The potential of Industrial Ecology in agri-food clusters (AFCs): a case study based on valorisation of auxiliary materials

Alberto Simboli[a], Raffaella Taddeo[a], Anna Morgante[a]

[a] *Department of Economic Studies, University "G. d'Annunzio", V.le Pindaro 42, 65127 Pescara, Italy.*

E-mail address: a.simboli@unich.it; r.taddeo@unich.it; morgante@unich.it

Simboli A., Taddeo r., A. Morgante (2015). The potential of Industrial Ecology in agri-food clusters (AFCs): A case study based on valorisation of auxiliary materials. Ecological Economics 111 65–75. ISSN 0921-8009.
https://doi.org/10.1016/j.ecolecon.2015.01.005

The potential of Industrial Ecology in agri-food clusters (AFCs): a case study based on valorisation of auxiliary materials

ABSTRACT

The location of agricultural activities in favourable geographic areas has led to the development of local agglomerations of companies, recognised as agri-food clusters (AFCs). AFCs are characterised by typical environmental problems such as changes in land use, CO_2 emissions, energy and water consumption, and chemical pollution. Recent technological changes in the agri-food industry have influenced the economic and social development of AFCs towards progressive industrialization. Such changes have also been the source of new environmental problems, such as those related to the large-scale use and disposal of auxiliary materials. Industrial Ecology (IE) proposes approaches and applied solutions to reduce the environmental impacts and improve the competitiveness of production activities. Major applications of IE in AFCs currently involve the valorisation of animal and vegetable by-products and scraps. Further improvements can be achieved by adopting IE-based solutions focused on auxiliary materials wastes. This article analyses the potential development of IE-based approaches in a representative Italian AFC. Empirical evidence shows that efficient solutions can be implemented through materials substitution, repair, and recycling, and by exploiting collaborative strategies among the agri-food and industrial companies established in the area.

Keywords: Agri-food Cluster; Industrial Ecology; Auxiliary Materials Wastes; Industrial Symbiosis; Repair; Agricultural Plastics

1. Introduction

Development of the agri-food industry is critical to the economy of many countries, as it has direct and indirect effects on public health and well-being and on economic growth and employment. Dominant food-system models in advanced countries are characterised by industrialised and intensive agriculture, market-oriented production, chemical dependence, intensive water and energy consumption, large-scale capital investment, and the presence of specialised corporations and organizations with low labour intensity (Senauer and Venturini, 2004). While those characteristics have allowed a consistent increase in the quantity and quality of production, they have had negative effects on the environment as a result of changes in land use, CO_2 emissions, energy and water consumption, and chemical pollution (Kroyer, 1995). In recent years, environmental and social issues have become an integral part of agricultural policy objectives (Mouysset, 2014). Renewed energy policies, climate shocks, and the ever-increasing demand for quality of life have contributed to the acceleration of this process. As a result, the goals for agricultural companies are first to produce healthy and wholesome foods, and second to contribute to environmental protection and sustainable development in agricultural regions (Fresco, 2009; Notarnicola et al., 2012). In addition, conservation of resources, materials reuse and recycling, and efficient use of by-products and wastes have become important aspects of agricultural sustainability (Pretty, 2008; Koohafkan et al., 2012).

At the local level, the spontaneous agglomeration of agricultural activities in favourable areas, has led to the development of systems of small, medium, and large-scale enterprises recognised as agri-food clusters (AFCs). Recent technological changes in the agri-food industry have influenced the development of AFCs towards a progressive industrialization. This process may represent an additional source of local environmental problems, related to the extensive use of auxiliary materials in different stages of the production chain (cultivation, conditioning, packaging, logistics and transportation activities). Such materials consist mainly of plastics but also include paper, cardboard, wood, and metals; despite their relevance, the potential for valorisation has not yet been widely studied.

Industrial Ecology (IE) proposes approaches and applied solutions for improving the socioeconomic and environmental performance of companies through more efficient management of material and energy flows. Major applications of IE-based solutions in the agri-food industry concern animal and vegetable by-products and scraps; few studies have focused on the use of auxiliary materials.

This article describes a study carried out in one of the most representative Italian AFCs, the Fucino upland in the Abruzzo region. The aim is to analyse the features of the AFC and the flows of auxiliary materials wastes, identifying solutions for their efficient management from an eco-industrial perspective. The next sections of the article describe the background of the study, present the research project, and the methods used. The following sections outline the empirical context in which the research was grounded and discuss the potential IE-based solutions identified. Finally, conclusions are drawn.

2. Plastic materials in the agri-food industry

Among auxiliary materials, those that generate the most severe environmental burdens are plastics, often defined as “agricultural plastics”. The main applications of agricultural plastics include film mulches, drip irrigation tape, row covers, tunnels, silage bags, hay bale wraps, plastic trays, pots, and containers. The most-used plastics are polyethylene (PE) and polypropylene (PP), followed by ethylene vinyl acetate (EVA), polyvinyl chloride (PVC), and to a lesser extent polycarbonate (PC) and polymethyl methacrylate (PMMA) (Orzolek, 2003).

Despite benefits that include earlier harvests, food conservation, less reliance on herbicides and pesticides, and frost protection, the increasing use of agricultural plastics also results in the production of large quantities of wastes. Official and reliable data on the use of agricultural plastics are sporadic or unavailable (Briassoulis et al., 2013). Data from 2007 show that agricultural plastics constitute approximately 2–5% of the total plastics consumed in the EU each year (EUPC, 2007). A rough estimate of the total amount of agricultural plastic wastes (APWs) produced in Italy is 210 kt/y (Briassoulis et al., 2010).

APWs are homogeneous and geographically concentrated and are generated at specific times of the year. These materials can be contaminated with pesticides, vegetation, and other organic materials; the contamination level depends on the type of application, the care taken during their use, and the removal practices and storage conditions. A relatively small proportion of APWs is currently recycled. A large proportion is buried in the soil, burned, or discarded in fields; such disposal has negative effects on the environment, food safety, and human health (e.g. landscape degradation, irreversible soil contamination, polluted or poor-quality food, and release of toxic substances including dioxins) (Briassoulis et al., 2010).

3. Industrial Ecology and the agri-food industry

IE can be considered as a conceptual framework for the study of relationships between industrial systems and the natural environment (Garner and Keoleian, 1995). The approaches and tools used in IE can operate at different levels (company, local, regional, supra-regional), with the aim of reducing environmental impacts at every stage of production and consumption. Many of these approaches focus on “closing the loop” of material flows and are based on recovery and recycling (Despeisse et al., 2012); others involve products and process design and technology, organisational and management strategies, and governmental operations (Frosch and Gallopoulos, 1989; Allenby, 1996; Ayres and Ayres, 1996; Erkman, 1997). Approaches that involve communities of co-located companies generally are based on the concept of Industrial Symbiosis (IS). IS focuses on the synergistic or collaborative management of material and energy flows. IS-based solutions may concern the use of wastes, scraps and by-products of a production process as raw materials for another process, and also the sharing of utilities and services (Ehrenfeld and Gertler, 1997; Chertow, 2000; Mirata and Emtairah, 2005). The adoption of IE-based solutions in AFCs takes place through initiatives aimed at the valorisation of vegetable by-products and scraps derived from selection, pruning, harvesting, and conditioning/processing activities (Table 1). Some

IE-based initiatives in the agri-food industry have given rise to so-called Agro-Eco-Industrial Parks (AEIPs) (Lowe, 2001).

Table 1

Examples of IE-based solutions in the agri-food industry.

