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Technologies and innovation for sustainable management of Agriculture, Environment and Biodiversity

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Roberto BARBUTI, Stefano CHESSA, Roberto FRESCO, Paolo MILAZZO

PREFACE

The technological innovation in biology and agriculture often leveraging on innovation in computer science and engineering, pushed forward the process of integration among these disciplines. In particular, information technology (IT) provides common methodologies and tools for the automatic acquisition and analysis of the data that concern the management and optimization of the natural and territorial resources.

In agriculture, applications of IT enable the integration of interventions concerning its sustainability and productivity, by offering methods and tools to monitor, control, analyse and optimize the production while keeping it respectful of the environment. Similarly, the best practices for bio sustainability, for the management of bio-diversity and for the bioremediation of the environment (including soil, water etc…) are also progressively adopting IT, which enable more focused (and thus more effective) applications.

In this context, the conference "Technologies and innovation for sustainable management of Agriculture, Environment and Biodiversity" (TI4AAB), was held in July 2016 at the Natural History Museum of the University of Pisa located in the Calci Charterhouse (Calci, province of Pisa) in order to encourage the sharing of emerging knowledge about the above topics.

In fact, the conference was dedicated to fostering innovative cross-disciplinary research and applications and to stimulating the exchange of strategies and experiences, among academic and company experts from different disciplines (agriculture, biology, computer science and engineering and environmental decision making), in order to encourage a common, interdisciplinary discussion about the adoption and perspectives of IT in modern agriculture, environmental management, biodiversity and bio-sustainability in general.

The conference was held under the auspices of the municipality of Calci, the University of Pisa and of the "Ordine dei Dottori Agronomi e Dottori Forestali". It was also attended and supported by some leading national and worlwide industries, like CAEN RFID, OSRAM, STMicroelectronics, EBV Elektronik, Qprel Srl, AEDIT Srl, EMipiace Srl, and Zefiro Ricerca & Innovazione Srl, and by the Italian National Forestry Authority.

This volume constitutes a selection of the contributions presented at the conference and cover the aspects of innovation in agriculture, biology, and applied information technology. In particular, concerning innovation in agriculture, the paper by Nin et al. studies new soilless cultivation systems for wild strawberry growing in the Tuscan Appennine mountains. The paper by Prisa describes experimental research concerning the use of zeolites in combination with effective microorganisms, in order to improve the quality of olive trees. Finally, the paper by Lombardo et al. describes collaborative approaches to innovation in agriculture (co-generation of technology).

Concerning innovation in biology, the paper by Baldacci et al. describes the results of the preliminary phases of the AIS-LIFE project, which aims at developing aerobiological information systems in order to improve pollen-related allergic respiratory disease management. Still concerning the AIS-LIFE project, the paper by Natali et al. aims to describe the strategy used in AIS-LIFE project, to evaluate daily pollen concentration in the atmosphere produced by many allergic plant species. The use of data and GIS system are shown as an approach to assess allergy risk maps.

Concerning innovation in computer science applied to agriculture and biology, two contributions focus on modeling approaches, and two contributions provide a survey of information technology applied to agriculture and biology. Specifically, the paper by Bodei et al. describes the application of the IOT-LYSA formal modelling framework to a possible scenario of grape cultivation, in order to assess water consumption, and the paper by Barbuti et al. proposes a mathematical model of artificial reefs, in order to study the dynamics of algal coverage and of populations of fish in some Italian artificial reefs. Finally, the paper by Fresco et. al. explores the current challenges and IT solutions in order to realize a digital agriculture framework, intended as an evolution from Precision Farming to connected knowledge-based farm production systems, and the paper by Pucci et al. provides a survey on biologging methodologies for the collection of knowledge about animals' behaviour, making a review of some related common data analysis techniques.

All papers have been carefully reviewed by experts in the specific fields. Here is the list of the reviewers, that we thank for the collaboration.

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PROPOSAL FOR SPACES OF AGROTECHNOLOGY CO-GENERATION IN MARGINAL AREAS

Abstract: S. Lombardo, D. Sarri, M. Vieri & G. Baracco, *Proposal for spaces of agrotechnology co-generation in marginal areas.*

In the European agriculture sector the basic training levels is very low, despite the dedicated funding. The challenge of the new industrial revolution in agriculture toward precision farming is an opportunity to promote this new paradigm among all stakeholders of the agricultural sector. The new paradigm could start changing the top-down approach by abandoning the technology transfer used to date. To this end, it shall be introduced open innovation to research in order to enable social innovation in rural communities for a bottom-up approach. The ultimate goal is the agro technical co-generation of products and services that can take place in collaborative spaces such as Fablab.

