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The Agricultural Innovation Under Digitalization

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ABSTRACT

This chapter aims to discuss how the rapid evolution of digital technologies is creating opportunities for new agricultural business models. First, it provides an overview of what the authors consider to be part of the digitalization in agriculture. Then it addresses the emergence of a community of practice based upon the data exchange and interconnections across the agricultural sector. New business opportunities are presented first through an overview of emerging start-ups, then discussing how the inventor farmer profile could create opportunities for new business models through the appropriation of technologies, eventually highlighting the limits of some classic farm business models. Finally, the chapter presents an example of farmer-centered open innovation based on the internet of things and discusses the related business model. The conclusion provides some perspectives on the use of agricultural digitalization to increase the share kept by farmers in the value chain of agricultural productions.

Keywords: Digitalization, Agriculture, Innovation, Business Model, Internet of Things

INTRODUCTION

Agriculture in the 21st century should produce sufficient high-quality food, for more than 9 billion inhabitants, without increasing the surface of production, while limiting ecological impact. The production's increase should be about 70% (World Population Prospect, 2012). Historically, during the second half of 20th century, the intensification of agriculture has been supported by mechanization, plant breeding and chemistry, with some bad consequences over the long term, like pollution and loss of biodiversity.

So, farmers have to decrease the inputs (pesticides, fertilizers, energy, and soil cultivation) and to increase the outputs (production) over the same global surfaces. According to FAO – Food and Agriculture Organization of the United Nations –, the global challenge for agriculture is to produce more with less, in keeping with sustainability (FAO, 2016). Agriculture and farming are inherently linked to food with two aims: enough production and good quality. However, the global increase for both encounter the physical limits of the planet. Waste has to be controlled, water use should be optimized and its quality increased, chemicals and energy inputs should decrease, and biodiversity should be at least maintained. At the same time, it is forecasted an increased innovation in plant breeding, including “orphan crops” (Vanderschuren, 2012), probably a growing amount of livestock and an increased role of urban agriculture. New Business Model (BM) for the food industry are requested and nutrition will be a priority for consumers (Trautler et al. 2018).

This situation leads to a deep paradigmatic change. The soil should no more be used as a simple substrate to which all the necessary elements should be added. It has to be recognized as a global system integrating physical elements, chemical and biochemical elements, and living beings. The mass of living beings in the soil is generally much higher than our domesticated animals which put a hoof on the ground. The interactions of the soil, the plants and the climate define the core of the productive system. The aim of agriculture is to obtain the maximum production, through minimum inputs and so to optimize the functionalities of any element of the system, living or inert. For a farmer, the time is to be spent in thinking about how to organize crop rotations, intercrops, double and even triple plant cultivations, how to maintain the productivity of the soil and the biodiversity of the whole agro-ecosystem, how to sell at the best price a good quality production, how to provide useful energy without buying fossil energy, how to decrease the production costs. The aim of the activity of the farmer cannot be any more a simple producer whose all actions are answers to demands. In order to be adapted to local conditions, it appears that agriculture will become more and more diversified, including both urban agriculture and aquaculture. This new paradigm transforms the farmer job. To be able to increase production by overcoming these constraints, the approach must be globally and radically changed. The agriculture world must leave a simplifying and homogenizing model to move towards a systemic approach in which interactions are increased at different levels. This means being able to produce in a sustainable way, according to the pedo-climatic context and the needs of the territories. Agriculture should be both more and more precise and flexible in a context of global growth (Trautler et al. 2018).

Generally speaking, digitization is the process of producing information into a digital format. It produces a collection of a finite number of signs taken from a countable set of valid signs. Digitization “is of crucial importance to data processing, storage and transmission, because it allows information of all kinds in all formats to be carried with the same efficiency and also

intermingled” (McQuail, 2000). Digitizing means the conversion of analog source material into a numerical format through which is provided a discrete representation; hence it is a reduced or restricted point of view about the use of digital tools.

Herein, the authors use the definition of digitalization according to Business Dictionary. The concept of “digitalization” is much more general than digitization; it includes also the new activities which need digitalized data that means robotics and connected objects, any sensors able to transmit stable information, any tool for the transmission, the treatment or the sharing of data and any type of innovation made possible by digitalization. Digitalization can be considered as a powerful process to produce memory, traceability and previsions.