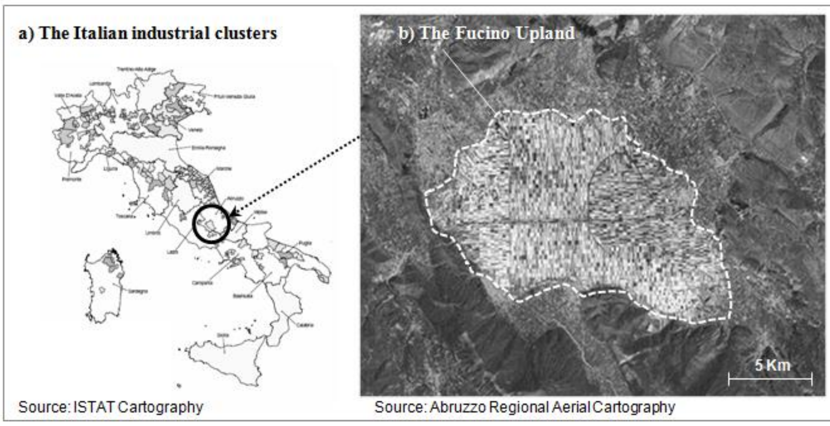
As the contributions show, there is still no a reference model for the development of IE-based solutions in the agri-food industry. They are strongly influenced, as usual in the IE studies, by the characteristics of the context in which they will be implemented (Boons and Baas, 2006; Doménech and Davies, 2011; Simboli et al., 2014).

4. Project description

4.1 The analytical context: the Fucino upland

The Italian agri-food industry is an important pillar of the national economy; agri-food activities are responsible of the 16% of the national gross domestic product (close to 250 billion Euros), and the agri-food chain provides 7.4% of total Italian exports (Federalimentare, 2011). The sixth General Agricultural Census (Istat, 2010) recorded 1,620,884 farms with an average size of 7.9 ha of utilised agricultural area (UAA). Over time, the progressive spatial concentration of agricultural activities was accompanied by increasingly specialised processes (Istat, 2010). In many cases, more than 50% of value-added domestic production is contributed by a single agricultural product (e.g. milk, red meat, poultry, fruit, vegetables) and is concentrated in a few provinces (Brasili, 2003).

The Fucino upland (in the Abruzzo region), in which the present analysis was conducted, is a representative AFC at the national level (Fig.1a). The Fucino upland (700 m a.s.l.) consists of a drained wetland basin of nearly 16,000 ha that is named for the karst Lake Fucino, formerly the third-largest lake in Italy. Because of its irregular water level, Lake Fucino was subjected to long-lasting drainage that ended in 1942. Drained land was allocated to farmers in lots of 1–4 ha, which resulted in fragmented plots that still characterise the area (Fig.1b) and in the establishment of a large number of small and medium-sized enterprises in a geographically restricted area. Vegetable crops are most common in this area; the main crops are potato, carrot, fennel and lettuce (Fig.1c). Industrialization of the Fucino upland has taken place over the last 50 years. The process of industrialization can be attributed to two main causes: first, incentives and tax benefits which, during the '60, led to the establishment of some large companies operating in the metalworking and electronic industries; second, the presence of the agri-food settlement, which has gradually promoted the birth of companies involved in the production and maintenance of agricultural machineries, transformation and conditioning of the agri-food products and production and commercialization of auxiliary materials.



c) The main crops produced

CROP	ha
Corn	975
Potato	4378
Grass	381
Carrot	2303
Lettuce	1660
Other	3387

Fig. 1. Italian industrial clusters, the Fucino upland, and the main crops grown.

4.2 General aims of the project

The exploratory research presented here was developed from 2011 to 2013 as part of a multi-year study designed to investigate potential solutions for the valorisation or revitalisation of local industrial networks and clusters. The specific objective is to identify the most suitable IE-based solutions, considering the context, the auxiliary materials wastes produced and their potential synergistic management. This research did not consider animal or vegetable waste flows and by-products.

4.3 Research design and methods

The research used qualitative and quantitative methods and was structured according to the following phases:

i) *Preliminary desk analysis*

A review of the international literature on IE-based solutions and their development in AFCs was conducted. The keyword research was performed using the following words and related synonyms: *agri-food industry*, *agri-food clusters*, *sustainable agriculture*, *agricultural plastics*, *Industrial Ecology*, and *agro-eco-industrial park*. A historical, geographic, and economic analysis of the Fucino upland was also conducted using website materials and secondary literature on regional and local economic geography.

ii) *On-site survey*

The survey was developed in collaboration with the provincial Association of Agricultural Producers and a local waste management platform. The Association supports companies in selecting their annual crop plans and in performing other management practices, including operational procedures for wastes. In accordance with Heeres et al. (2004), the survey was structured to gather the following information about the Fucino AFC:

- General data about the agri-food companies located there (number, size, location, number of employees, certifications);
- Typical agricultural and production/transformation processes developed;
- Summary of annual auxiliary material wastes produced and related management practices.

In the first part of the survey, general information and descriptive data were collected through face-to-face non-structured interviews with the head of the Association, followed by semi-structured interviews with the technical staff by telephone or e-mail. The technical staff also provided support in the identification of a representative sample of companies. The parameters considered were average size, crops produced, and processes performed. Twenty-three companies were included in the survey (11.6% of those registered at the provincial Association of Agricultural Producers). Quantitative production data were obtained from crop plan databases; data related to auxiliary materials were obtained from environmental declaration forms that detailed the quantity of wastes produced by each agricultural company. Data were collected for the 2011 crop year.

The considerable homogeneity of products, processes, and organisations that typically characterise AFCs such as the Fucino upland, enables accurate estimation and minimisation of problems associated with land fragmentation and the difficulty of collecting reliable data in rural contexts. The local waste management platform provided additional data and descriptive information on current practices and destinations of waste flows of auxiliary materials. Three representative production sites were also examined to collect data about agricultural and transformation processes, products, farming and production practices, and characteristics and suppliers of auxiliary materials used. Data were processed to determine the main activities performed in the Fucino AFC and to identify the qualitative and quantitative characteristics of primary material flows. The results were used to define the most suitable IE-based solutions for this context. At the end of the project, the results and identified solutions were presented to representatives of the organisations involved; the feedback thus acquired was used to assess the potential and limits of these solutions.

5. Features of the context: current state

This section includes information about production processes, material flows, and existing relationships among the agri-food companies located within the Fucino AFC. Data provided by the provincial Association of Agricultural Producers showed that more than 2,200 farms were registered at the provincial Chamber of Commerce in 2011, many of which were “micro family companies”. Among these, 330 were considered “structured” companies, equipped with a dedicated plant, a set of agricultural machinery, and external employees. Table 2 summarises the main categories of the structured companies settled in the Fucino AFC, classified by land area.

Table 2

Characteristics of agri-food companies located in the Fucino AFC.

The typical agronomic processes detected were: seeding, land preparation, transplanting, treatment and irrigation, and harvesting. Some crops, such as carrots and lettuce, also require a washing step before packaging. These processes were considered in building a referential model for the study. Land-preparation activities are usually performed from February to March, seeding and transplantation occur between March and April. The soil and climatic conditions of the area are conducive to one harvest period (June–August) for annual crops, and two harvests (May–June and September–October) for seasonal crops.

Most of the small and medium-sized companies sell their products to fresh markets or to larger companies that process the crops (Table 2). Crop-processing companies in the Fucino upland include: one plant that produces juices and carrot puree; one plant that produces frozen potato dumplings and pies; one plant that produces pre-fried and frozen potato sticks, frozen cubes of potatoes for soups, pre-fried potato wedges, and potato flakes. A sugar factory that processes all beets produced in the area is currently undergoing restructuring, and a mid-sized gas power plant is attached to this factory.

