EIP-AGRI Focus Group – Circular horticulture
Mini-paper – Clusters Enhancing Circular Horticulture

Francisco J. Egea Gonzalez, Joaquim Miguel Costa, Guillaume Morel-Chevillet, Irene Vanninen, Patrick Eninge, Alain Grenet

Introduction

Clustering is an efficient strategy to achieve circularity in horticulture. Traditionally, the food chain of the fresh products fits to an end-of-life concept generating a large amount of waste with different characteristics and a great potential for its valorisation. For example, the waste generated in the region of Almeria, with a surface above 30,000 ha of medium-low tech greenhouses for horticulture generates more than 2 million tons of waste per year[1]

The EU Clusters Portal[2] defines clusters as groups of specialised enterprises (often SMEs) and other related supporting actors that cooperate closely together in a particular location. They should be considered as regional ecosystems of related industries and competences featuring a broad array of inter-industry interdependencies They are defined as groups of firms, related economic actors, and institutions that are located near each other and have reached a sufficient scale to develop specialised expertise, services, resources, suppliers and skills. Clusters are referred to both as a concept and a real economic phenomenon. Their effects, such as employment concentration, can be measured as is done by the cluster mapping of the European Cluster Observatory.

Although clusters have a local/regional dimension, the 2014 Communication "For a European Industrial Renaissance[3]" highlighted clusters as being able to facilitate cross-sectoral and cross-border collaboration, helping SMEs to grow and internationalise. The Commission is launching several initiatives under the Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME) and Horizon 2020 programmes to support SME innovation and growth through clusters. COSME launched the European Strategic Cluster Partnerships for Smart Specialisation Investments (ESCP-S3) and the European Strategic Cluster Partnerships for Going International (ESCP-4i) aiming to facilitate cluster cooperation in thematic areas related to regional smart specialisation strategies, and to collaborate on strategies to go international jointly and to help European SME access third markets.

The European Cluster Collaboration Platform (ECCP) is an action of the Cluster Internationalisation Programme for SMEs. It provides networking and information support for clusters and their members aiming to improve their performance and increase their competitiveness through trans-national and international cooperation. Among other services, ECCP provides a cluster organisations mapping tool, where more than 800 clusters are registered. The European Clusters Observatory identified more than 2000 regional clusters in 258 regions divided into 38 categories

The regulation Reg 651/2014[4] defines "innovation clusters", and establishes funding to promote them. Innovation clusters are structures or organised groups of independent parties (such as innovative start-ups, small, medium and large enterprises, as well as research and knowledge dissemination

[1] Francisco J. Egea, Robert G Torrente and Alfredo Aguilar. New Biotechnology 40 (2018) 103–112
2 http://ec.europa.eu/growth/industry/policy/cluster_en

3 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0014&from=en

[4] Commission Regulation (EU) No 651/2014 of 17 June 2014

funded by European Commission

organisations, non-for-profit organisations and other related economic actors) that are designed to stimulate innovative activity through promotion, sharing of facilities and exchange of knowledge and expertise and by contributing effectively to knowledge transfer, networking, information dissemination and collaboration among the undertakings and other organisations in the cluster.

Porter[5] introduced the term "cluster" from an economic point of view, although clusters take varying forms depending on their depth and sophistication. Most of them include end-product or service companies, suppliers of specialized inputs, components, machinery, and services, financial institutions, and firms in related industries. In view of this definition, geographical, economic, social and environmental aspects of value chains are closely related with clusters.

In the context of circular horticulture, clusters are organized structures, which are focused on transforming the current concept of linear chain, towards a concept that aims to comply with the principles of the circular economy (CE). These structures are made up of a set of companies, activities, services and products that, when incorporated into a given value chain, allow for greater efficiency in all the stages, through a better management of inputs and wastes. Table 1 shows main characters of clusters that are related with horticulture in different links of the value-chain[6]

Cluster type> Aspects	Primary production/ Inputs	Processing/Packaging/ Logistic/marketing	Raw Materials/ Waste	Innovation/Research/ Training/
Location	Near each other	Regional	Regional	Regional or more wider connectivity
Main goals	Economy of scale in production Reduction of plastics	Developing products Logistics Chain and market strength Digitalisation Reduction of plastics	Reduce residues/waste/	Help the partners fast development
Circularity aspect positive	Easier to get big bio/other masses to be circulated Less logistic demands	Reduce logistic demands New packagings e.g. biofilms Reduce food waste Traceability	Diminution of life cycle Reduction of waste Valorisation of sub-products Bioenergy Cascade approach	Finding and studying new processes Alternative inputs sources e.g bioenergy Funding access
Circularity aspect negative	Ecological impact on natural resources, landscape and biodiversity Residues generation	Increase life cycle compared with local consumption		

Table 1. Main characters of clusters that are related with horticulture in different links of the value-chain

The most positive aspect, in terms of circularity of horticultural crop systems, is to increase the sustainability of primary production, which is a big source of biomass, generate new products and new value chains. Moreover clustering is able to increase the efficiency of the system, permits input savings (e.g. energy) and helps to optimize profitability (e.g. recycling activities). Moreover clustering can provide an improved basis for learning and innovation by promoting the close interaction with schools, universities, research and SME horticulture enterprises regionally based for growers to learn from each other sharing the knowledge and the performance indicators for inputs and outputs. In this

[5] Porter, M. E. (1990). "The Competitive Advantage of Nations." Harvard Business Review
6 https://ec.europa.eu/growth/industry/policy/cluster/observatory/european-cluster-trend-report_en

funded by European Commission

sense, Danneberg and Kulke (2005)[7] highlighs the substantial economical benefits of clustering and defines two types of relations among partners in a cluster (i) exchange of "material" goods in a symbiotic approach, and (ii) exchange of "immaterials" e.g. knowledge. Geographical factors affect both type of cross-linking, the first would have success when companies are closely located, but the exchange of knowledge needs to be opened to supra-regional or international networks.

Finally it is important to note that in terms of functionality, clusters should counts with an organizational framework, defined missions, stakeholder's representatives, identified priorities, collaboration in common projects, with a leadership and political influence.