Can digitalization be a good answer to the challenges of future agriculture? Can digitalization offer new opportunities for agricultural development? Is digitalization a new set of tools for extracting more value from agriculture to upstream and downstream actors of agriculture, in the food chains? Or can it be an opportunity for the farmers to obtain more value from their production? And how can digitalization transform the BM of the farmer in order to create added value?

The bias and the commitment of this text is to analyze the activity of a farmer as if he ran a conventional business. His strategy would be to optimize his revenues by taking into account all its markets and sales and also all its costs. Its choices correspond to a well-identified business model. Instead of looking for subsidies, he demands the payment of the services and products he brings. He uses digitalization as a new way to increase revenue and behaves strategically (mutualization, sales of services, etc.). This proposal is therefore a liberal based model.

First the authors propose hereinafter a simple classification and a description of the digitalization in agriculture. The second part, shows how digitalization of agriculture is an answer to agro-ecological evolution and to the emergence of communities of practice. The third part, describes the dynamics of digitalization in agriculture insofar and some perspective for the twenty coming years. The fourth part is focused on BM in agriculture and the possibility to set up innovative BMs in agriculture, as a fast pace of agricultural digitalization will need innovation BM. The fifth part presents an experiment which offers the possibility to test new models. The conclusion provides some challenges and recommendations for the farmers to keep a part of the added value within agriculture.

DIGITALIZATION IN AGRICULTURE: WHAT IS ALL ABOUT?

Computers, robotics, connected agriculture, Big Data and Artificial Intelligence happen in accordance with the global economic and social change and not only as an answer to the challenges of food production. Both the absolute and relative growths of urban population, increasing cost of labor, decreasing interest to work in the field, or computers and smartphones as companions of everyday life are some robust worldwide trends. The result is a large production of data, so large that Big Data technologies could be useful and Artificial Intelligence (including deep learning) could become a necessity even more than an opportunity.

Nevertheless, the global unfolding of such new techniques can be also an important answer to the challenges of food and agriculture production entangled with the properly agricultural solutions for “producing more with less” (FAO, 2016). Digitalization occurs when agriculture undergoes a need for more precision associated with many constraints on labor and input consumption; so, precision agriculture can be understood as a positive technical answer and could be an opportunity for farmers. However, one can ask the question: under which conditions? We try to propose one of them below.

Precision farming is not a static concept, but an evolutionary process. It is difficult to identify the exact dates when emergence of each cluster of inventions that could take place in the agricultural sector. In most cases, the innovations are made from and through the existing technologies adoption from other fields. We must also take into account the improvement of all these technologies that are constantly evolving. Nevertheless, it is clear enough that the geolocalization began in the 1980s; the agronomic information gathering and data flows processing exist through the development of both Geographic Information Systems (GIS) and sensors for harvesting, soil, climate, plants, during the years 1990-2000; controlled traffic farming, and agricultural production management software around 2000-2010. Data acquisition systems, sharing, integration and valuation (Big data), decision-support tools and artificial intelligence are arising since 2010. The digitalization evolution of these technologies contributes to optimizing and anticipating agricultural production. All this is supported by the mechanical evolution of agricultural equipment.

Computer and Digital Tools

For many years, as soon as micro computers were becoming available, most of the farmers in industrialized countries have been using classical tools of data management, including accounting software and many computerized management tools. In the most advanced countries, for greenhouse agricultural production, computer use has been oriented towards the control of lightening, sprinkling, watering and temperature control. From the outset, drip irrigation was computer-controlled. The most technical agricultural production, in market gardening, horticulture, greenhouse production, and also irrigated production, requires the use of automatisms or computer control that generates data.

Market Data

Farmers can access market information according to commercial data sources, directly from web platforms. It is a source for inspired decisions to sow, harvest or sell. With the global computerization, each decision provides data, useful for traceability, for analyzing the effects of such decisions and for modelling of expected future actions. The market data can shape a completely new customer-oriented agriculture.