The main categories of auxiliary materials waste flows produced by the agri-food companies are shown in Table 3.

Table 3

Auxiliary materials wastes produced annually by agri-food companies in the Fucino upland (data from the 2011 crop year).

Observed APWs (classified according to the European Waste Catalogue – EWC) include:

i) *Plastic packaging* - EWC 15.01.02 (PE, PP, high density polyethylene [HDPE], polystyrene [PS]): seed trays; bags for seed, fertiliser, and feed; fruit boxes; nursery containers; other containers (bins); and reclaimed phytosanitary containers.

ii) *Non-packaging plastic wastes* - EWC 02.01.04 (PE, PVC, PP): sheet mulching, irrigation pipes, hoses, plastic sheeting for greenhouses.

iii) *Mixed packaging* - EWC 15.01.06 (PE, PP, HDPE): bags for seed, fertiliser, and feed; fruit boxes; nursery containers; other containers (bins); reclaimed phytosanitary containers.

The companies were also asked to associate the various wastes with specific production stages. The temporal distribution of the waste flows showed regular trends (Table 4) that were consistent with the findings of Briassoulis et al. (2010). These trends should facilitate the efficient waste collection and management.

Table 4

Flows of auxiliary materials and production phases for major crops in the Fucino AFC.

Considering the high degree of homogeneity of the agricultural processes and wastes, a rough estimate of the quantity of wastes produced in a crop year was performed according to Briassoulis et al. (2013). The estimate has been obtained by standardizing the wastes of the sample companies (Table 3) to the land area allocated to different crops within the AFC by the 330 structured companies, according to the relationship between waste materials and agricultural phases (Table 4). The estimates were as follows:

- >27,000 kg of sheet mulching;
- >840,000 kg of films and packaging;
- >15,000 kg of damaged boxes and pallets;
- >75,000 kg of scrap iron and steel;
- >46,000 kg of other packaging materials.

Most of the companies managed their wastes by using authorised external companies specialised in collection and storage. In some cases, suppliers take back discarded products at their end-of-life. However, some wastes were abandoned (e.g. pallets and damaged PE containers) or burned in fields (pallets and wooden boxes). There are currently no companies in the Fucino upland that specialise in treatment, recovery, and recycling of auxiliary materials wastes. Thus, most of these wastes are treated outside of the area, which has negative economic and environmental repercussions.

6. Results and discussion

The most significant elements emerged from the analysis of the context that argue in favour of a more efficient management of the auxiliary materials wastes produced are the following:

- High volume and homogeneity of easily recyclable materials (plastic, paper and cardboard, metal, wood);
- Low volume of hazardous materials;
- Seasonality of agricultural activity that may favour the development of complementary activities and businesses;
- Limited geographical extent that enables transportation and waste-handling impacts to be reduced.

The following section describes proposed solutions, formulated both as a single plant and collective measures, highlighting their potentials and limits. These solutions were identified using waste management hierarchy principles (Directive 2008/98 EC) according to contextual relevance and degree of novelty. For those considered the most promising, environmental and economic aspects have been further investigated. These solutions exclude hazardous materials, for which reclamation prior to disposal is mandatory.

6.1 Identified solutions: potential and limits

A. Single-plant solutions

This first set of solutions includes alternative options for more efficient management activities that exploit benefits derived from new and alternative materials or maintenance techniques. These solutions can be implemented by individual companies, do not require large investments, and can be developed immediately.

A1) *Materials substitution.* Materials substitution is a preventive measure that can be applied to all auxiliary materials for which there is an option for reducing the environmental impacts of production, use, and disposal. This solution is primarily relevant to biopolymers that can be used as pots for plants, as mulching or solarising films, as peat bags, as ribbons, and as materials that mediate fertiliser release. The biodegradability of biopolymers can reduce wastes and consumption of fossil fuels and other materials required for generating virgin plastics (Kasirajan and Ngouajio, 2012). In the Fucino upland, the strongest potential application of biopolymers is related to the use of PP mulching sheets. Currently, at end-of-life, these sheets are collected, stored, and after transferred to treatment plants outside the area with high costs and environmental risks related to their detention and transportation. The current cost of disposal is approximately 0.090 €/kg. This solution could thus help to limit a major problem in agricultural waste management related to the cost and difficulty of treating dirty sheet mulching, and could promote the diffusion of innovative materials for applications such as packaging or materials handling. However, the use of biopolymers as mulching sheets has not yet been approved by farmers because of higher materials costs (more than 30% higher than the cost of PP sheets) and lack of confidence in their effectiveness. Farmers’ concerns about biopolymers include uncertainty about their decomposition in cold climates, and their potential release of organic compounds, fertilisers, and pesticides during decomposition. Therefore, this solution was not investigated further.

A2) *Repair*. Repair has been considered for materials that can have an extended life cycle beyond the normal period of use. This is a less practiced solution because of technical, regulatory, aesthetic, and functional challenges (King et al., 2006); however, the characteristics of some materials and product uses can make repair feasible. This is true for auxiliary agricultural equipment that does not need to meet aesthetic requirements. The repair solution was considered for agricultural containers (bins) used to collect, store, handle, and transport products to processing plants. These containers consist of 35–40 kg of homogeneous plastic materials (PE or HDPE), and at end-of-life (which typically occurs for breakings) they are usually collected for recycling or incineration. Approximately 70% of waste containers are considered reusable. The average price of the typical container used in the Fucino upland is ~200 €; approximately 16,000 containers are disposed of annually in this area.

The repair option is a novel and more efficient end-of-life management practice for containers and represents an effective solution for the AFC analysed. Therefore, it was decided to evaluate its technical feasibility and potential environmental benefits. A survey identified a company located ~70 km from the Fucino upland that was dedicated to the repair of plastic products (mostly garbage cans and industrial containers consisting of PE, HDPE, and PP). The company was contacted in order to obtain data for a pilot test, which was performed under the assumption that repair of damaged containers results in the same functionality as new containers and thus avoids their replacement. The average cost of a repair is approximately 10% of the price of a new container, the economic benefits can be therefore relevant. A comparative screening analysis based on life cycle assessment (LCA) methodology (ISO 2006a, 2006b) was developed to compare the environmental benefits of repair with current practices of recycling and incineration. Results indicate that the effectiveness of the repair solution could lead to an environmental impacts reduction of up to 30% compared to recycling and up to 50% compared to incineration in respect of the performance indicators used (see Appendix A). Widespread implementation of repair would avoid the impacts of production and disposal of large plastic products. Some agri-food companies are beginning this practice, which indicates that there is strong opportunity for developing this solution. The existing container-repair company might be interested in establishing a plant in the Fucino AFC. The major concerns relate to the performance of repaired containers over time and to the aesthetics of repaired products.

B. Collective solutions

Collective solutions exploit the large, homogenous mass of auxiliary material wastes produced in the Fucino AFC for which efficient management practices are not currently available. These solutions require a higher level of organisation and complexity compared to materials substitution or repair. Collective solutions involve a number of companies in the more efficient management of waste flows following IS-based approach. The IS approach can incorporate synergies within individual supply chains or from shared use of utilities and local use of by-products, energy, or wastes (Chertow, 2004; Van Berkel, 2004). Literature recognises some pre-existing contextual factors related to the development of IS-based solutions (Lowe, 1997; Roberts, 2004; Sakr et al., 2011; Tudor et al., 2007); they are also known as key drivers (Taddeo et al., 2012; Simboli et al., 2014). Table 5 summarises the most relevant of these factors.

Table 5

Contextual factors (key drivers) considered.