Advantages of Clustering for new value chains

In terms of modifying the current value-chains making them more circular and create new ones, the advantages of clustering are:

- ✓ Clusters combine resources and economies of scale boosting economic development
- ✓ Clusters are closely related with the value chain management, incorporating new processes, bioprocesses, practices and business models that can either feedback the primary links of the value chains or supply new value chains with new products or services.
- ✓ Clusters intend to achieve synergistic benefits by the integrating vertical value chains, which involve agricultural production, processing, packaging, logistics, storage and trade, to horizontal value chains, accordingly to sustainable principles
- ✓ Clusters are themselves a potential destination market of their own products (e.g. primary production of fruits and vegetables can generate energy rom biomass residues, treated wastewater, biodegradable packaging obtained from biomass, etc
- ✓ It implies a win-win relationship between producers of raw materials and companies managing them into the clusters with a synergistic effect
- ✓ By clustering, SMEs reach a certain size that facilitates their access to, knowledge, innovation, technical infrastructures and new markets exploration, as well as their participation in R+D+I projects and/or public-private partnership.
- ✓ Clustering around the primary production value chain permits saving in logistics, and facilitates to overcome likely administrative and legal barriers.
- ✓ Clusters would encompass not only the productive sectors, but also social, public administration and consumer stakeholders to share concerns, plan strategies and communicate the benefits derived from the whole cluster.
- ✓ Clusters would increase resiliency and reduce vulnerability of production systems by diversifying business, incorporating R+D+I resources and reducing their dependency to fossil and non-renewable sources.
- ✓ Clusters can drastically reduce environmental footprints, thereby contributing to mitigate climate change, adapting value chains to more sustainable systems and considering the value of ecosystem services.
- ✓ Clusters strength the social fabric, they are geographically bounded, boosting agricultural heritage areas through the protection of the local/regional agricultural landscape and the locally produced food, finally they can encourage stewardship of local resources and the environment.

Clusters to enhance circularity of horticulture value chain

Clusters are closely related to specific value chains to give circularity. Circular horticulture clusters are designed to adapt linear value chains to circular criteria, identifying gaps and proposing solutions. Concerning the value chain of fresh fruits and vegetables, we consider a down streaming approach in

[7] Dannenberg and Kulke, Die Erde 136 (2005) Contribution to Human Geography pp. 291-309

funded by European Commission

which greenhouses are the starting point from which other activities are derived. In this context, clusters play different roles:

- ✓ To consolidate efficient intensive production areas in terms of sustainability
- ✓ Integrate technologies and knowledge for increasing efficiency in terms of resources demands
- ✓ Integrate technologies and knowledge to manage wastes as raw material in other processes
- ✓ To explore new business models, markets and products
- ✓ To provide to the value chain knowledge and technology, including Communication and Information Technologies

The relationship between clusters and value chains can be considered from two majors points of view, having into account that they are both:

1) Clusters aimed to supply products or services, which will be used by the own value chain. The main function of the cluster is to provide sustainable measures to the vertical value chain, including modern quality and efficiency-oriented solutions. In this case the cluster arises itself as the destination market of products or services generating gains in circularity. For example:
   - ✓ A greenhouse complex that generates biomass and wastewater from hydroponics, which are re-introduced in the vertical value chain after processing ex:
   - ✓ Energy production from biomass, production of new fertilizers from biomass treatments
   - ✓ Treated waste water derived from hydroponic saline waste water
   - ✓ Other biodegradable tools such as pins, wires, which are obtained from biomass
   - ✓ Production of containers from biomass, which are used for packaging fruits and vegetables produced in the area of the cluster.

2) Clusters aimed at the production of products or services mainly intended to feed new value chains. For example:
   - ✓ Recycling industry
   - ✓ Extraction of high-added value compounds for cosmetic, agro-food and/or pharma industry
   - ✓ Production of bio-blocks for chemical and new material industry
   - ✓ Production of raw materials with purposes different than agriculture (eg construction)
   - ✓ New business models, ex: aquaponics linked to crops, new saline crops irrigated in cascade with hydroponics, microalgae plants, production of feed for livestock farming.

Urban farming could be considered in both groups because it is a new business model created in locations that are not usually dedicated to agricultural activities, but the production and the consumption stages, are intended to take place within the cluster facilities (or very close as local market).

Smeets et al[8] introduces the concept of Metropolitan Food Clusters (MFC) considering specific geographical areas, close to urban areas. Clusters deal with food production through vertical and horizontal integration of value chains. MFC facilitates the use of resource efficient technologies, including modern quality and efficiency oriented solutions in food production, processing and storage; vertical integration of food chain but also horizontal integration developing cost-effective and eco-sustainable solutions enabling the concept of industrial ecology, which integrates different value chain to capitalize synergies.

Concerning R+D+I, clusters are the most appropriate organized structures to bring technology and knowledge to the value chains. In the case of primary production a set of knowledge-based companies provide structures, climatization systems, seeds, fertilizers, efficient irrigation, plant

[8] Peter J.A.M. Smeets, Renze van Och, Mirte Cofino, Steef Buijs & Arjen Simons Metropolitan Food Cluster and Agroparks: Design and implemented examples, Alterra Wageningen UR 2015

funded by European Commission

protection and decision making tools. At farming level clusters provide training and advice to farmers related with sustainability and efficiency. The above referred Smeets et al consider a fundamental part in MFCs research and innovation centers, not only to fulfill the R+D+I demands of the cluster but also to attract funds and investors. In The Netherlands, the University of Wageningen leads clustering projects in the country and worldwide.

Geographical and economics considerations influencing clustering

Clusters are much more than simply an addition of companies. The true aim is to take more advantages of the cluster than from the sum of the individuals. Territorial management which is important in terms of profitability, environmental and social benefits, consider:

- ✓ Rural areas with a high concentration of production, (e.g. Almeria (Spain), Sicily (Italy), Westland (The Netherlands), etc.)
- ✓ Metropolitan areas with potential for urban farming, vertical roofs, etc
- ✓ Eco-industrial parks that have explicitly been designed to support circularity (they can be either in urban or rural areas), this concept allows to maximize the benefits of clustering as states Smeets et al (2015).