Sensors

Many farmer’s actions are typically limited by agronomic constraints including weather conditions. These conditions can be monitored by different sensors, on the moving equipment (flying, rolling, and walking) or set up in the field. The sensors concern different light wave lengths (including infrared and ultraviolet), level of humidity, temperature, ions concentration in the soil, soluble fertilizers, density of some living organisms; they can be associated with

image recognition software. More and more sensors are now used at different scales, in such a way that the entire technical itinerary can be further analyzed and compared to other ones.

Robotics

The first real robots seem to appear in animal breeding (John et al. 2016), and the reason is easily understandable. An animal is a valuable concentrate, and this is probably the historical reason for the development of livestock and herds. Breeding requires a lot of human labor and constant monitoring of the herd.

The converging elements can be resumed as following: labor costs, monitoring and accuracy, improved productivity, and also animal welfare and quality of life for workers. So, it is precisely in the production with the greatest added value that robots have been first put in place.

Generally speaking, the development of IT (Information Technologies), robotics and digital technology began within high value-added professions. The fall in the costs of these technologies (Moore's law) has led to a gradual widening of uses, with the following chronology of computerization: military industry, banking-insurance, pharmacy, aeronautics, automobile, food industry, then agriculture (livestock followed by vegetable farming with high added value and then large field crop farms).

For crops, the highest added values are in vineyards, market gardening, horticulture, and then fruit groves. When highly mechanized, large field crops can also have good added value per worker. New regulations to limit herbicides and phytosanitary products lead to opportunities for land rolling and flying robots. In particular, the will to avoid herbicides leads to robotic weeding, the first uses of which concern vineyards and market gardening. The robots' latest generation carry more and more sensors.

GPS, Imagery, Mapping

Field crops have entered the digital age thanks to global techniques used in other markets (GPS, image processing). Cognitive processes derived from knowledge of plant physiology and agronomy have been integrated into the system to provide precise tools for monitoring and anticipation.

Smartphone

Farmers have adopted smartphones (Pongnumkul et al. 2015) very quickly as a support for many applications in monitoring production and acquiring daily information. Smartphones become terminals allowing access to all the more or less autonomous tools of the farm. It can also be used as a sensor (imaging).

Internet of Things (IoT)

Today, all tools can be interconnected, allowing farmers to follow in real time what is happening on their farms. They can now even design new tools that they will be able to control. Connected objects, which produce a large amount of data, can feed Artificial

Intelligence and interconnected robots can evolve towards a more and more adapted behavior through detecting and monitoring of the actions.

Data processing, Big Data, Artificial Intelligence and Deep Learning

All these techniques produce data from different origins, in different formats and in such quantities that no classical statistic can be used for translation or interpretation. It is the domain of Big Data.

As the conditions on a farm are all the time changing, Artificial Intelligence and Deep Learning will be very quickly useful. As the cost of these techniques should decrease, it could be within farmers' grasp. Big Data, Artificial Intelligence and Deep Learning could be done at the level of the farm and at the level of groups of farms before being directed at integrating operations across larger scales. These treated Data could have high values.

IMPLEMENTATION OF DIGITALIZATION AT FARM LEVEL: EMERGENCE OF NEW COMMUNITIES OF PRACTICE

The global digitalization of economies around the world has its counterpart in agriculture. Precision farming cannot be developed on a large scale without digital tools. Mapping of farms is now possible thanks to GPS and drones with multispectral sensors. The geospatial information provided by the satellite has an important application in so-called "precision agriculture", improving crop management. Drones could also be important for a similar aim. Specific physic-chemical sensors provide the measurement of edaphic and meteorological conditions. Sensors can also drive precision mechanics and new technological tools (autonomous tractors, robots). Collected data can be transferred and processed at the level of the farm or a collective of farmers for decision-making aids. All information coming from the field can be connected to the analysis of marketing and consumption data. Web-based platforms can be used for information exchange and comparison performance between the farmers. The challenge of information connection networks is important for farmers because it is their autonomy that is at stake. They must be able to process the information themselves before scaling up and being able to value the information.