Regarding technical requirements, data collected show that the Fucino AFC is in a good geographic position. A railroad ensures good connectivity, and the nearest airport and commercial port are located less than 100 km from the cluster. The scale of the analysis refers to a “meso”-level context. With the exception of the gas power plant that fuels the sugar refinery, there are no energy facilities close to the network that feed into the electric grid. No synergistic activities related to heat recovery were recognised, but a feasibility study for the establishment of a biogas energy plant is underway.

In Italy, regulatory limits prohibit companies (unless authorised) from directly managing or using scraps, wastes, and by-products from other companies. These restrictions force the involvement of companies that are officially allowed to perform pre-treatment activities in the development of collective solutions. This makes it difficult to develop internal relationships and reduces the economic efficiency of the symbiotic solution.

Social aspects (communities and stakeholders) are a critical element in the development of IS. The support of local stakeholders can be considered in the design stage. Community consensus must be also managed in the long-term development of the IS because it is essential to building a culture for sustainable local development. In this case study, external support provided by stakeholders (especially the provincial Association of Agricultural Producers) facilitated the collection of technical and economic data and helped to identify potential sources of project criticalities. Support from stakeholders suggested interest and an open attitude about the project. No coordinating body or key individual was identified.

On-going debate in the literature confirms that homogeneity of processes is a complex issue in managing the development of an IS. The establishment of material exchanges (symbioses) among companies can be achieved only if “offers” (outputs) and “demands” (inputs) of scraps, by-products, or wastes can be integrated within a cluster; otherwise, the applicability of collective or synergistic solutions must be evaluated. The high degree of homogeneity of processes and materials that characterises AFCs composed of only agricultural farms favours the development of solutions related to crop wastes and by-products (section 3) but severely limits the possibilities for input/output exchange of auxiliary materials. The increased variety of companies settled as a result of industrialization of AFCs, as in the Fucino upland, may broaden the opportunities in this direction. Two IS-based solutions that are considered suitable for the Fucino upland are described below.

B1) *Development of a common local recycling platform*. Currently, about 35–40% of APW produced in the Fucino AFC is recycled. The lack of companies engaged in recycling activities and the cost and impacts of the current external treatment of plastics make this an economic and environmental priority. The development of a local platform for the recovery and recycling of auxiliary materials could enable establishment of a plant that would produce additional social benefits (wealth and employment) for the area. Considering regulations concerning the use of recycled materials for food packaging (EC 282/2008), additional potentials include the creation of agricultural support devices (e.g. sewage drain pipes, greenhouse materials) or secondary logistics devices (e.g. road signs). Findings of the survey revealed factors that could limit the adoption of this type of solution. First, the collected wastes must be properly sorted, separated, and (if necessary) washed, or reclaimed to ensure effective recycling. This is especially true for APWs, which are typically contaminated by soil, crop residues, pathogens, and pesticide and fertiliser residues. Therefore, recycling of agricultural plastics is still considered by companies to be complex and expensive. Second, the scale of investment required for the construction of storage facilities, treatment, and recovery/recycling, combined with a lack of support or incentive from local authorities, represent a criticality.

B2) *Involvement of other industries*. Investigation of the second solution was based on extension of the study to include non-agricultural companies in the Fucino upland. An additional survey was performed based on data obtained from the online database of the provincial Chamber of Commerce. A number of industrial plants that were considered relevant for this project have developed recently in the Fucino upland. Most of these plants support the agri-food and food-processing companies. Figure 2 shows the locations of these companies and the activities they perform.

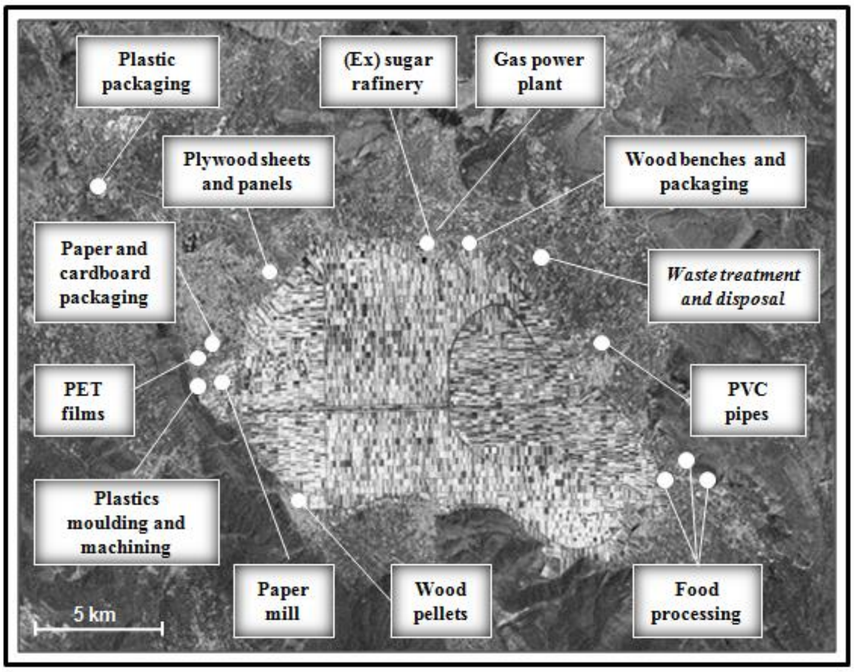


Fig. 2. Non-agricultural industrial activities located in the Fucino upland.

Some of the most promising companies were contacted to evaluate their willingness to receive waste flows of auxiliary materials as inputs for their production processes. These companies included:

- a *paper mill* that currently buys wastepaper from outside the Fucino upland and that would be interested in receiving paper and cardboard wastes that are currently stored and disposed of outside the area;
- a company that produces *PVC sewer pipes* and that would be willing to use a percentage of plastic wastes in addition to virgin materials;

- a company that produces *pellets* and *plywood panels* and that would be interested in wood and cardboard wastes.

Further synergetic relationships can be investigated matching all the inputs and outputs of materials and energy of the industrial companies located in the area.

Part of the products obtained may be used as supplies for agricultural facilities, for the realization and the maintenance of sewers and drainage ditches within the area and for the heating of local settlements. The establishment of these types of synergies would provide economic and environmental benefits related to reduced disposal costs for farms, reduced costs and impacts of transportation, and reduced use of virgin materials. The strongest benefit is related to the use of by-products and scraps as feed sources, which would require no additional investment. The major limits to implementing IS-based solutions expressed by companies were related to regulatory issues, which require intermediaries for pre-treatment of wastes and which will increase the complexity and costs of solutions, and the low level of differentiation and separation of wastes, which can lead to contamination of secondary raw materials.

An additional challenge to implementing the proposed IE-based solutions is related to the presence of micro-scale and family companies. This aspect could lead to increased costs of collection and selection of materials and make it difficult to define procedures and strategies. The most suitable IE-based solutions for efficient and synergistic management of auxiliary materials wastes are summarised in Figure 3, which illustrates process steps and activities flows. The solid lines represent flows that already exist in the current state of the AFC; the dashed lines represent flows related to the solutions proposed.