Both scenarios are completely different. In general terms, production of raw materials must be closer to the processing industry to reduce logistics (costs and footprint). However, the fate of the product obtained should also be taken into account. For example, the biomass to be used for heat production, should be obtained practically in situ. But for manufacturing construction materials, this aspect is not important.

The case of urban farming is a typical scenario where the production and consumption of the cluster should be at the same place, as the aim of this kind of agriculture is to reduce footprint minimizing logistic issues, to sensitize citizens and for shortening the food chain.

Cluster dimension and location

Urban clusters: The scale can be really small. For indoor farming, a productive container near a restaurant can provide food, sensitize consumers to local production and reuse organic waste for example. Once an urban farming project is installed on a roof, the building itself can be part of the cluster by providing energy, water or gases (CO_2) to the urban farm. Food processing or logistical aspect can take place into the building (eg: Lufa farm in Montreal[9]: greenhouse on top of the roof and packaging to make food basket on the floor). By implementing a farm into an old building, agriculture can participated to the rehabilitation of building (and not necessarily destroy them to build new ones). On the other hand, for an urban farmer, a city can be seen as a relevant scale. For example collecting the organic wastes of diverse sources (restaurants, hospitals, schools..), process it (mostly by composting it) and reuse it into cultivation activities. The case of mushroom production using coffee grounds is relevant. Still into city center, greenhouses can be part of the urban farming cluster by providing seedlings to other urban farmers. Normative on the use of waste as compost and/or the intended use of soil should be revised to avoid legal barriers.

Advantages of urban farming building greenhouses on top of the roof, as it is claimed from the Lufa farms project in Montreal[10], are related with energy, material and water saving:

- ✓ Reduction of heating demands due to thermal mass of city buildings and roads at night
- ✓ Reduction of carbon footprint due to the minimization of logistics. Products are sold in a local trade concept.
- ✓ Reduction of packaging. Following the local trade concept, products are delivered in a customized basket that can be reused all times.

[9] https://www.ellenmacarthurfoundation.org/case-studies/high-yields-high-above-the-city
[10] https://montreal.lufa.com

funded by European Commission

- ✓ A sustainable hydroponic agriculture is performed by recirculating almost 100 % of water and nutrients. Pest control is performed fitting to biological control principles, using beneficial insects.
- ✓ A farm size close to 13,000 sqm can provide fresh vegetables (herbs, greens, tomatoes, peppers and other vegetables) to about 2000 customers.

However, some disadvantages are the small size of farms and the lack of storage infrastructure, which can lead to food waste in certain cases, or the accessibility to expensive innovations. Additional concerns are related with food safety and the presence of pollutants in products that could be used for feeding animals or fertilizers.

Peri-urban clusters: At this scale, notions of recycling of water, organic wastes or energy from cities are relevant. New topics like reuse of wasteland (brownfield) by agriculture can be included into circular economy topic. By working and investing together, horticulturists can create new value supply chain. For example in South of Paris, growers cultivate aromatic plants and process them in a common distiller in order to make, and sell, essentials oils.

Rural clusters: The dimension of these areas and the volume of raw material produced allow planning companies big enough to be able to supply services and goods to farms. The ideal cluster is built in a greenhouse concentration area, where farmers have shared concerns, interests, priorities, fate and sense of community. The concept of Agropark explained by Smeets et al is a good example of efficient cluster. In brief, the rural areas are endowed with an infrastructure as it is shown in Figure 1. It organizes primary production farms around Agroparks. The agropark combines logistics, processing and support-actions and permits an optimal valorization, for example combining different value chains following principles of industrial ecology, exchanging byproducts between them, cascade approach, etc. In addition, Agroparks act as advising, educational and training centers for farmers and as drivers of innovation to farmers, linking research centers with the value chain. As an example Wageningen university in The Netherlands and the University of Almeria in the South Spain are playing an important role in the knowledge transfer to farmers providing, not only innovations, but also high-qualified people to the labor market related with the value chain.

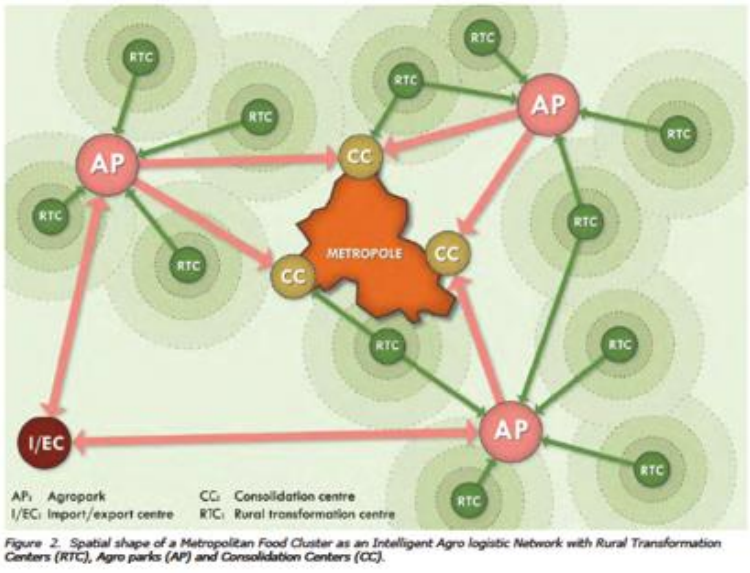

Figure 2. Spatial shape of a Metropolitan Food Cluster as an Intelligent Agro logistic Network with Rural Transformation Centers (RTC), Agro parks (AP) and Consolidation Centers (CC).

Figure 1. Linkages between cluster´s units in the Netherland

One of the major advantages of clusters derives from the ability to scale their size. CITs provide clusters of a network to manage the value chains. The relevance of CIT is not only related with efficient production e.g precision farming but also with digitalization of the value chain the Ellen

funded by European Commission

MacArthur Foundation describes the role of CIT on the linkage of rural areas with peri-urban and urban farming, acting as a driver of the innovations flow along the value chain.