Keywords: Rural Fablab, rural training, Co-generation agrotechnology spaces, social innovation, open innovation, Digital Innovation Hub.

Riassunto: S. Lombardo, D. Sarri, M. Vieri & G. Baracco, *Proposta di spazi di co-generazione agrotecnologica in aree marginali.*

Nel settore agricolo europeo, il livello di formazione di base è molto basso, nonostante i finanziamenti dedicati. La sfida della nuova rivoluzione industriale in agricoltura rappresentata dall'agricoltura di precisione è un'opportunità per promuovere questo nuovo paradigma tra tutti portatori di interesse nel settore agricolo. Il nuovo paradigma può innescare un cambiamento nell'attuale approccio top-down, consentendo il superamento delle tecnologie utilizzate al momento. A tal fine, si introdurrà il concetto di "*open innovation*" alla ricerca in modo da rendere possibile l'innovazione sociale nelle comunità rurali favorendo un approccio bottom-up. L'obiettivo finale è la co-generazione agro-tecnologica di prodotti e servizi che possa aver luogo in spazi collaborativi come i Fablab.

Parole Chiave: Fablab rurali, formazione rurale, Spazi agrotecnologici di co-generation, innovazione sociale, open innovation, Digital Innovation Hub.

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INTRODUCTION

The main social, economic and technological transformations that human history experienced have been determined by innovation factors in three fields: energy, communications, logistics (Rifkin, 2014).

Now, we are at the beginning of the IV industrial revolution dominated by computerization with the possibility to share, more or less immediately, and to create information, goods and services through sharing and collaboration. This change affects all productive sectors, including the agricultural one that is, however, in some respects back to others, in terms of access to information and knowledge. Data resulting from a study promoted by the European Commission's Science and Technology Options Assessment (STOA) on the future of agriculture in Europe have shown that 91% of farmers have a basic education and only a 6% are specialized. On the other hand, the 80% of people over 65 (representing one third of the current farmers) have not received none (EC, 2016). Figure 1 shows an average of training level across Europe: among the Mediterranean countries, Italy obtains, even if only slightly, the best result.

The histogram (Fig. 1) highlights that the basic training level is still very low in all the age bands (not more than 35%) and the younger classes (below 35 years and from 35 to 44 years) suffering of considerable basic training gap. This shows the gap between agriculture and the ability of accessing innovation, and consequently this leads to considering the endogenous and exogenous reasons associated with it. In Italy, the first agrarian revolution finds fulfillment in the foundation of the Agriculture school promoted by Cosimo Ridolfi (Centro studi sulla civiltà Toscana, 2008) that constitutes the birth of modern agriculture. The second revolution started after the industrial revolution and the Second World War, and it is known as the "green revolution" of the XX century. Nowadays, in view of a new paradigm (industry 4.0), in agriculture the condition for the third fundamental evolution/revolution of modern agricul-

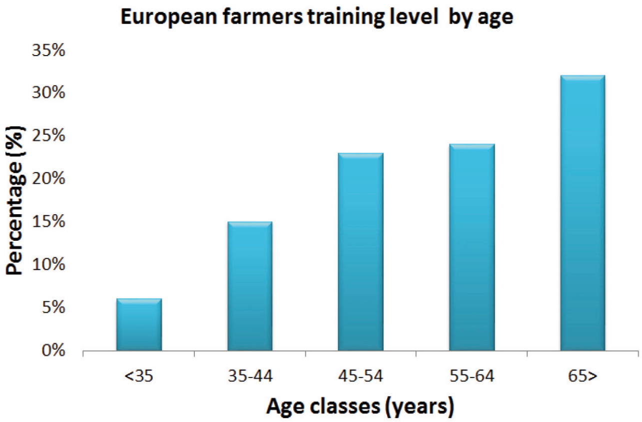

Fig. 1 - Results of European farmers training by age.

