC_B]$</td><td>5 (benchmark)</td></tr>
<tr><td>$PC \in [50\%*PC_B, 75\%*PC_B]$</td><td>6</td></tr>
<tr><td>$PC \in [25\%*PC_B, 50\%*PC^B]$</td><td>7</td></tr>
<tr><td>$PC \in [0, 25\%*PC_B]$</td><td>8</td></tr>
<tr><td>PC = 0 (no use of pesticides on crops)</td><td>9</td></tr>
<tr><td>PC = 0 (no use of pesticides, including non-curative uses on livestock)</td><td>10</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th>Calculation methods, benchmarks and scoring scales</th></tr>
<tr><td>Energy use and climate change</td><td>Lubricant Consumption (LC)</td><td>This indicator monitors the consumption of the fuel energy used to produce lubricants for agricultural machines (tractors and machinery)</td><td>The indicator is calculated by converting (through coefficients) the quantities of lubricants (expressed in kg) into energy.
The quantities of lubricants are converted into MJ / ha UAA as follows (Ecoinvent, 2014): 81.73 MJ per kg of generic lubricant available on the market.
Due to lack of ISTAT data, the benchmark value (LC_B) will be calculated using the average amount of lubricants per hectare used by Apulian companies requesting environmental certification.
Scoring scale:
<table>
<tr><td>LC</td><td>Score</td></tr>
<tr><td>$LC > 200\% LC_B$</td><td>1</td></tr>
<tr><td>$LC \in [175\%*LC_B, 200\%*LC_B]$</td><td>2</td></tr>
<tr><td>$LC \in [150\%*LC_B, 175\%*LC_B]$</td><td>3</td></tr>
<tr><td>$LC \in [125\%*LC_B, 150\%*LC_B]$</td><td>4</td></tr>
<tr><td>$LC \in [+25\%*LC_B, -25\%*LC_B]$</td><td>5 (benchmark)</td></tr>
<tr><td>$LC \in [50\%*LC_B, 75\%*LC_B]$</td><td>6</td></tr>
<tr><td>$LC \in [25\%*LC_B, 50\%*LC_B]$</td><td>7</td></tr>
<tr><td>$LC \in (0, 25\%*LC_B]$</td><td>8</td></tr>
<tr><td>$LC = 0$</td><td>10</td></tr>
</table>
</td></tr>
</table>

Theme	*Indicators*	*Description of indicators*	*Calculation methods, benchmarks and scoring scales*
Energy use and climate change	Plastic Material Consumption (PMC)	This indicator is aimed to monitor the consumption of the energy used to produce the plastic materials used in the farm	The indicator is calculated through the conversion (via coefficients) of the quantities of plastic materials (expressed in kg) into energy. The quantities of plastic materials are converted into MJ / ha UAA as follows (Audsley, 1997): 94.02 MJ per kg of plastic material (using the value corresponding to the most common plastic materials e.g. polyethylene). Bio-plastics are excluded from the count. Due to the lack of ISTAT data, the benchmark (PMC_B) will be calculated using the average quantity of plastic materials per UAA used by Apulian companies that request environmental certification. Scoring scale:

PMC	Score
PMC > 200% PMC_B	1
PMC $\in$[175%*PMC_B, 200%*PMC_B]	2
PMC $\in$[150%*PMC_B, 175%*PMC_B]	3
PMC $\in$[125%*PMC_B, 150%*PMC_B]	4
PMC $\in$[+25%*PMC_B, -25%*PMC_B]	5 (benchmark)
PMC $\in$[50%*PMC_B, 75%*PMC_B]	6
PMC $\in$[25%*PMC_B, 50%*PMC_B]	7
PMC $\in$(0, 25%*PMC_B]	8
PMC = 0 (only use of bio-plastics)	9
PMC = 0 (no use of plastics)	10