Cluster implementation and governance sectors of activity, farmers and government

Clustering can benefit greenhouse sector in different degrees as function of the type of companies' activity. Indeed, a set of specific sectors would be more prone to clustering, namely:

- ✓ Water management:
  Recirculation of hydroponics, desalination of groundwater or recirculate water, treatment of wastewater, mixing, connections with aquaponics etc
- ✓ Energy production:
  To supply either to farms as companies in the cluster. For example. data centers which waste a large amount of energy (heating) are a good opportunity for growers using greenhouses.
- ✓ Biomass processing:
  High volume of biomass processed and high volume of by-products obtained (but relatively low added value): fertilizers, substrates, cattle feed, energy…
  High volume of biomass processed and low amount of by-products obtained (but high added value): extraction of chemical compounds with properties useful to plant protection, chemical, pharmaceutical, cosmetic, food industry. In general new products for relatively new markets.
  High volume of biomass processed to obtain bio-plastic or bio-blocks for packaging or other industries
- ✓ Logistics:
  A good example can be seen at the above mentioned Lufa Farm project, where the urban farm is playing the role of a hub which centralize peri-urban products in order to distribute them to urban consumers. In rural and peri-urban areas of greenhouse concentrations, clusters influence positively on logistics with a significant reduction of environmental footprint. Digitalization of distribution and logistics channels is relevant to achieve more efficient value chains.
- ✓ Plastic wastes:
  Plastics and containers residues need high dimension treatment plants with good logistic connections.
- ✓ Business models different than the above cited and from biomass processing.
  Such as aquaponics, which in rural areas can be dimensioned big enough to guarantee profitability as a new value chain, connecting farms, and logistics related with commercialization to take advantage of synergies; Agroturism is another example of business diversification in this field, as well as those related with ICT
- ✓ Advice, training, educational and knowledge transfer

Clusters are characterized by the integration of many stakeholders sharing interests and concerned by the economic development of the area.

- ✓ Growers: It is important to communicate (in a simple and effective way) to growers that they do not have to change their business to take part of a cluster, with the key role of supplying raw materials to the rest of companies and acting as a final destination of an important part of the cluster´s production, taking advantage of reduction of costs, and the increasing sustainability of their business. It is relevant that growers be open-mind to innovation and participate in training and educational programs. This approach will reduce likely resistance to face this new challenge.
- ✓ Government and public administration: Although clusters should be managed and set by the private sector with important inputs of SME´s the governmental administration (regional, national, European) must establish norms that regulate the scale-up new business models in the current production areas, promoting good business practices, more efficient production and minor waste production. Regarding public administration, general population and consumers representatives have to be present in the governance of clusters through the

funded by European Commission

public administration. It is important to communicate how efficient clusters impact to the global society, the value of ecosystem services, the benefits on the environment, reduction of footprints, fossil dependency, jobs creation and thus the positive impact for future generations.

- ✓ Entrepreneurs with enough knowledge and technical skills have to become part of the cluster as new actors in the horticultural value chain, promoting investment in novel technologies of production and novel recycling systems.
- ✓ Scientists and knowledge managers to support technology development, up-scaling, marketing etc
- ✓ NGOs and Community members to address cultural heritage, social and environmental issues related with the geographical area.

Clusters implementation requests a good organization and the concurrency of value chain actors and stakeholders, some activities have been identified to set-up a successful cluster:

- ✓ Current value chains will be planned considering its potential for circularity. Therefore a complete analysis of the current value chain in each production area is necessary
- ✓ Analysis of biomass (wastes, residues) in terms of amount and availability (logistic)
- ✓ Characterization of biomass (wastes, residues) to know potential uses, as well as characterization of the final products to be re-incorporated to the value chains.
- ✓ Identification of gaps for circularity (which in turns some of them might become in business opportunities) and profile of companies that can potentially be involved
- ✓ Identification of common interests within the clusters partners, ex pretreatment of biomass to feed different companies, desalination of wastewater, energy from co-generation. For example the industrial cluster of Kalundborg Symbiosis in Denmark[11] is organized as an eco-industrial cluster in which flow of material, energy and water are managed into a win-win symbiosis, Figure 2.

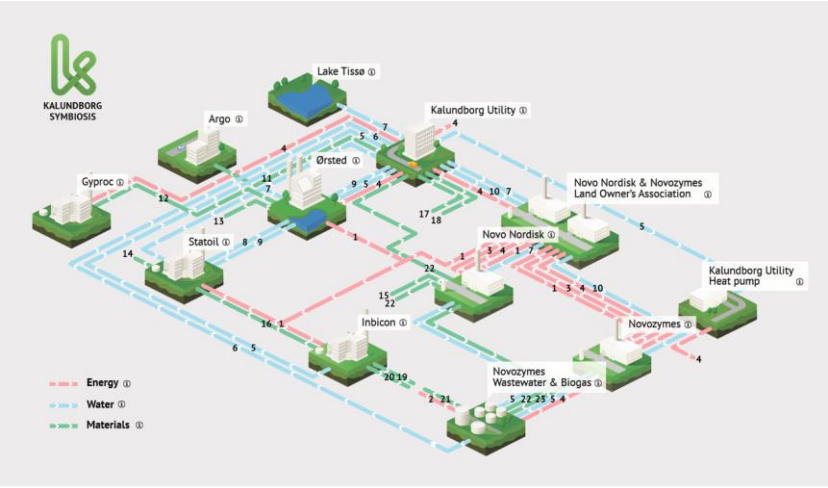

Figure 2. Industrial cluster of Kalundgorg Symbiosis

- ✓ Connection with other sources ex: urban wastewater treated in order to optimize resources and reduce natural resources dependency
- ✓ Identification of knowledge and technology gaps
- ✓ Database with pilot or laboratory scale projects able to scale-up
- ✓ Roadmap with business possibilities adapted to the value chain
- ✓ CITs system to forecast raw material supplies and markets evolution
- ✓ New Products and Market explorations, either within the value chain as new value chain
- ✓ Informatics design a GIS system with biomass resources and its potential for reusing

[11] http://www.symbiosis.dk/en/business-strategy/

funded by European Commission

- ✓ Promoting products and benefits of the cluster even through labelling including ecosystem services and environmental footprints reduction. Ex: Life Cycle Assessment (LCA) can be a tool to set some indicators for comparing individual processes or individual company´s footprint with the total LCA of the whole cluster.
- ✓ Establish a network between clusters to benchmarking

Keys to success and Barriers

Clusters aim to joint in a geographical area, value chain actors sharing similar goals and visions on local economic development in a sustainable approach, considering environmental, social and economic fields.