Technologies are allowing agriculture to be more precise and smart. The development of precision agriculture and its support, the digitalization of agriculture, is leading to the emergence of many new approaches that combine agronomic knowledge and agricultural know-how with computer skills (Caroux et al., 2018). The emergence of such trends is seen by the publication of recommendations or work by actors and specialists of the agriculture domain, by the creation of many startups since 2010 and by the development of new applications. Indeed, all around the world, there are hundreds of start-ups counting on the digitalization of agriculture.

The animators of the Digital & Agriculture Network ACTA in France, analyze the problematics related to the explosion and the capture of Big Agricultural Data (Brun and Haezebrouck, 2017). They propose through ten recommendations, three key areas of improvement for data management and use in agriculture: “Innovate”: collaboration and technicality, “Fluidize”: both accessible and shared data and “Reassure”: a transparent and respectful use. *Farmers Business Network SM*, an independent network of thousands of America’s most advanced farmers is already sharing data for production improvement. Technologies related to agriculture data are able to transform the profession of farmers and also that of companies in the sector: cooperative or private agricultural distribution companies, food industrial firms (traceability for crisis prevention), consumer relations (personalized marketing), etc. Agricultural social networks providing valuable data is a possible consequence of the emergence of agricultural “Big Data”.

Precision agriculture is made of techniques that allow farmers to deal specifically with those parts of a field that require special or different attention; this precision could reach the level of one plant.

Digitalization involves networking and connecting farmers: with each other, with their suppliers, their advisers, their customers, and also with the connected objects providers. Connected objects are mobile or transportable objects like sensors in the field, robots, drones, smartphones, or even autonomous tractors.

All these connected objects could send their information to treatment centers at different spatial scales. Farmers should be aware that information control concerning their own data is a really an important issue. The precision required for the monitoring of agricultural production will require many precise actions that can only be performed by more or less mobile, interconnected and interacting objects.

All the data produced already by agriculture require large processing capacities. The generalization of precision agriculture, which means connected objects and “internet of things”, will require the implementation of Big Data tools. However, these developments need first to be able to qualify the data that means to choose the useful data for agriculture and the first best level is the farm.

Connected agriculture can be described as a community of interconnected farmers suppliers and customers through digital operators (solution providers, agri-equipment and robotics players). Connected agriculture allows for a high accuracy of actions and monitoring of production. Interconnection of data coming from connected agriculture, from the different markets of the food chain and from the demands of consumers could provide a lot of new solutions to solve the global social demands.

Current solutions, such as service providers where data is retrieved by reselling companies either as Decision Support Systems (DSS) or to other companies for marketing / commercial purposes, are unsatisfactory to farmers. (1) Most of the proposed solutions are generic solutions, they do not necessarily correspond to specific cases; (2) customized solutions realized by businesses, (often SMEs) would be too expensive (3) the collaborative aspect between farmers involving knowledge sharing is then low: indeed, providers can centralize both data and “black box” decision tools, without great collaboration between farmers of the same regions (Information collected through interviews with French farmers).

According to Stratus Ag Research survey conducted in 2016, less than half interrogated farmers are satisfied with their current methods for analyzing and interpreting their agronomic data to make decisions.

In addition, farmers are increasing their awareness and concerns about the access to and the use of their farm data (American Farm Bureau Federation, 2016) and the related major shift in role and power relations. Finally, a report prepared for the European Parliament warns “As a result of these asymmetries, farmers’ own particular needs and rights may be ignored, and inequalities are at risk of growing due to data-driven insights, rather than be reduced” (Kritikos, 2017, p. 41).

THE NEW BUSINESS OPPORTUNITIES OF DIGITALIZATION IN AGRICULTURE

Emergence of Start-Up in Agriculture

The development of precision agriculture and its support, the digitalization of agriculture, is leading to the emergence of many new professions that combine agronomic knowledge and agricultural know-how with computer skills. The emergence of these new professions can be seen by the creation of the many Startups since 2010. A lot of them are founded by young graduates from the agricultural world.