Theme	*Indicators*	*Description of indicators*	*Calculation methods, benchmarks and scoring scales*
Energy use and climate change	Use of off-farm animal feeds (FC)	This indicator aims to monitor the consumption of the fuel energy used to produce the animal feeds that are not produced within the farm, but are purchased	The indicator is calculated by converting (through coefficients) the quantities of non-self-produced feed used by the firm (expressed in kg) into energy. The LCA databases do not contain average values for the feed used, given the extreme variability of these, the different production methods (e.g. organic, conventional, integrated production) and geographical environments. It is therefore necessary to determine the coefficients according to the type of feed used by the firm and to try to approximate it with existing data. These data are available for the Netherlands and for Switzerland in the LCA databases e.g. Agrifootprint database (Ecoinvent, 2014). The benchmark (FCB) is calculated using the average mix of feed used in Apulia region for the reference year (currently 2012) and its average quantity used by companies that request environmental certification. Scoring scale:

FC	Score
$FC > 200\% FC_B$	1
$FC \in [175\%*FC_B, 200\%*FC_B]$	2
$FC \in [150\%*FC_B, 175\%*FC_B]$	3
$FC \in [125\%*FC_B, 150\%*FC_B]$	4
$FC \in [+25\%*FC_B, -25\%*FC_B]$	5 (benchmark)
$FC \in [50\%*FC_B, 75\%*FC_B)$	6
$FC \in [25\%*FC_B, 50\%*FC_B)$	7
$FC \in [0, 25\%*FC_B]$	8
FC = 0 (exclusive consumption of self-produced feed)	10

Supplementary material 4. Environmental indicators relating to the use of chemical inputs theme.

Theme	*Indicators*	*Description of indicators*	*Calculation methods, thresholds/benchmarks and scoring scales*
Use of chemical inputs (fertilisers, soil amendments, conditioners, plant protection products)	Nitrogen consumption (N_{tot})	This indicator is aimed to assess the N inputs applied at the farm level as related to the regional mean	Benchmark: 42 kg ha^{-1} i.e. average use of N in Apulia region calculated from ISTAT data referring to 2012 (ISTAT, 2019a); The value corresponding to the minimum score is that recommended by the Nitrates Directive (170 kg ha^{-1}) for areas at risk. Scoring scale: N_{tot} (kg ha^{-1}) — Score Nitrogen fertilization without soil analysis — 1 170 > N_{tot} > 84 — 1 84 > N_{tot} > 73.5 — 2 73.5 > N_{tot} > 63 — 3 63 > N_{tot} > 52.5 — 4 52.5 > N_{tot} > 42 — 5 42 > N_{tot} > 31.5 — 6 31.5 > N_{tot} > 21 — 7 21 > N_{tot} > 10.5 — 8 10.5 > N_{tot} > 0 — 9 Ntot = 0 — 10
	Use of total phosphorus pentoxide (P_2O_5) (P_{tot})	It assesses phosphorus inputs at the farm level as related to the regional average	Benchmark: 12 kg ha^{-1} i.e. average input of total P, expressed as phosphorus pentoxide, calculated from ISTAT data referring to 2012 (ISTAT, 2019a). Scoring scale: P (kg ha^{-1}) — Score Phosphate fertilization without soil analysis — 1 P > 24 — 1 24 > P > 21 — 2 21 > P > 18 — 3 18 > P > 15 — 4 15 > P > 12 — 5 12 > P > 9 — 6 9 > P > 6 — 7 6 > P > 3 — 8 3 > P > 0 — 9 P = 0 — 10