A first key/barrier for the success/failure of clusters are personal attitudes to face the challenges:

- ✓ Clusters are inclusive structures but with a strong organization and solid leaders
- ✓ Clusters are not vertical organizations to control the suppliers of a value chain nor horizontal organization to control competitors
- ✓ Although the core of the cluster is the primary production activities, producers have to integrate SMEs or Micro-companies in mutual benefit. Clusters promote a shared vision engaging diverse stakeholders; personalities and egos can be a risk, if priorities are not well defined.
- ✓ Mission statements of clusters must be defined, with indicators of goals achievements and strategic plans and projects, agreed by the core group and the stakeholders.
- ✓ Environmental impact, ecosystem services, sustainability principles, social and educational issues must be perceived as common benefits within the actors of the clusters but also must be communicated to consumers.
- ✓ Quantitative indicators, such as those derived from LCA of the whole cluster compared with individual activities, can help to avoid resistances.
- ✓ Producers have to be open-mind to adopt changes related with innovative measures related with efficient production or business diversification, including predisposition to R+D+I investments.
- ✓ Within clusters, by-products from a link of the value-chain serve as raw material to feed another, the perception of such by-products as "garbage" leads to consumer rejections; a typical case is when rejected fruits and vegetables are processed to produce animal feed, consumers might perceive that these animals have been fed with garbage and reject that, or even the livestock farmer can reject this kind of feed to prevent further consumer rejections.
- ✓ In the same way consumers might reject products from urban farming at open-air locations, rooftops or peri-urban land, because the perception that urban contamination gets into the product.
- ✓ In consequence value chains in the clusters have to be monitored to guarantee in all cases the chemical and biological quality and safety either of the sub-products resulting in each stage as of the foodstuffs produced in new business models, in order to guarantee confidence to customers.

Normative have to be adapted in some cases to circular economy principles, but regarding safety for consumers and the environment. Legal barriers sometimes, difficult companies to set-up and sometimes, difficult economic activities, for example:

- ✓ Regulations on fertilizers or animal feed. Very often it is not possible to convert rejected fruits and vegetables or plant biomass in animal feed or fertilizers because they are considered as residues and the normative exclude residues as ingredients for animal feed. The same case occurs with fertilizers, in some cases the movement of residues to fertilization plants is not possible from a legal point of view.
- ✓ Changes in the uses of soils. Urban farming can be difficult because the urban uses of the soil or rooftop do not includes agricultural production, this uncertainty might discourage likely investors or entrepreneurs. The same occurs in several countries when land is legally defined

funded by European Commission

as "land for agricultural uses" and it is impossible to set at the same place other activities such as energy, aquaponics, or microalgae production to link with the farming activities. In this case a kind of "cluster activities" denomination would make easier to set-up a cluster

Finally concerning new business development we find barriers such as:

- ✓ New business carry a high risk of failure, the interdependency among the different value-chain actors, within the clusters require a solid management structure to avoid a "failure in cascade" due to the products in one stage serve as raw material for the next stage.
- ✓ High risk for entrepreneurs to scale-up laboratory or pilot processes to industrial in order to obtain bioproducts from feedstock, this is an extensive and sometimes long-term investment with high uncertainty in the result.
- ✓ Immaturity of markets for new bio-products manufactured in clusters, both factors are very relevant, it is about new markets for new products.

These barriers are relevant, in fact outside the cluster and entrepreneur would have less chance of success. It is very important to highlight that funding can be regarded as another service in the cluster. Successful clusters have a solid organization and a sufficient size to be able to achieve and manage funds from European, national or regional programs, from their own budgets or attracting investors. In this sense the participation of financial entities in the clusters is relevant to minimize risks for entrepreneurs. In an ideal case the cluster would take part of public-private partnership like Biobased Industries Cosortium (BIC)[12] providing access to funding, knowledge, innovation and technology to the clusters members.

The following diagram from the project Agrocycle[13] depicts the potential of circularity of horticulture

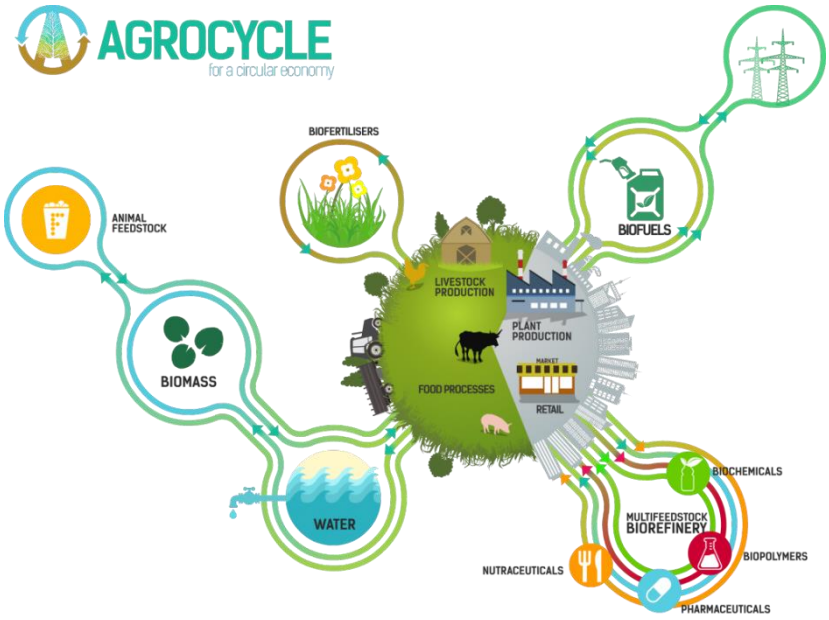

Figure 3. Diagram of circular horticulture cluster activities

In conclusion clustering protected cultivation systems with other facilities, industries and activities could improve the circularity of horticulture. Figure 4 shows the production chain based on inputs such as water, fertilisers, energy and CO_2. In red bottom are main raw material, which can be valorised by clustering with facilities depicted in blue bottom, giving as results those in green bottom. It can be

[12] http://biconsortium.eu
13 http://www.agrocycle.eu

funded by European Commission

seen that cities can play an important role supplying the production system with treated wastewater, energy and CO_2. Innovation clusters play an important role in the circularity, supplying knowledge for setting the different valorisation routes and keeping the general society informed and aware of the importance of circularity, including the environmental and social benefits as well as monitoring the performance of the cluster, for example through LCA.