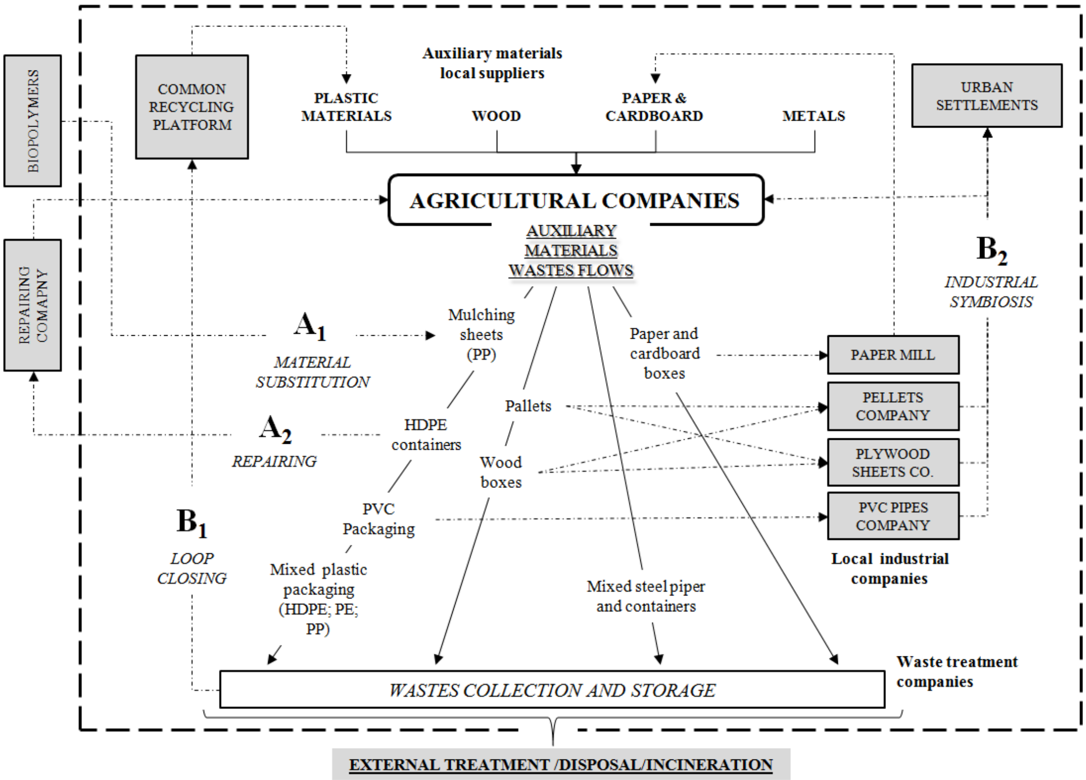


Fig. 3. Summary schematic of the solutions proposed.

7. Conclusions

Although major applications of IE-based solutions in AFCs involve the valorisation of animal and vegetable by-products and scraps, this case study shows that additional solutions are possible for the efficient management of auxiliary materials wastes. The context in which the exploratory analysis was conducted—the Fucino upland in the Abruzzo region—is one of the most representative Italian AFCs. More than 2,000 farms are located in this area, and approximately 300 of these are structured companies. Data collected from a sample of these companies show that a large amount of auxiliary materials wastes are derived from agronomic and conditioning/processing activities.

These wastes are mostly agricultural plastics (HDPE, PP, EVA, PVC, and PC) that are used as film mulches, drip irrigation tape, row covers, tunnels, silage bags, hay bale wraps, containers, trays, and pots. Other materials include paper, cardboard, wood, and metals. These wastes are currently collected and stored within the AFC and are periodically transported outside of the AFC for treatment and disposal. Cases of abandonment or burning of materials wastes were also observed. Current management practices are sources of economic and environmental inefficiencies. The high volume and homogeneity of easily recyclable wastes, low volume of hazardous materials, seasonality of agricultural activities, and limited geographical extent of the AFC favour a more detailed investigation from an eco-industrial perspective.

Single-plant and collective solutions based on materials substitution, extension of product life cycle (through repair), closing the loop (through an on-site common recycling platform), and IS were identified. Limitations were observed for substitution (e.g. the use of biopolymers rather than PP for mulching sheets) and development of a common recycling platform. They especially concern a lack of confidence in the use of innovative materials and the scale of investment required.

The solutions considered to have the greatest potential were the repair solutions and the IS. The first was discussed in respect to the PE and HDPE containers: their weight, the homogeneity of materials, the specific use, that does not need significant aesthetic requirements, makes it feasible and innovative in the agri-food industry. The results of a screening LCA confirmed the environmental benefits that would be produced by repair of PE and HDPE containers compared to current recycling and incineration practices. IS can also be considered an innovative solution for the management of auxiliary materials in the Fucino AFC. We observed the presence of technical factors (key drivers) that are required for the development of an IS, and the availability of companies that could use auxiliary materials wastes to feed their processes. These companies included a paper mill, a producer of PVC pipes, and a producer of pellets and plywood panels. These synergies became apparent after extending the investigation to include all the companies established in the area during its industrialization stage. Thus, industrialization, which historically has been considered a source of environmental impacts in agricultural contexts, has proven to be one of the condition for the development of more efficient waste management strategies. Current regulatory constraints, fragmentation, and the limited size of agricultural companies have emerged as major limits to the development of collective solutions in the Fucino upland.

The analysis presented here provides useful insights for the field of IE. Firstly it contributes to further clarify the dynamics of use of auxiliary materials in AFCs and the management practices of the related wastes. In addition, findings confirm the unrealised potential of existing AFCs to develop more efficient waste management solutions, and they emphasise the need for a multidisciplinary, context-based perspective in IE studies. The next stages of our research will include feasibility studies of solutions that were identified as promising. A more detailed map of input and output flows will be necessary in order to verify additional sources of synergies among companies that could lead to the development of IS-based solutions. This study can be further refined by improving the use of integrated life-cycle-based approaches (LCA and life-cycle costing), mapping tools such as input–output or material/substance flow analysis, and tools for providing strategic decision-making frameworks to assess the identified solutions.

Appendix A. LCA screening study

Aims and scope

The aim of the LCA screening study was to assess, from an environmental standpoint, the repair solution as an alternative option for end-of-life management of agricultural containers compared with the conventional options of plastic recycling and incineration. The repair solution was assessed for agricultural containers made of HDPE. Repairing involves the use of a blend of plastic materials and a process of heat welding. Repaired containers have the same features and operational properties as new products.

Description of the product-system

The system boundaries extend from the extraction of raw materials through the finished product for the three alternative options of recycling, incineration, and repair (cradle-to-cradle approach). The stages considered were:

Production: The containers used by the companies we sampled are produced by suppliers located between 350 and 400 miles away using an injection-moulding process; they are transported by articulated lorries with carrying capacity of 7.5–16 t. Each vehicle is operated at full load (130 containers).

Use: The theoretical average lifespan of a container was estimated by the companies as 10 years. However, as a result of damage, containers rarely reach the end of their technical useful life. On average, complete turnover of containers occurs at least twice in a 10-year period.

Conventional end-of-life solutions: Scraps are disposed of by specialised companies located within a 20-km radius. The scraps are stored and then transferred to external companies for recovery through incineration or mechanical recycling. The recycling and energy-recovery plants are located approximately 60 and 100 km, respectively, from the Fucino upland.

Repairing and end-of-life solution: Repair is made with a proprietary blend of ethylene polymers. The blend does not contain harmful substances, and all components are derived from virgin materials. Production of the blend involves melting, extrusion, cutting, and granulation phases. The repair process involves removal of an oxidation layer, welding, and drying. A typical repair uses a 150/200 g blend. Technical tests show that the condition of repaired products is comparable to that of new products, such that a container can undergo multiple repairs over time.

Figure A.1 describes the process units considered in the analysis, the source of data (measured or database), and the distance between the sites of production, use, and end-of-life.