For example, among the fifty or so start-ups of the French Agtech in March 2017, we can list: Agriconomie, a web platform specialized in agricultural supplies; Agrifind, a web platform that allows experienced farmers to maximize the value of their know-how and/or to help other farmers who need reliable and operational information; Airinov, with the first multi-spectral sensor carried by a drone to measure crop growth; CarbonBee that uses specific sensors to discover blight at an early stage; CompareteurAgricole.com, a web marketplace where farmers sell their grain at the best price; Diimotion, with the PiX, a “printer” for phytosanitary products; Ekylibre, which offers open source tools to enable more efficient and simpler management of farms. Inalve, which proposes the production of a microalgae-based plant meal for animal feed; Karnott, the connected notebook, allowing to share agricultural machines; Les Grappes, a community platform for the direct purchase of wine from winemakers; MiiMOSA, a crowdfunding platform dedicated to agriculture and food; Monpotager.com, a concept of kitchen garden connected between the producer and the consumer; Myfood, sells connected greenhouses to those who wish to produce their own food. Naïo, sells agricultural robots helping farmers to weed, hoe and harvest; NeXXtep, offers smart and connected objects for farms (traceability, supervision, security); Piloter sa ferme, the robot consulting platform in agriculture dedicated to risk management; La Ruche qui dit Oui !, a short distribution channel through direct exchanges between local producers and consumer communities; Tibot technologies, automates some difficult and repetitive tasks in poultry farming; Vitirover, the robot which maintains the inter-rows of vineyards. YourMachine.com, a digital platform of localization / mutualization of agricultural equipment; Weather Measures, an expert in precision meteorology; Weenat, with ultra-local data sensors transmitted in real time to farmers.

In addition to start-ups, groups are developing new applications in many areas. All stages of agricultural activity are now transformed by the use of digital tools.

Early Adopters or Inventor Farmers

Why should farmers be inventors? How can they be? It seems that there are several modalities of technical invention in agriculture. Caroux et al. (2018) categorize innovators according to two ordinates: more or less machines, and more or less strong suitability for the dominant model. However, whatever are the general representations and objectives of innovative farmers, their main and common quality is to seek concrete solutions to local and recurrent problems.

Cost and lack of knowledge are widely identified as the two main obstacles that farmers have to overcome to involve into new technologies (Doye et al. 2000; Reichardt et al. 2009; Pignatti et al. 2015). The approach we will propose in the last part of this study is to put farmers at the heart of innovation, for instance by observing their propensity to innovation based on low cost and do-it-yourself tools. The aim is to correct a common research and development approach that considers farmers as simple end-users. The main limit of such an approach is to fail at embracing the complexity of their decision-making (Douthwaite and Hoffecker 2017).

The presentation hereafter aims to trace the evolution of agriculture in terms of BMs that have been designed and developed for about 60 years to understand how the farm operates in its environment. Then, a new type of platform, such as “AgriLab®”, a collaborative innovation center for agriculture based in Beauvais (northern France), will be described, with the questions: can this new technical proposal lead to a new type of successful BM? Can farmers be inventors directly involved in the future of agriculture? Is the digitalization of agriculture able to foster a new kind of development? Is there a new type of development able to answer to the challenges of today’s agriculture? The authors will try to clarify these questions and to propose a global model and possible tests in the conclusion.

AN OPPORTUNITY FOR BUSINESS MODEL CHANGE: APPROPRIATION OF TECHNOLOGIES BY FARMERS

Business Model Concept in Agriculture as a Conceptual Revolution

For a very long time, during the history of agriculture, farmers were producers. Farming was more a way of life, the basic way of life of the population, than a job. They were obliged to produce enough to feed their family and also to return a tithe that means to feed more than their own family. In some historical cases, reduced by serfdom or slavery to meet only survival needs, they could achieve a much higher production, added value that was confiscated.

Jobs and businesses were invented about the same time as agriculture and increased with metallurgy, development of handicraft and trade. Since antiquity commercial activities have developed in more or less luxurious delicacies: bakery, sausages, dairy products, sweet and alcoholic products, drinks, sweets, ice creams ... We know the history of Thales which was able to cause a shortage of oil and an increase in prices by buying a sufficient number of oil presses in time.

The customer-oriented products were not pure farmer's products. And even the grain trade was a state activity or wealthy merchant's activity.