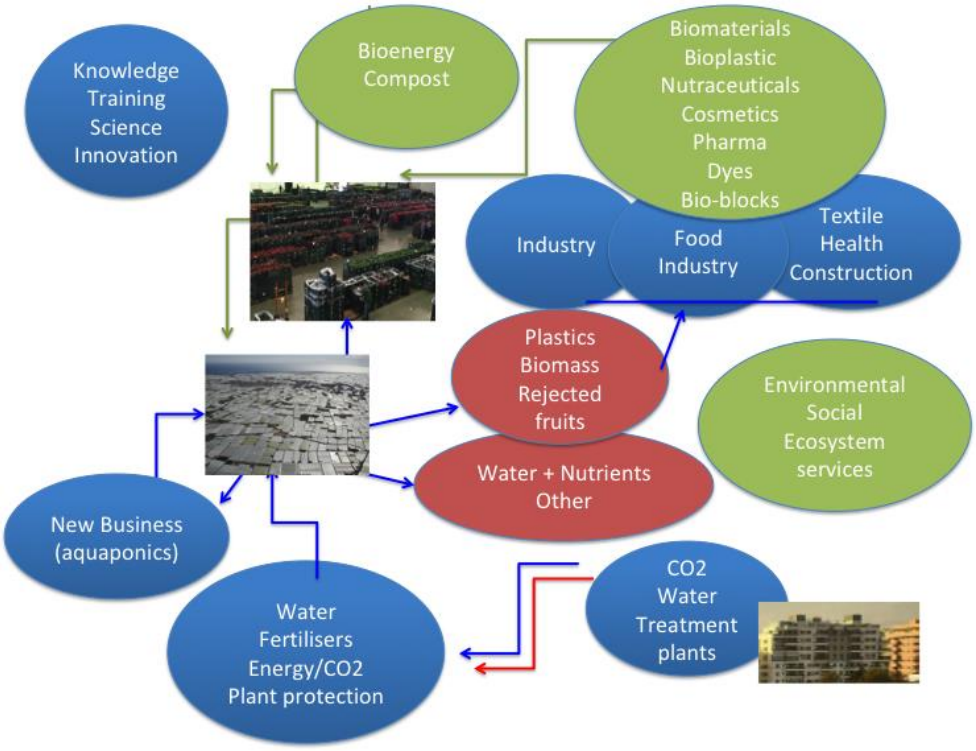

Figure 4. Potential clustering boosting circular horticulture.

Examples of projects

The European Clusters Observatory maps more than 2000 clusters in the EU. They can be checked from different fields, for example clusters can be selected by countries, industrial sector activity, regions, etc. The report on the agro-food sector shows regions in France, Spain, Portugal, Belgium, Austria, Romania and Germany with successful clusters related with this industry. Most of them enhance the role of facilitating access to science, innovation and technology to their associated. Table 2

Cluster	Country	Web
Agrisud-ouest innovation	France	http://www.agrisudouest.com
Cluster de la acuicultura de galicia	Spain	http://www.cetga.org
Flanders' food	Belgium	http://www.flandersfood.com/
Inovcluster	Portugal	http://www.inovcluster.pt/
Lebensmittel cluster niederösterreich	Austria	http://www.ecoplus.at/de/ecoplus/cluster-niederoesterreich/lebensmittel

funded by European Commission

Portugalfoods	Portugal	http://www.portugalfoods.org
Vitagora	France	http://www.vitagora.com
Vegepolys	France	http://www.vegepolys.eu/
Agrotransilvania cluster	Romania	http://www.agrocluster.ro
Food-processing initiative e. v.	Germany	http://www.foodprocessing.de/
Foodnetwork	Denmark	http://www.foodnetwork.dk/
Foodregio	Germany	http://www.foodregio.de/
Ind-agro-pol	Romania	http://www.inma.ro/indagropol

Table 2. Regions and Agro-food clusters described by the European Cluster Observatory

Many others several publications deal with on-going clusters around the world, although there are few examples specifically related with circular horticulture. The most cited authors concerning theory of industrial clusters are the above-cited Porter and Marshall. Van der Linde[14] reports a general review on clusters in 2002. Concerning developing countries, Gálvez-Nogales (2010)[15] reports clustering as an effective strategy for competitiveness in some value chains in Latin-America, Asia and Africa. In general terms, clustering reduces vulnerability in food systems through cooperation between members, business diversification and incorporation of efficient crop practices. European initiatives in Research and Cooperation programs with Africa promote sustainable intensification, which meets with clustering in several aspects, to reduce hunger and malnutrition[16]. The World Bank published benefits of agro-clusters in several regions of Africa (Theus and Zeng 2012)[17] and review cases of clusters, such as the wine cluster in South Africa, flowers in Kenya and Tanzania or Sesame industry in Paraguay. Duncan Hilchey[18] describes agricultural clusters in several areas of USA, mainly related with specific value chains as wine production. Hilchey highlights the value of strong clusters considering not only economical indicators but also environmental, cultural and social benefits in the geographical areas were clusters are set-up.

The Ellen MacArthur Foundation[19] publishes an extensive number of reports, study cases and guides concerning Circular Economy. The point of view is to address the potential for circularity of different industries, such as mobile phones, textile, or agriculture or materials like plastic. It is also addressed geographical clusters, for example the potential of circular economy in India. This Foundation focuses its activity in promoting Circular Economy within the society, specifically academia, policy makers and industry. The interesting project on urban horticulture LUFA FARM in Montreal, has been discussed in page 5. Another project on urban farm is described in Barcelona, with a similar approach[20].