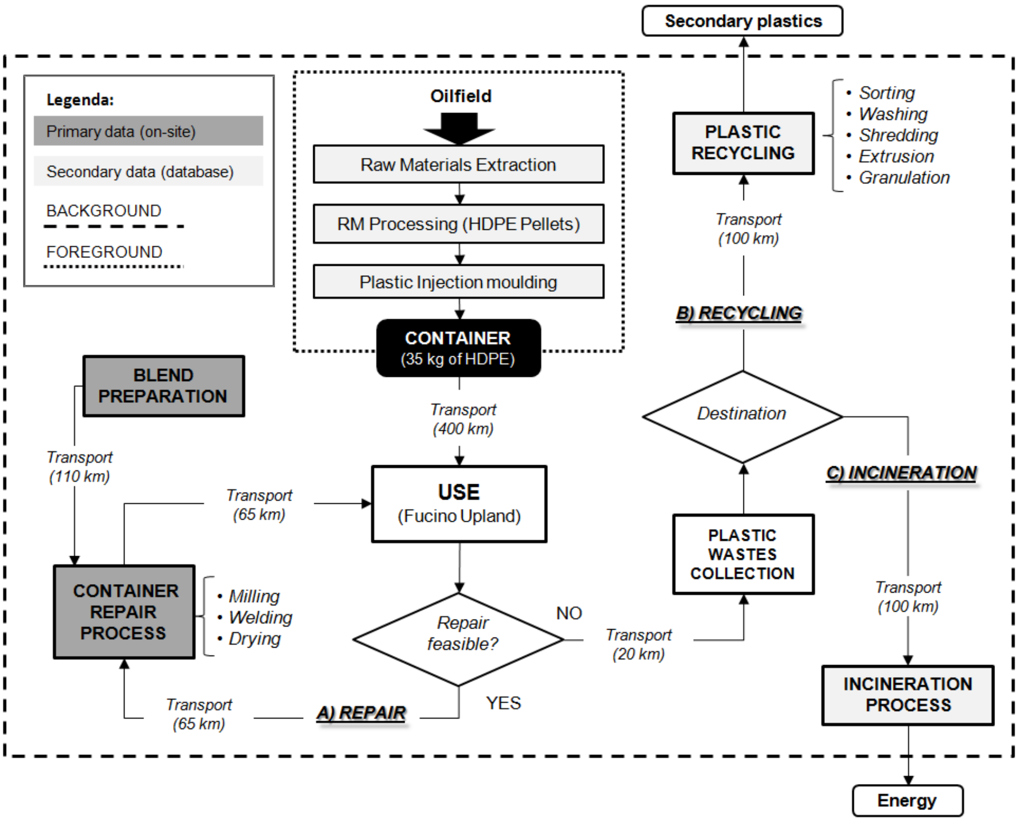


Fig. A.1: The product-system considered in the analysis.

Methods

The LCA study was based on ISO14040 series standards and other technical guidelines (European Commission, 2010; Weidema et al., 2004). The functional unit was defined as 10 years of use of the container. Damage was assumed to occur during the 5th year of use, and repair was assumed to use 150 g of blend welding. The reference flow was one 35-kg container made of homogeneous HDPE. Excluding repair processes (the data for which were collected on site in 2013), other life-cycle inventory (LCI) data were imported from LCA software and related databases. The LCIA method used was ReCiPe 2008 (Goedkoop et al., 2009). Data for inputs and outputs of the repair process were obtained using an inferential calculation based on annual production. The model considered both impacts of transportation and environmental credits associated with recycling and waste-to-energy solutions.

Results

The repair solution can reduce the total impacts considered in the LCIA method. In most of the indicators provided by the Recipe 2008 method these reductions range between 30 and 50% compared to the recycling solution. The benefits are even greater in the case of comparison with the solution of incineration (between 50 and 70%). The largest differences are found in the emission of any harmful substances (human toxicity; ionizing radiation; particulate matter) and in the use of land and resources depletion.

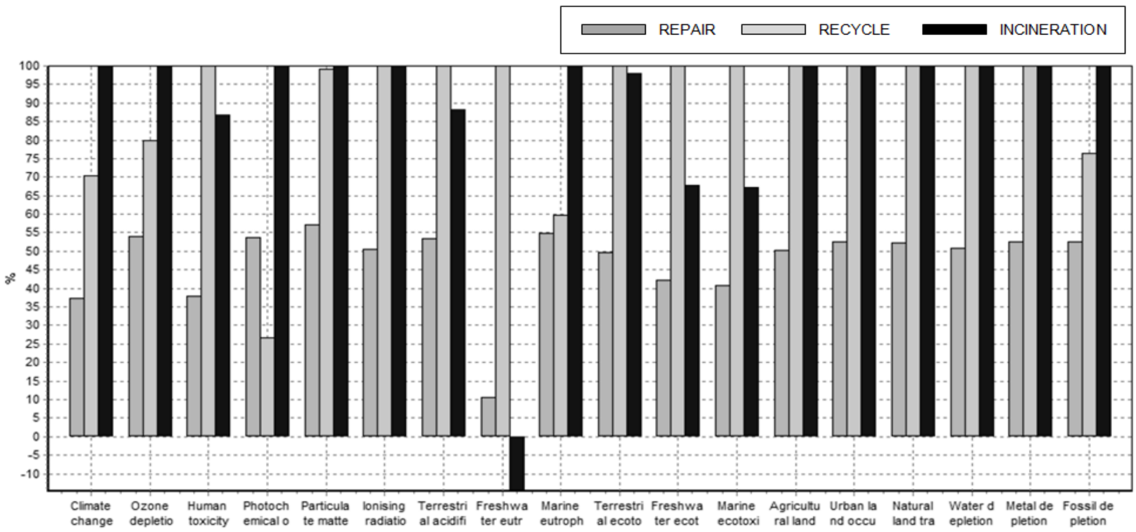


Fig. A.2: Environmental performance of three solutions expressed as a percentage in relation to the base alternative.

The LCA showed that, over 10 years of useful life, container repair can considerably reduce environmental impacts relative to conventional solutions. This is true when the repair leads back the container to conditions of use capable of producing a utility of use unchanged for the rest of its useful life. The positive performance is mainly related to the fact that it is not necessary to use a second container to cover the remaining five years of useful life (thus reducing impacts of production and transport). Another positive contribution derives from avoiding impacts related to treatment and recycling/waste-to-energy processes, although those impacts can be balanced by the generation of environmental credits. The repair company considered is located ~70 km from the Fucino upland; additional economic and environmental benefits could be achieved if this company were relocated within the area. These results encourage further investigation of the use of repair as an effective and eco-efficient alternative for end-of-life management of these products.

Appendix references

European Commission, 2010. International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance, first ed. Publications Office of the European Union, Luxembourg.

Goedkoop, M.J., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., Van Zelm, R., 2009. ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. First edition Report I: Characterisation. Available at: http://www.lcia-recipe.net. Accessed May 2013.

Weidema, B.P., Cappellaro, F., Carlson, R., Notten, P., Palsson, A., Patyk, A., Regalini, E., Sacchetto, F., Scalbi, S. 2004. Procedural guideline for collection, treatment and

quality documentation of LCA data. ENEA - Italian National Agency for New Technologies, Energy and the Environment, Bologna.

References

Abuyuan, A., Hawken, I., Newkirk, M., Willians, R, 1999. Waste equal food: developing a sustainable agriculture cluster for a proposed resource recovery park in Puerto Rico. Bulletin 106, Yale F & ES Bulletin, USA.

Alfaro, J., Miller, S., 2013. Applying Industrial Symbiosis to Smallholder Farms Modeling a Case Study in Liberia, West Africa. J Ind Ecol. 18, 145-154.

Allenby, B., 1996. A design for environment methodology for evaluating materials. Total Quality Environmental Management. 5, 69-84.

Authayanraksa, N., 2007. Environmental and techno-policy analysis of an agro eco-industrial network in Chachoengsao Province. Thesis Master of Science in Environmental Engineering and Management, Asian Institute of Technology, School of Environment, Resources and Development, Thailand.