ture is being created. It focuses on the computerization (e.g. Internet of Things, IoT) with the objective to increase efficiency, preserving the land (cross-compliance) and sustainability in all its aspects as well as people. In this framework, education in innovation is a useful step to allow farmers to enter quickly and effectively in the transformation underway. In that way, moving from the bottom up approach, toward horizontal and participatory improved methods, can enhance the resilience (intrinsic in rural communities) facilitating the transition to environmental sustainability and social economic models now necessary and urgent (Vieri *et al.*, 2016). About the transfer of innovation, two significant examples of "best practices" at the Italian and European levels related to technology and research results transfer and achieved through the social component of the involved people, were the MATEO (http://www.olivicoltoritoscani.it/pagine/progetti/mateo) and Mars Plus (http://www.marteplus.eu) projects. The MATEO project (Criteria for introducing mechanical harvesting of olives oil: Results of a five-year project in Central Italy), pertaining to the technical and economic business models in Tuscany olive growing, helped to identify the criteria for effectively introducing mechanization (Vieri *et al.*, 2010). The study, in addition to the different levels of mechanization applicable according to well-defined criteria, underlined that the entrepreneurial and managerial skills of the farmer affect the capacity for innovation and improvement of production. This statement is very important because the olive growing is, after cereal crops growing, one of the main agricultural activities in Europe. On the other hand, also the maintenance of the tradition in the harvest should not be seen as backwardness but, instead, as an opportunity for the territory to maintain a knowledge that can be useful for the mechanization, from the standpoint of replication and the improvement of a sustainable and suitable process for that area and community. Another case of European project aimed at increasing the competitiveness of the olive and wine-growing sectors in mountain zones, the so-called "heroic agriculture" was the MARS+ project. The project, starting from an analysis of the evident challenges in the territories of Liguria, Tuscany, Sardinia regions as well as Corsica Island, has set out a framework to transfer technological innovation in order to facilitate the process of mechanization and more generally to increase the enterprise' innovation level in these fragile areas (Tirrò *et al.*, 2013). (The cross-border project between France and Italy MARS+. Sub-project - Innovative technologies for the mechanization of the areas hard to reach). These last two examples showed that combining data on education in agriculture is necessary, also in view of computerization and of the rising of new technologies, to experiment new methods of technology transfer. This is linked with the progress being made in other sectors, where fruitful results are being achieved with working methods that predict and predispose to the creation of development situations and collective, open and horizontal research. This work aims to propose the use of collaborative approach through social innovation methods to achieve the goal of technological co-generation in agriculture (and not technology transfer with top-down method).

FROM TECHNOLOGY *TRANSFER* *TO CO-GENERATION OF TECHNOLOGY*: OPEN INNOVATION IN AGRICULTURE

Technology transfer, in a context in which there is a lack of training and low rate of innovation, and depending on social and cultural factors is still a necessary goal for the competitiveness of the agricultural sector, and especially for small and medium-sized agricultural enterprises (SMEs) often present in limited and marginal territories.

The area of research and development as we know is changing and more and more often is contaminated by the open innovation paradigm.

In this regard, Chesbrough said, "The Open Innovation is a paradigm which states that companies can and should use external ideas as well as internal ones, and access to internal and external paths to market if you want to advance in their technology skills." (Chesbrough, 2003) Figure 2 shows graphically the current closed innovation paradigm and the open paradigm. The old paradigm has certain inputs and outputs, derived by the contribution of technical knowledge and internal development of company products. In the new paradigm, the boundaries between company, territory and community become porous and there is not a defined control of all outputs with the possibility of forming new markets and technological spin-offs. The definition given is important, but not easy to implement if the reality that you take under consideration is the agricultural one. One of the levers to assist in this process is the triggering of a fruitful approach among multiple actors, through spaces dedicated to collaboration and exchange.

The technology transfer model based exclusively on research and development within universities, research centers and companies today is combined if the needing is agriculture oriented to short chains, territory and communities. For these reasons, it is more appropriate to start talking about co-generation of technology in agriculture, which provides a common-based peer production (CBPP) (Benkler, 2006) rather than technology transfer, which provides a top-down approach.