[14] http://www.isc.hbs.edu/metastudy2002bib.pdf
[15] Galvez-Nogales E. Agro-based clusters in developing countries: statying competitive in a globalized economy. FAO Rome. 2010
[16] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/sfs-35-2019-2020.html
[17] Agricultural Innovation Systems: an investment source book, World Bank 2012, https://www.innovationpolicyplatform.org/sites/default/files/rdf_imported_documents/Agricultural_Clusters.pdf
[18] http://www.newleafnet.com/docs/New_Leaf_Agriculture_Industry_Clusters.pdf
[19] https://www.ellenmacarthurfoundation.org
[20] Sanyé-Mangual E. and al. 2015. Integrating horticulture into cities: A guide for assessing the implementation potential of Rooftop Greenhouses (RTGs) in industrial and logistics parks. Journal of Urban Technology 22(1):87-111.) http://www.fertilecity.com/

funded by European Commission

Concerning Europe, Dannenberg and Kuklke (2005)[21] published the importance of agrarian clusters for rural areas of Eastern Germany and Western Poland and discussed different interactions and networks between value chain actors. The aim of the above-cited eco-industrial park in Kalundborg[22] symbiosis is to achieve sustainability by managing the flows of water, material and energy, as it has been shown in Figure 2. Within the cluster facilities, residues of biomass from companies are used to generate biogas, and after degassing the biomass can be used as fertilizers, being a double recycling, the objective is to complete up to ten projects by 2025.

Probably the most active institution in Europe promoting clusters is Wageningen University and Research[23] the key for Clusters design is the system innovation Metropolitan Food Cluster, which has been discussed above. Smeets[24] review several projects managed by Wageningen UR: The Agropark Bergerden, which collect rainwater for irrigating a total of 180 cultivated Ha with vegetables, ornamental and flowers. Climate control of greenhouses is based on a collective Combined Heat and Power installation (CHP), which produces heat and power with co-generation from greenhouse wastes and manure from surrounding livestock farms to produce biogas, both are owned by a co-operative in which growers participate. Innovations in climate control have been developed to store heat during summer in groundwater, which is used during winter. An extra income for growers is power production, which is sold to the national grid. An important barrier is that it is too small for attracting investors, learning that agroparks have to be planned with expansion possibilities.

This is the case of AgriportA7, which was planned in 2005 to count with more than 1000 Ha of growing surface, more than 300 ha in a first phase. Growers have their own CHP. In addition geothermal heat from wells 2.1 km depth provide half of the heat demand of the Agropark. This investment reduces CHP installations and thus CO2. Large livestock industry is incorporated to the cluster providing manure for processing in a co-digestor to produce biogas. This model is being exported to China in collaboration with Wageningen UR. Figure 5 shows an industrial ecology network in which different economic activities are clustered

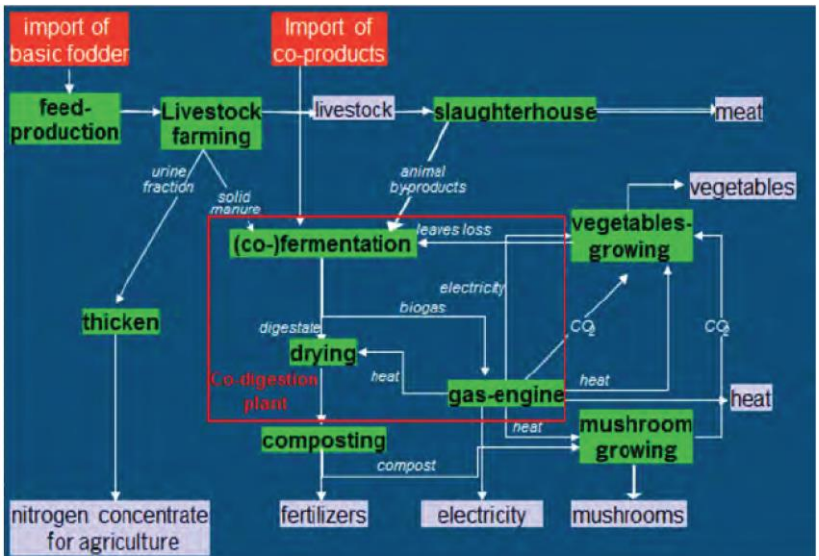

Figure 5. Potential Activities to achieve circularity in the horticultural sector

[21] Dannenberg and Kulke, Die Erde 136 (2005) Contribution to Human Geography pp. 291-309
[22] http://www.symbiosis.dk/en/blog/laying-the-foundation-the-new-biogas-plant/
[23]https://www.wur.nl/en/Expertise-Services/Research-Institutes/Environmental-Research/Projects/Metropolitan-Food-Clusters-and-Agroparks.htm
[24] Peter J.A.M. Smeets, Renze van Och, Mirte Cofino, Steef Buijs & Arjen Simons Metropolitan Food Cluster and Agroparks: Design and implemented examples, Alterra Wageningen UR 2015

funded by European Commission

This approach for designing Agroparks is very effective in terms of efficient production and business diversification, proof of that is that it has been adapted and exported to other parts of the world. There are ongoing projects dealing with Agroparks in Mexico, different parts in China, India and several areas in The Netherlands.

Other examples of eco-industrial parks is Kirkkokallio in Honkajoki[25], Finland, where two large greenhouse companies are located and utilize for heating from waste heat coming from a rendering plant (=destroys animal carcasses and produces side-streams from them).

The H2020 NEFERTITI[26] project (Networking European Farms to Enhance Cross-Fertilisation and Innovation Uptake through Demonstration), which has been launched in January 2018 in Almería, Spain. It is coordinated by ACTA and will establish an EU-wide highly connected network of well-specified demonstration and pilot farms, which is designed to enhance thematic knowledge exchange, cross fertilisation among actors and efficient innovation uptake in the farming sector through peer-to-peer demonstration of techniques. It stablishes 10 thematic networks bringing together regional clusters (hubs) of demo-activities.

One of the most interesting projects related with clusters is the Biorefine Cluster[27], which is a multinational cluster related with several topics of the agro-food sector. The cluster deal with topics directly related with circular economy in horticulture, mainly the valorisation of residues from the primary production stages. The aim of Biorefine is to obtain byproducts such as bioenergy, biogas, biowastes, crop residues, food waste, manure and animal byproducts, microbial techniques, biofibres, biocomposites, biomaterials, LCA, phytoremediation, sustainable wastewater treatment and nutrients recovery. In addition, several projects in the Biorefine cluster, deal with knowledge transfer, intellectual property and funding Figure 6 shows on-going projects in the within the Biorefine Cluster where a total of 30 countries take part of the clusters, including non-european as Canada, China or India.