Ayres, R.U., 1996. Creating industrial ecosystems: a viable management strategy. Int J Technol Manage. 12, 608-624.

Ayres, R.U., Ayres, L.W., 1996. Industrial Ecology: Towards closing the material cycles, Edward Elgar, Cheltenham.

Boons, F., Baas, L., 2006. Industrial Symbiosis in a Social Science Perspective. Discussion proposal for the Third Industrial Symbiosis Research Symposium, Birmingham.

Brasili, C., 2003. Efficiency of the italian agri-food industry: an analysis of “districts” effect. 25th International Conference of Agricultural Economists (IAAE), 16-22 August 2003 Durban, South Africa.

Briassoulis, D., Hiskakis, M., Babou, E., 2013. Technical specifications for mechanical recycling of agricultural plastic waste. Waste Manage. 33, 1516-1530.

Briassoulis, D., Hiskakis, M., Scarascia, G., Picuno, P., Delgado, C., Dejean, C., 2010. Labeling scheme for agricultural plastic wastes in Europe. Quality Assurance and Safety of Crops & Food. 2, 93-104.

Chertow, M. R., 2007. “Uncovering” industrial symbiosis. J Ind Ecol. 11,11-30.

Chertow, M.R., 2000. Industrial symbiosis: literature and taxonomy. Annu Rev Energ Env. 25, 313-337.

Chertow, M.R., 2004. Industrial Symbiosis, in: Cleveland, J.C., (Eds.), Encyclopedia of Energy. Elsevier Academic Press, New York, pp. 407-415.

Commission Regulation EC No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods and amending Regulation (EC) No 2023/2006.

Despeisse, M., Ball, P.D., Evans, S., Levers, A., 2012. Industrial ecology at factory level – a conceptual model. J Clean Prod. 31, 30-39.

Directive 2008/98/EC of the European Parliament and of the Councilof 19 November 2008 on waste and repealing certain Directives.

Doménech, T., Davies, M., 2011. The Role of Embeddedness in Industrial Symbiosis Networks: Phases in the Evolution of Industrial Symbiosis Networks. Business Strategy and the Environment. 20, 281-296.

Ehrenfeld, J., Gertler, N., 1997. Industrial Ecology in practice. The evolution of interdipendence at Kalundborg. J Ind Ecol. 1, 67-79.

Erkman, S., 1997. Industrial ecology: an historical view. J Clean Prod. 5, 1-10.

EUPC, 2007. Plastic for agriculture. Available at: http://www.plasticsconverters.eu/markets/agriculture. Accessed April 2013.

Federalimentare - Federazione Italiana dell'Industria Alimentare, 2012. L'agroalimentare Italiano. Available at: http://www.federalimentare.it/banche_dati.asp. Accessed June 2012.

Fresco, L.O., 2009. Challenges for food system adaptation today and tomorrow. Environ Sci Policy. 12, 378-385.

Frosch, R.A., Gallopoulos, N.E., 1989. Strategies for manufacturing. Sci Am. 261, 144-152.

Garner, A., Keoleian, G.A., 1995. Industrial Ecology: an introduction. University of Michigan, National Pollution Prevention Center for Higher Education, pp. 1-35.

Gibbs, D., Deutz, P., 2007. Reflections on implementing industrial ecology through eco-industrial park development. J Clean Prod. 15, 1683-1695.

Heeres, R.R., Vermeulen, W.J.V., de Walle, F.B., 2004. Eco-industrial park initiatives in the USA and the Netherlands: first lessons. J Clean Prod. 12, 985-995.

Hewes, A.K., Lyons, D.I., 2008. The humanistic side of eco-industrial parks: champions and the role of trust. Reg Stud. 42, 1329-1342.

ISO 14040. 2006a. Environmental management – Life cycle assessment – Principles and framework, International Organisation for Standardisation (ISO), Geneve.

ISO 14044. 2006b. Environmental management – Life cycle assessment – Requirements and guidelines, International Organisation for Standardisation (ISO), Geneve.

Istat - Istituto Nazionale di Statistica, 2010. 6º Censimento generale dell'Agricoltura. Available at: http://censimentoagricoltura.istat.it/index.php?id=73. Accessed November 2010.

Jensen, P.D., Basson, L., Leach, M., 2011. Reinterpreting Industrial Ecology. J Ind Ecol. 15, 680-692.

Kasirajan, S., Ngouajio, M., 2012. Polyethylene and biodegradable mulches for agricultural applications: a review. Agron Sustain Dev. 32, 501-529.

King, A.M., Burgess, S.C., Ijomah, W., McMahon, C.A., 2006. Reducing waste: repair, recondition, remanufacturing or recycle?. Sustain Dev. 14, 2457-267.

Koohafkan, P., Altieri, M.A., Holt Gimenez, E., 2012. Green Agriculture: foundations for biodiverse, resilient and productive agricultural systems. Int J Agric Sustain. 10, 61-75.

Kroyer, G.T., 1995. Impact of food processing on the environment – an overview. LWT - Food Science and Technology. 28, 547-552.

Lowe, E.A., 1997. Creating by-product exchanges: strategies for eco-industrial parks. J Clean Prod. 5, 57-65.

Lowe, E.A., 2001. Eco-industrial Park Handbook for Asian Developing Countries: Report to Asian Development Bank, Indigo Dev. Co, Oakland.

Martin, M., Eklund, M., 2011. Improving the environmental performance of biofuels with industrial symbiosis. Biomass Bioenerg. 35, 1747-1755.

Mirata, M., Emtairah, T., 2005. Industrial symbiosis networks and the contribution to environmental innovation: the case of the Landskrona industrial symbiosis programme. J Clean Prod.13, 993-1002.

Mol, A.P.J., Dieu, T.T.M., 2006. Analysing and governing environmental flows: the case of Tra Co tapioca village, Vietnam. NJAS-Wagen J Life Sc. 53, 301-317.

Mouysset, L. 2014. Agricultural public policy: Green or sustainable?. Ecol Econ. 102, 15-23.

Niutanen, V., Korhonen, J., 2003. Industrial ecology flows of agriculture and food industry in Finland: utilizing by-products and wastes. Int J Sust Dev World. 10, 133-147.

Notarnicola, B., Hayashi, K., Curran, M.A., Huisingh, D., 2012. Progress in working towards a more sustainable agri-food industry. J Clean Prod, 28, 1-8.

Orzolek, M. D., 2003. Plasticulture in North America. Plasticulture. 122, 33-47.

Özyurt, D. B., Realff, M. J., 2002. Combining a Geographical Information System and Process Engineering to Design an Agricultural-Industrial Ecosystem. J Ind Ecol. 5, 13-31.

Pretty, J., 2008. Agricultural sustainability: concepts, principles and evidence. Philos Tr Soc B. 363, 447-465.

Reniers, G., Dullaert, W., Visser, L., 2010. Empirically based development of a framework for advancing and stimulating collaboration in the chemical industry (ASC): creating sustainable chemical. J Clean Prod. 18, 1587-1597.

Roberts, B.H., 2004. The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study. J Clean Prod. 12, 997-1010.

Sakr, D., Baas, L., El-Hagger, S., Huisingh, D., 2011. Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context. J Clean Prod. 19, 1158-1169.

Schwab Castella, P., Massard, G., Erkman, S., Blavot, C., 2007. Agro-Industrial Symbiosis and Population's Living Condition Improvement in North Nigeria. Conference proceedings of the 4th International Conference of the International Society for Industrial Ecology "Industrial Ecology for a Sustainable Future", Toronto, Canada, 17-20 June.