The famous "crisis" of the tulip in the Netherlands, which occurred in 1637, can be conceived as an indicator of the beginning of a new type of agriculture, market and business oriented. It is significant that it began in horticulture, in the richest European country. Many new species were cultivated and an economy of plant breeding appeared. In northern Europe, and more particularly in the United Provinces, horticulture and gardening became a real market. Dutch gardeners cultivated roses, lilies, iris, peonies, columbines, wallflowers, carnations, anemones, snapdragons, hyacinths, jasmines, lilacs and of course tulips. Flanders and United Provinces entered in a new technical and marketing revolution in agriculture, from a producer stance to a merchant stance.

In parallel, the movement of enclosures began in the United Kingdom at the end of the sixteenth century. Between 1604 and 1914, thousands of official enclosure acts were passed, covering millions of acres. Community-grown open fields and pastures were converted by wealthy landowners into pastures for sheep in the aim to answer to an expanding wool trade. In more rural countries, the agricultural economy remained a productive economy.

According to the historian Patrick Verley (1985, p. 204), "historiography has long focused on the phenomenon of enclosures and its social consequences, however they do not constitute an agricultural revolution, they are only a prerequisite, which does not lead automatically to a progress in production and productivity". To transform the farmers from producers to entrepreneurs and managers is a long way. It is probably not a coincidence that the most efficient and most digitalized European agriculture is in the Nederland.

The concept of the farmer's BM is not yet obvious. Even in the most advanced countries, many barriers do exist when farmers are led to consider the possible innovations of agricultural BMs. A start-up has a high probability to fail. So, the farmer cannot take this type of risk. . "The farmers were quite comfortable talking about their existing farming operations with the help of the Canvas (its blocks and barriers). However, farmers had more difficulties in creating a new BM that required innovation. Their focus was nearly always on their own farms, and not on meeting customers' needs" (Sivertsson and Tell, 2015).

The history of Dutch agriculture, very early focused to meet customers' needs could give an idea of the difficulties to build a BM in agriculture. Any business is focused first to the customers' needs (Amit and Zott, 2012). However most of the farmers, on many European farms, are focused on production, on what is done on the farm. It could be useful to understand what the implicit BMs are in standard agriculture and to have a review of the existing proposed BMs up to now.

Is There an Implicit Business Model of European Farms?

It is difficult, and it could have no sense, to define a single BM for agriculture. Indeed, there are different types of production for which the relative costs of land, investment in material or productive living organisms, or even labor costs are different. For example, viticulture, arboriculture, field crops, market gardening, floriculture, breeding for milk production, production of eggs or broilers; there BM is as different as the markets they serve.

It is true that a large part of agricultural production releases a small margin (as any row materials production), contrary to high value products/services. Nevertheless, there are a few counter-examples. The range of the food and beverage products remains very broad, from commodity products to highly specific technical products even to luxury products; for example, how can you compare the wheat food chain and Champagne?

Generally speaking, the design of a BM in agriculture poses specific problems compared to anything known in industry or services. Indeed, a fundamental trait of the implicit agricultural BMs, as it was installed in the developed countries, since the 50s of the XXth century, is to associate the features of a heavy production industry of intermediate goods - which has long required large structures - to those of micro-enterprises which cannot individually control their markets.

About the production of high yielding cereals, in France, structural costs are close to 75% of total expenses, those corresponding to material investments (land + equipment) often exceed 40% (ARVALIS, 2005; Longchamp and Pagès, 2012). In viticulture or arboriculture, the investment for plant growing until production begins may require from 3 to 10 years.

An important share of agricultural products has a short shelf-life and consequently a significant degradation of the potential value over time. It should be sold quickly, even if it means selling off. Under these conditions, the end customer loses its importance; the priority concerns of quick sale if not immediate. In some cases, the answer is to be found in additional investments (for example, conservation of apples or potatoes in cold rooms). The exception concerns mainly cereals which nevertheless know the other two problems (structural costs and return on investment).

A farm manager is very often, if not generally, under the pressure of a high debt ratios with a return on investment that is constituted by the overall capital valuation of the farm. It can be compared to insurance companies, drinking water suppliers or steel industry. It is therefore the conventional risks of a low-differentiated intermediate goods company that must invest continuously in order to lower its production costs. Such managers have acquired the necessary training that farmers have generally not received.