Figure 6. Diagram of projects within the Biorefine cluster.

25http://www.nordregio.se/en/Publications/Publications-2016/GREEN-GROWTH-IN-NORDIC-REGIONS-50-ways-to-make-it-happen/Circular-economy-/Kirkokallio-Industrial-Park-/

26 http://www.cema-agri.org/publication/h2020-nefertiti-project-innovation-demo-farms

27 http://www.biorefine.eu

funded by European Commission

Proposal for potential operational groups

In general terms we identify three potential operational groups (OG) and two more specifics.

One OG dealing with the Analysis of agrofood systems in terms of Life Cycle Assessment allow to plan clusters facing environmental, social, geographical and economical challenges, identifying value chains to be integrated for achieving goals. The operational group would identify appropriate quantitative indicators of success. Experts on agrosystems analysis, agribusiness, researchers, farmers, environmentalists, biotechnologists and NGO would integrate the operational group. The objective is to value immaterial benefits associated to clusters, for example by setting LCA, to establish quantitative indicators of footprints and social aspects, such as education improvement, cohesion, employment, ability to attract investors, community awareness etc.

Another OG dealing with specific challenges of chemical and biological safety of material flowing within the clusters, mainly those that are intended for food, pharma or cosmetic industry. Specific concern on the safety and quality of products from open-air urban crops, water recycled destined to irrigation and safety of fertilizers from biomass. Urban farming can be considered as a specific study case in the frame of this group, identifying appropriate measures of waste disposal, and inputs management. The operational group would identify potential risks associated to products and working activities. Experts on risk assessment, food safety, laboratory analysis, NGO, clusters managers and agribusiness would integrate the operational group.

An operational group would deal with clustering in developing countries facing food insecurity and malnutrition. Strategies to connect small family farming holdings and to organize, training, storage and distribution systems, having into account that in this kind of countries most of food waste takes place at the first stages of the value chain.
A specific OG to deal with the diminution of plastics use in horticulture, either in primary production or as alternative flow-pack to plastics in the commercialisation stages. Alternatives to plastics with biobased biodegradable materials should be addressed by the concerned industries, farmers and value chain managers. In consequence the OG should integrate all the value chain actors and scientists.
Finally the last potential OG would deal with markets development for new by-products, exploring the potential markets for products becoming from valorisation of biomass. Participants from pharma, food and beverages, cosmetic and textile industries could share their expertise and their requirements concerning new products from circular horticulture clusters.

Proposals for (research) needs from practice

One of the most difficult challenges for entrepreneurs is up-scaling pilot and laboratory processes to demonstration and industrial size. Concerning existing knowledge at laboratory scale it would be necessary to research the up-scaling to profitable size and check the profitability of new industrial processes.
The adaptation of processes and infrastructures to different cluster sizes, exploring ways of connectivity among companies.
Communication and Information Technologies applied to integrate small production units of value chains to upscaling to clusters size.
Potential of greenhouses wastes to produce high added value products and bio-blocks. It is necessary to design an efficient cascade system for the valorisation of all residues produced by the fresh fruit and vegetable value chain. Extraction processes optimization, conservation and safe use of new products obtained from clusters.
To research the extent of environmental and social benefits of circular horticulture, including LCA of whole value chains, climate change mitigation or adaptation indicators and social studies.

funded by European Commission

Recommendations for further development

Most of clusters in the literature deal with the integration of companies to produce energy or to manage water and fertilizers. However the valorisation of waste biomass through extraction of high added-vale compounds is scarce.
The valorisation of environmental and social aspects is not well quantified. Usual indicators of success in clusters are the amount of inputs saving, as a measure of efficiency. The advantage of this indicator is that it is easy to translate in money for growers but the disadvantage is that it underestimates the total balance of benefits. Clusters needs to value immaterial flows such as ecosystem services and social cohesion.

Conclusion

In conclusion, clusters are important tools to give circularity to vertical value chain. The integration of companies to achieve an efficient production not only results in economical profit but also environmental benefits, reduction of resources dependency and long-term sustainability.
Most of the reviewed clusters emphasize water management, fertilizers and energy production, being less frequent biomass uses for different purposes than biogas production or fertilizers. Other processes such as extraction of nutraceuticals or chemicals compounds for cosmetic or pharma industries are less frequent in clusters.
Most of clusters reincorporate the manufactured products into their value chains, being the own market of their production. That is the case of water recycling, geothermal and CHP climate systems using biomass. Business diversification holds mainly in CHP power, which it is sold to the grid, being an alternative income for growers. Among the integration of other value chain the most frequent issue is linking livestock farming with greenhouses and CHP power plants, which provides CO_2, heat and fertilizers from livestock manure and is used in greenhouses for growing, heating and lighting.
Urban farming is a promising agricultural production that take advantage of heat, CO_2, thermal mass of the city, rainwater etc,. Being its main strength the reduction of footprint avoiding logistics and packaging, considering a local marketing point of view. However the size of this clusters may be a barrier.
Although clusters can be considered at a wide range of sizes, small clusters have many difficulties, for example, to attract investors and to access innovations or infrastructure (eg geothermal), so that it is necessary to link productions unit (in agreement with the concept of MFC) to gain in size. Urban farms can be interconnected to peri-urban areas to take advantages in inputs supply, and local distribution of the production.
Clusters are not only a sum of companies interconnecting value chains; they provide services, such as training, education and knowledge transfer. They also provide organization, political influence and services to market placing, for example chemical or biological safety of the products and the raw materials flowing between the different value chains in the cluster.
Finally clusters contribute to the value of ecosystem services, environmental benefits, and social cohesion.
The inclusion of R&D&I centres as part of the clusters is a valuable assets. In a symbiotic relationship, clusters are able to funds innovation projects to improve the value chain, furthermore strong clusters can be integrated public-private partnerships and in stakeholders groups with active participation in the elaboration of research strategies and policy agendas.

funded by European Commission

funded by European Commission