Senauer, B., Venturini, L., 2004. The globalization of food systems: A conceptual framework and empirical patterns. Working Paper 05-01. The Food Industry Center University of Minnesota.

Simboli, A., Taddeo, R., Morgante, A., 2014. Analysing the development of Industrial Symbiosis in a motorcycle local industrial network: the role of contextual factors. J Clean Prod. 66, 372-383.

Sterr, T., Ott, T., 2004. The industrial region as a promising unit for eco-industrial development reflections, practical experience and establishment of innovative instruments to support industrial ecology. J Clean Prod. 12, 947-965.

Taddeo, R., Simboli, A., Morgante, A., 2012. Implementing eco-industrial parks in existing clusters. Findings from a historical Italian chemical site. J Clean Prod. 33, 22-29.

Tudor, T., Adam, E., Bates, M., 2007. Drivers and limitations for the successful development and functioning of EIPs (eco-industrial parks): a literature review. Ecol Econ. 61, 199-207.

Van Berkel, R., 2004. Industrial Symbiosis in Australia: An update on some developments and research initiatives, in: The Industrial Symbiosis Research Symposium at Yale: Advancing the Study of Industry and Environment. Yale School of Forestry & Environmental Studies, New Haven.

Table 1
Examples of IE-based solutions in the agri-food industry.

Author	Year	Title	Journal	Major concept
Abuyuan et al.	1999	Waste equals food: developing sustainable agriculture cluster for a proposed resource recovery park in Puerto Rico.	Bulletin 106, Yale F & ES Bulletin	Residues from agricultural activities are used to generate products such as biogas, fibre, and nutrient-rich liquid fertiliser. These products may be used as inputs for paper mills and as nutrients for farmland.
Özyurt and Realff	2002	Combining a geographical information system and process engineering to design an agricultural-industrial ecosystem.	Journal of Industrial Ecology	Peanut hulls are a potential feed stream for an industrial complex based on biomass.
Niutanen and Korhonen	2003	Industrial ecology flows of agriculture and food industry in Finland: utilizing by-products and wastes.	International Journal of Sustainable Development & World Ecology	Manure is used as fertiliser and as an energy source.
Mol and Dieu	2006	Analysing and governing environmental flows: the case of Tra Co tapioca Village, Vietnam.	Wageningen Journal of Life Sciences	Fibrous residues and pulp are used as animal feed and fertiliser or in alcohol production. Tapioca wastewater is re-used to produce biogas and is used in aquaculture and irrigation.
Schwab Castella et al.	2007	Agro-industrial symbiosis and population's living condition improvement in North Nigeria.	The 4th International Conference of the International Society for Industrial Ecology "Industrial Ecology for a Sustainable Future", Toronto, 2007	Biomass from cotton, jatropha, and sunflower is used as fuel for a cement factory.
Authayanraksa	2007	Environmental and Techno-Policy Analysis of an Agro Eco-Industrial Network in Chachoengsao Province.	Thesis Master of Science in Environmental Engineering and Management, Asian Institute of Technology, School of Environment, Resources and Development, Thailand	Rice-based material flows are used for the development of an agro eco-industrial network.
Martin and Eklund	2011	Improving the environmental performance of biofuels with industrial symbiosis.	Biomass & Bioenergy	Bioenergy symbiosis (e.g. stillage from the ethanol industry) is made into fodder and used to produce biogas.
Alfaro and Miller	2013	Applying Industrial Symbiosis to Smallholder Farms - Modeling a Case Study in Liberia, West Africa.	Journal of Industrial Ecology	Animal feed is derived from rice production, methane is obtained from manure, and biogas digestate is used as fertiliser.

Table 2
Characteristics of agri-food companies located in the Fucino AFC.

Size category	Proportion of total, by number (%)	Land area	Typical activities
Small	40%	4–5 ha	Cultivation for their own consumption; sale to processing centres
Medium	30%	15 ha	Cultivation and sale to processing centres, fresh markets, farms
Large	25%	50 ha	Cultivation and processing (washing, conditioning, or packaging)
Extra large	5%	Up to 100 ha	

Table 3
Auxiliary materials wastes produced annually by agri-food companies in the Fucino upland (data from the 2011 crop year).

Auxiliary materials	kg/y	Current destination
Mulching sheets (PP and nonwoven)	1903	Disposal
Films and packaging (PE, HDPE, PS)	58841	Disposal
Boxes and pallets (wood)	1100	Internal heating
Mixed packaging (plastics, paper, cardboard)	3275	Disposal/external recycling
Tires	4520	Disposal /external recycling/waste to energy
Iron and steel scraps	5400	External recycling
Used oils*	2200	Mandatory consortium for used oils
Spent oil filters*	176	Mandatory consortium for used oils
Spent batteries*	115	Treatment and disposal
Septic sludge*	8980	Treatment and disposal
Mixed packaging* (containing residues of hazardous substances)	432	Treatment and disposal
Other mixed materials* (containing residues of hazardous substances)	95	Treatment and disposal

*Special and/or hazardous waste. Abbreviations: PP, polypropylene; HDPE, high-density polyethylene; PS, polystyrene.

Table 4
Flows of auxiliary materials and production phases for major crops in the Fucino AFC.

<table>
<tr><th></th><th>Seeding and planting (greenhouse)</th><th>Seeding and transplanting (fields)</th><th>Treatment and irrigation</th><th>Harvesting</th><th>Washing and packaging (conditioning)</th></tr>
<tr><td>Salad greens (lettuce, endive, radicchio)</td><td>Scraps of cover sheets; nursery containers used (PS and PVC)</td><td>Scraps of seed trays; bags used for fertilisers; scraps of tubes (PS, PE, PVC)</td><td rowspan="4">Bags for seeds and fertilisers; phytosanitary containers; nylon and nonwoven mulch; scraps of tubes (PP, PE, HDPE, PVC)</td><td rowspan="4">Bins and containers damaged during collection and handling stages (HDPE)</td><td>Damaged boxes (PE and HDPE)</td></tr>
<tr><td>Carrots</td><td>–</td><td rowspan="3">Bags for seeds and fertilisers; waste tubes and irrigation hoses (PE, HDPE, PVC)</td><td>Scraps of bags, trays, and film (PE and PS)</td></tr>
<tr><td>Fennel</td><td>–</td><td>Scraps of wooden boxes; trays (wood and PS)</td></tr>
<tr><td>Potatoes</td><td>–</td><td>–</td></tr>
</table>

Table 5
Contextual factors (key drivers) considered.

KEY DRIVER	Description	References
i) Geographical and technical requirements of the site.	These include strategic location, availability of resources, and the presence of utilities within the industrial site.	Chertow 2000; Hewes and Lyons, 2008; Jensen et al., 2011; Roberts, 2004
ii) Regulatory system.	Environmental legislation and standards in line with the principles of IE are critical factors to supporting the engagement of companies in a given area or region.	Chertow, 2007; Gibbs and Deutz, 2007
iii) Homogeneity/heterogeneity of the industries.	There is no consensus in the literature on this issue. Some authors argue that individual industries (e.g. chemical manufacturers) have specific advantages in developing an IS; others state that greater internal heterogeneity increases the chance of finding suitable partners for exchange relationships.	Reniers et al., 2010; Sterr and Ott, 2004
iv) Active participation of the local community and stakeholders.	Local governments, agencies, and communities can play an important role in each stage of development of an IS by financing projects, providing data and information, and enabling adoption by the involved companies. Among them, Key individuals that promote and support the IS can be recognised.	Ayres, 1996; Heeres et al., 2004; Hewes and Lyons, 2008; Sakr et al., 2011