Apart from the most advanced agriculture, as in the Netherlands, whose historical component we have seen, in agriculture we continue to calculate with reference to the surface of the exploitation (ARVALIS, 2005), that is to say by hectare and not according to the quantities produced and the value of the production per unit produced. Farmers are able to track their production costs per unit of economic output are still few, and of course fewer master any marginal analysis.

As a result, obtaining accurate data on cost allocations per unit of economic output is generally difficult in agriculture.

A farm is mostly a microenterprise because even a farm of 3000 ha or more, in field crops, is a small business, with no more than six full time employees. In comparison a 30-ha farm of vegetable production can be equivalent or even larger in turnover, and so is rarely described. Agricultural enterprise with a staffing level near 100 full-time employees exists only in countries like Brazil, Argentina, and Malaysia or in the “Black Sea countries”. There are concerns in France about emergence of 1000 cow’ farms without realizing that compared to any sector, it is only a small office. The majority of farms in Europe are personal enterprises whose business transfer is that of inter-family and intergenerational exchanges of the property.

Patrimonial security prevails over all other considerations. There is probably a fundamental contradiction between the agricultural legal status and the BM. The separation between land and ownership of productive material could reduce the inconsistency between BM and heritage issues, while it can make more visible the other components that slow down the choice of a new BM.

This leads on almost all agricultural markets to the fact that there is still a large number of farmers producing the same products, with the result that there is a very great difficulty of differentiation, with a market definition that can only be obtained through large mutualization of the production. Consequently, farmers are focused on their production tools much more than on the satisfaction of their customers.

It is under those terms that agricultural activity has to deal with a variability that most other economic activities have been able to protect themselves against: climate variability. It leads to more or less chaotic succession of over- and underproduction. The current globalization context leads to competition between multiple agricultures whose cost structures, pedo-climatic conditions and climatic variability are very diverse; this also does not simplify the construction of suitable BM, apart from the focus on lowering costs and the race for productivity. Historical series, from longer terms perspective, show that agriculture needs regulation, stock control and subsidies in order to maintain a satisfactory level of production at a reasonable price and good quality and to be able to quickly compensate for local underproduction due to climatic accidents, and/or for global overproduction that causes price collapses and local failures. Can a new type of BM be installed within an agricultural undertaking that would be closer to standard industry and service valuations? Is this transformation conceivable? Moreover, if the value brought by the farmer also includes the maintenance of the landscape, we should define who pays for it. It’s an old debate (Beuret, 2002; Raymond et al. 2015; Kissinger et al. 2013). Can and should we incorporate subsidies into the BM? According to the BM approach, subsidies should be considered as a revenue which should be received according to a production or a service. Is it just a solidarity between the haves and the have nots, or a payment for a fundamental service to the society?

BUSINESS MODELS REVIEW AND ITS APPLICATION IN AGRICULTURE

Business Models Review

Different notions of BM have been studied in management research, including Canvas BM (Osterwalder, 2004; Teece, 2010), BM Innovation (Chesbrough, 2007a; Amit and Zott, 2012;

Foss and Saebi, 2015; 2017), BM for sustainable innovation (Boons and Lüdeke-Freund, 2013) and sustainable BM (Bocken et al. 2014; Biloslavo et al. 2018). These authors have tried to clarify the origin of these concepts and the future research questions using some theories (such as Innovation and Entrepreneurship theories) and research streams like open innovation and sustainability (Foss and Saebi, 2018).