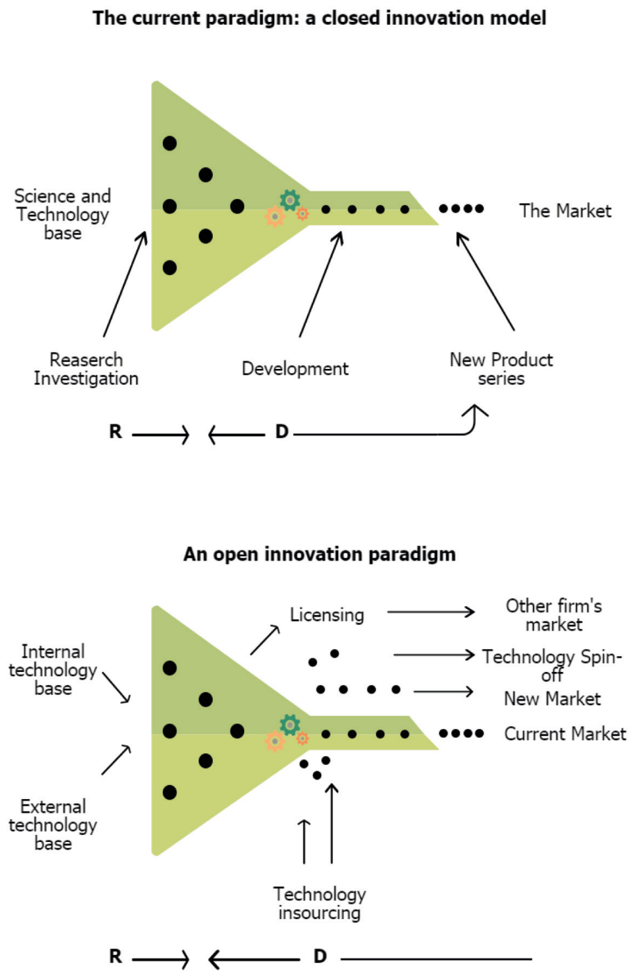

Fig. 2 - Graphical illustration of Closed innovation model vs Open innovation model.

SOCIAL INNOVATION

Starting with one of the possible definitions, we define social innovations as "new ideas (products, services and models) to meet social needs (more effectively than the existing alternatives) and at the same time, create new relationships and collaborations. In other words, useful innovations for society and that increase the possibilities for action" (Murray *et al.*, 2010). Innovation as we have known it is no longer just a matter of new products or services, but often focuses on people. Just think of the social platforms or applications and tools that disintermediate processes (smartphones, for example). Technological co-generation in enabling individuals oriented to sharing and creating value and products generates progress of social innovation in communities making them more resilient and ready to change. There arises the objective of which tool to use to ensure the co-generation of technology in the marginal areas.

CO-GENERATION OF TECHNOLOGY: THE COLLABORATIVE SPACES

Ensuring technological co-generation through appropriate tools can mean resorting to the creation or discovery of physical space to share as, for instance, a collaborative space. The collaborative space is a physical and/or virtual place where there are groups of people finding forms, methods and ways of working, and exchange knowledge involving a high level of cooperation, responsibility and partnership between actors different from each other (researchers, artisans, professionals, businesses, etc.). The goal is to promote the exchange of ideas, co-designing services, places and products, in other words the basics of the open innovation paradigm (Montanari, Mizzau, 2016). In the agricultural sector, a collaborative space can be a useful tool to make up the shortage and fragmentation of skills and abilities, working at the level of co-generation of technology and peer-to-peer education and value creation. The approach used in the collaborative space is at par, of learning by doing, opening the possibility of exchange and comparison among the different actors living and working in the same area: researchers, makers, farmers and all other shareholders (not just stakeholders). Rural communities to support themselves, to be resilient and vibrant, in addition to adopting or perpetrating sustainable models must be permeable to knowledge and innovation. In this process, a crucial role is played by places of meeting and exchange for a community, such as collaborative space, whose main example in urban areas is coworking. In the same way, collaborative spaces in urban areas have been working as a catalyst to make it sustainable and competitive people, skills and activities that are likely to remain excluded from the classic working circuit (due to the crisis and…). It can be thought of borrow this mode - in appropriate forms, and meeting the needs of rural areas - by responding to the practicality of the needs related to the rural world, indicating a different route to outright collaborative spaces. It thus introduces the concept of "third place", which is a neutral ground where the heterogeneity of the actors can come out of traditional working dynamics to approach a new way of sharing, planning and realization of ideas, tools and actions. With this regard, we may need to use different tools from one computer, and we may need to take practical actions "in the field" using specific tools (think of the need for improvement or modification of tools aimed at of sustainable precision agriculture). The interest of this work falls on the so-called rural collaborative spaces and specifically on the role of Fablabs that, thanks to the computerization and philosophy, can be understood as a key tool for the application of Open Innovation paradigm. Fablabs are also community centers where different expertise and skills meet and experience made available for social innovation projects designed to meet the needs of the territory (Manzo, Ramella, 2015).