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th>Calculation methods, thresholds/benchmarks and scoring scales</th></tr>
<tr><td rowspan="2">Use of chemical inputs (fertilisers, soil amendments, conditioners, plant protection products)</td><td>Use of fungicides (F_{tot})</td><td>This indicator is aimed to assess the inputs of fungicides applied at the farm level as related to the regional mean</td><td>Benchmark: 5.15 kg ha^{-1} based on the average use of fungicides in Apulia region in 2012 (ISTAT, 2019b).
Scoring scale:
<table>
<tr><td>F (kg ha^{-1})</td><td>Score</td></tr>
<tr><td>Calendar-based treatments without monitoring</td><td>1</td></tr>
<tr><td>F > 10.3</td><td>1</td></tr>
<tr><td>10.3 > F > 9.013</td><td>2</td></tr>
<tr><td>9.013 > F > 7.725</td><td>3</td></tr>
<tr><td>7.725 > F > 6.438</td><td>4</td></tr>
<tr><td>6.438 > F > 5.15</td><td>5</td></tr>
<tr><td>5.15 > F > 3.863</td><td>6</td></tr>
<tr><td>3.863 > F > 2.575</td><td>7</td></tr>
<tr><td>2.575 > F > 1.288</td><td>8</td></tr>
<tr><td>1.288 > F > 0</td><td>9</td></tr>
<tr><td>F = 0</td><td>10</td></tr>
</table></td></tr>
<tr><td>Use of insecticides and acaricides (Ins_{tot})</td><td>This indicator assesses the inputs of insecticides and acaricides applied at the farm level as related to the regional average</td><td>Benchmark: 1.69 kg ha^{-1} i.e. average use of insecticides and acaricides in Apulia region in 2012 (ISTAT, 2019b).
Scoring scale:
<table>
<tr><td>Ins (kg ha-1)</td><td>Score</td></tr>
<tr><td>Calendar-based treatments without monitoring</td><td>1</td></tr>
<tr><td>Ins > 3.38</td><td>1</td></tr>
<tr><td>3.38 > Ins > 2.958</td><td>2</td></tr>
<tr><td>2.958 > Ins > 2.535</td><td>3</td></tr>
<tr><td>2.535 > Ins > 2.113</td><td>4</td></tr>
<tr><td>2.113 > Ins > 1.69</td><td>5</td></tr>
<tr><td>1.69 > Ins > 1.268</td><td>6</td></tr>
<tr><td>1.268 > Ins > 0.845</td><td>7</td></tr>
<tr><td>0.845 > Ins > 0.423</td><td>8</td></tr>
<tr><td>0.423 > Ins > 0</td><td>9</td></tr>
<tr><td>Ins = 0</td><td>10</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Theme</th><th>Indicators</th><th>Description of indicators</th><th colspan="2">Calculation methods, thresholds/benchmarks and scoring scales</th></tr>
<tr><td rowspan="13">Use of chemical inputs (fertilisers, soil amendments, conditioners, plant protection products)</td><td rowspan="13">Use of herbicides ($Herb_{tot}$)</td><td rowspan="13">This indicator is aimed to assess the inputs of herbicides applied at the farm level as related to the regional mean</td><td colspan="2">Benchmark: 1.74 kg ha^{-1} corresponding to the average use of herbicides in Apulia in 2012 (ISTAT, 2019b).
Scoring scale:</td></tr>
<tr><td>Herb (kg ha^{-1})</td><td>Score</td></tr>
<tr><td>Calendar-based treatments without monitoring</td><td>1</td></tr>
<tr><td>Herb > 3.48</td><td>1</td></tr>
<tr><td>3.48 > Herb > 3.05</td><td>2</td></tr>
<tr><td>3.05 > Herb > 2.61</td><td>3</td></tr>
<tr><td>2.61 > Herb > 2.18</td><td>4</td></tr>
<tr><td>2.18 > Herb > 1.74</td><td>5</td></tr>
<tr><td>1.74 > Herb > 1.31</td><td>6</td></tr>
<tr><td>1.31 > Herb > 0.78</td><td>7</td></tr>
<tr><td>0.78 > Herb > 0.44</td><td>8</td></tr>
<tr><td>0.44 > Herb > 0</td><td>9</td></tr>
<tr><td>Herb = 0</td><td>10</td></tr>
</table>

Supplementary material Table 5. Environmental indicators: waste management theme.

Theme	*Indicator*	*Description of indicator*	*Scoring scale*	
Responsible management of by-products and waste	Methods for the management of production by-products and waste	Qualitative indicator that assesses the sustainability of the management of production by-products and waste at the level of agri-firms	In the scoring scale, different scores are assigned to the different measures adopted by the agro-food companies for the management of waste and by-products. The scores can be accumulated for each firm for a maximum of 10 points. Scoring scale:	
			Waste management method	Score
			Prevention and reduction (e.g. concrete plans and strategies at the firm level for the reduction of waste production)	6
			Preparation for re-use (e.g. animal feed)	5
			Recycling (e.g. compost)	5
			Other types of recovery (e.g. energy recovery)	4
			Disposal under controlled conditions	2
			Landfill / waste collection containers	0

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