FABLAB – GARAGE 4.0

Fablab (fabrication laboratory) (Fablab, 2012; Fablab, 2016; Menichelli, 2014) were designed by Neil Gershenfeld, a US physics and information technology professor at the Massachusetts Institute of Technology at the "Center for Bits and Atoms" in 2005. They are a collaborative space for bits and atoms (organic matter) aimed at encouraging experiments with both digital technologies and physical objects, the use of open source software and open and big data processing, the development of solutions for Smart City and Smart Farming. They are spaces where it is possible to learn to use digital technologies in relation with physical reality. Fablab is therefore defined as part of a network, a community, a set of tools, knowledge, processes, but also a service, a business, not a franchise, but mostly it is a concept still under development. There are four rules that distinguish and define a Fablab:

- access to the laboratory should be public;
- the laboratories must sign and show the Fab Charter (http://fab.cba.mit.edu/about/charter/);
- the laboratory must have a set of tools and shared processes;
- laboratories must be active and participate in the global network.

At the moment there are about 663 Fablabs around the world, and Italy with its 63 laboratories (and the number is growing), ranks third in the world by number after the US and France. Of each laboratory activities range in all productive sectors. As for the primary sector, the rural fab lab is a reality less common but still present in the world (actually the first Fablab "ante litteram" was born in India in 2002 with the help of MIT with the goal of developing cheap technology in the rural community of the village of Pabal) (Walter-Herrmann, Büching, 2013). Economic, social and environmental sustainability is the main characteristic of these spaces. Collaborative reality that characterizes those makes them suitable to enterprise creation as well as technological and social innovation thus encouraging new relationships and new partnerships. Social innovation in rural areas is a useful approach to bring the focus back to the products, implies the co-generation of ideas and projects from the bottom, use of technology and new organizational forms that they take as a model the network logic of horizontality. Porter value chain model (product> logistics> branding> finance) is revisited and corrected moving from "chain" linear toward a "system" where the center is the product, whose value increases according those generated by wider communities through storytelling mechanisms and disintermediation. Fablab or rural collaborative spaces are based on real needs: the primary sector is characterized long-standing problems of size and fragmentation of ownership, data management, a lack of innovative capacity, etc. These rural collaborative spaces can therefore be useful to rural producers (farmers, businesses, neorural, "agrigiani"), university educational institutions, technical schools, institutions, community (citizens). All stakeholders in the primary sector can make Fablabs bearing in mind that the bottom co-generation processes are by definition invested in and this requires the presence of key figures such as community manager and/or influencer of rural communities that can be identified among researchers, professionals, farmers, citizens, institutions. Every can contribute with experience, expertise and capabilities, providing even physical meeting spaces. At the macroscopic level, the implementation of a rural Fablab can be anywhere, even if it is preferable to intervene in marginal areas and in peri-urban areas.

Concerning economic aspects, Fablab can be compared to private companies and their efforts to acquiring instruments and tools but the main difference is the knowledge level. Accordingly, the Fablab can be also economically compared, for instance, to a public library where is possible to access freely to the wide and high levelled knowledge. In Italy, usually, establishing a Fablab has the same bureaucracy of non profit associations in terms of rules, costs and constrains. As mentioned previously, the costs affordable for starting a Fablab ranging from € 1.000 for a micro Fablab to up € 100.000 for a big Fablab. The difference is mainly due to the tools' investments, while there are variable costs for spaces' acquisition and management.

The Fablab can be seen as the Renaissance workshops or garages that have given rise to the phenomenon of startups in Silicon Valley to pursue the objective of generating new products and services, models of learning peer to peer, learning by doing and opportunities for growth and cohesion of local communities like the KICs Knowledge Innovation Communities.

RURAL COLLABORATIVE SPACES, PHYSICAL AND VIRTUAL: EXAMPLES

Rural collaborative spaces revolve around the concept of social innovation and make it one of the pillars along with technology and sustainability. At the global level, the Open Source Ecology project (Opensourceecology, 2016) (OSE) is an example of that. The OSE mission is to create a global collaborative platform that optimizes economic development, production and logistics, through the open source collaboration to accelerate innovation like never before. Specifically, the project is aimed to develop and dissemination of the opportunity to create modular agricultural machinery and adaptable compared to all agronomic situations, made for self-construction. OSE is a virtual platform to access, to share and find information as for example, a default set for the realization of 50 different full-scale industrial machines (Global village construction set), like a LEGO set, achievable at much lower cost compared to market costs in order "to build a small, sustainable civilization with modern comforts". The web site specifies all construction costs, plans and the share of software for electronic components is driven primarily by Arduino. Everything is tested physically in a real farm located in Missouri where the reference community of OSE meets and collaborates in the project, also via conference call. The idea, even not easy to achieve because the regulatory reasons tied to the machine's testing (at least in Europe), enters into a well-known mechanism of commerce and embraces a new technology paradigm fully, disintermediating the availability of means and triggering a social innovation process that potentially can be global. In Vallaura, Barcelona, the "self-sufficient lab" is another example of rural collaborative spaces where a green lab, an energy lab and a food lab coexist with University of Barcelona and makers. This “self-sufficient lab”, has a passive structure, used as a place of training and transfer of knowledge to all stakeholders in the rural area around Barcelona (Valldaura, 2016). Other goals of the project are the preservation of the territory, an informed use of natural resources and the promotion of the Nature Park in which resides the complex, allowing, at the same time, the research and development of new water-saving systems or energy use. In Italy, Rural Hub (Ruralhub, 2016) was the first rural collaborative space that involves a network of researchers, activists, scholars and managers. Rural Hub pursuit new models of economic development to meet the social needs and market emerging from the world of new rural enterprises. Born as a collective research for the promotion of the connection between new innovative companies, investors and associations created to satisfy the lack of a business incubator capable of triggering entrepreneurial renewal, technological and sustainable in the food industry. Rural Hub was founded as the first hackerspace that allows the connection, the exchange and sharing between people, ideas, technology and social innovation projects applied to the rural world but also for sharing a living place (co-living) and working (co-working). The main peculiarity of the platforms is the fact of being a tool for enabling shareholders on the platform (physical or virtual) thus determining environmentally sustainable processes economically and socially. The start of these activities is not always an initiative of university or research centers, but as OSE shows us, can be an initiative that starts from the society, by the necessity to respond to a need, bringing back to the community the awareness of actions and of tools that are used in the territory.

FUTURE DEVELOPMENTS

The proposal to develop technological platforms of co-generation in rural areas, and thus supporting innovation in agriculture, is just one of the possible ways to help rural communities, often resilient, to enter in the IV industrial revolution. Other necessary items can be found through other training methods but mostly the key to introduce technological innovation in rural areas can no longer be delegated to agricultural informants or intermediate bodies. This because they are no longer able to intercept the needs of territories and farmers so effective for most of them, as could be a long time. In this, the disintermediation process is a fundamental part of the ongoing paradigm shift. The community platforms, online and offline, which focus on needs, can be an alternative development.

In addition, the collaborative spaces, as mentioned earlier, are trading platforms both physical and virtual. Ultimately, in order to assess whether a country collaborative space, a maker Fablab or space is an appropriate tool to transfer and generate innovation, you have to take into account various aspects, including:

- the land on which we act must be uniform for the needs and sufficiently large;
- the needs should be real and perceived by the community of reference;
- the technology introduced is selected by local actors (is needless to introduce techniques or items that are unfit for land and people) with CBPP approach;
- people who live and work the land are key players in the innovation process;
- a key role is played by the presence of active social innovators within communities (not all innovators know what they are);
- the approach “Open” and collaborative shall be applied by all the players involved or get involved in the process;
- the involvement of institutional players (public or private) has a key role in the sustainability of the starting-up phase of Fablab and of all cogeneration spaces.

Where these conditions occur, you can effectively build rural collaborative spaces. The sustainability of these spaces is another matter that should be thorough but surely, creating social and environmental value, it must be ensured. One of the possible ways, in the case of physical spaces, is the creation of collaborative spaces intended as territorial Hub, where you are delivering services that go beyond agriculture, thus expressing the multifunctional potential of rural areas.

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