Biloslavo et al. (2018) summarized the evolution of 20 definitions and components of BMs between 1998s and 2016. Timmers (1998) defined a BM as “an architecture for the product, service and information flows, including a description of the various business actors and their roles; and a description of the potential benefits for the various business actors; and the description of the sources of revenues” (p. 4). Between 2000 and 2005 the authors, like Hedman and Kalling (2003), focused the BM definitions on connecting different actors with strategic dimensions (core strategy, strategic resources, etc.). Since 2008, the BM definitions included other components: customer value proposition (Johnson et al. 2008); value creation, delivery and capture (Teece, 2010). In order to create value, the BM has been studied also in innovation and technology management domains. Chesbrough (2003) considered on one side the BM as “a subject of innovation”. On the other side, he showed that open innovation can contribute to create value by sharing information and knowledge between innovators. In this case, the BM is seen as “the open BM” (Chesbrough, 2007b) or “the BM Innovation” (Mitchell and Coles, 2003; Chesbrough, 2007a, 2010; Foss and Saebi, 2017).

In the last years, some authors have addressed the BM in the Internet of Things (IoT) industry. Metallo et al. (2018) present the main literature about IoT-oriented BM from two perspectives: technical and managerial. The first one, IoT technology is considered as “a platform-based ecosystem”. The platform’s architecture, governance and environmental dynamics can influence the co-created value within the ecosystem (Tiwana et al. 2010). The second one, the ecosystem included the connections between BMs designed by the firms and the external environment for IoT technology (Hui, 2014; Westerlund, 2014; Metallo et al. 2018).

Biloslavo et al. (2018) showed that BM definitions exclude “natural and social aspects of organizational environment”. Hence, they proposed a new model named ‘Value Triangle’ that includes three main components (p.755): the value proposition; the value co-creation and co-delivery system and the value capture system (Bocken et al. 2014).

The purpose of this chapter is to focus on new BM for open innovation in four French cases of farmers. So, the authors consider that the farmer, as an actor, can change the type of BM when his/her status changes. The authors tried to identify the BMs of farmers before and after digitalization and how these farmers are building their innovative BMs via IoT technology and are promoting sustainability.

Digitalization is a real challenge in agriculture; it is generally described that digitalization changes the efficient BM, and the emergence of new type of network companies is really convincing. However, as agriculture is still to produce the basis of food, as it has been for millennia, how could digitalization change that? Before trying to answer this question, we have to study what could have been the implicit BMs to explain the agriculture activity.

Business Models Application in Agriculture

The BMs research focused on large companies or technology innovations and pays little attention to the farmers' case. Sivertsson and Tell (2015) identified some barriers, linked to human, contextual or governmental parameters, existing when Swedish farmers tried to innovate in their BM.

The authors tried to adapt the BM canvas, as proposed by Osterwalder and Pigneur (2010), to four farm group models, i.e. "four major ways of conceiving and modelling the farm" that can be thought as trials to understand the farm in the evolution of agriculture, according to Laurent et al. (2003). The article by Laurent et al is premonitory by its anticipation of a multifunctional model that is becoming the agricultural reality of today. Through a selective literature review the authors highlighted four models to address farm multi-functionality. The fourth model looks like preliminaries of how to conceive multi-functionality afresh.

Based on the analysis of three research programs that are relevant to three major developments of the world of agriculture that are currently under way, this article described that agriculture is entering a new world that will have to be tackled in a totally new way (anticipation of digitalization). Recall that the year 2003 is the launch of the BlackBerry 7200, the first smartphone sold on a large scale that almost no family farmer could hear about. The market for such a product was concerning geeks or managers in large or international companies. The same year, organic agriculture, in its first period of growth, reached in France 400 000 ha, about 1.3% of agricultural land, the OGM surface reached nearly 80 million ha in the world (about 5% of cultivated land) after a regular growth during seven years and conservation agriculture began also a large growth and could have reached at least 50 million ha, most of them in the Americas and Australia.

For the last twenty years, agriculture has been changing at an accelerated pace, and it seems that the acceleration is going on, all around the world. This chapter presents a French experiment, although the change it described could be easily extended to European and worldwide agriculture.

Here the authors propose a simplified presentation of these four "farmer" groups of BMs based on the categorization by Laurent et al. (2003), according to the canvas proposed by Osterwalder and Pigneur (2010). Usually, the value proposition is considered as a value for the customer. We choose here to define this value as a pillar for the farmer. Even when he/her produces a labelled product (organic farming, protected designation of origin, quality labels, etc.), the labelling is mostly collective and not the property of the farmer.

This group of models (Table 1), described here schematically, according to BM Canvas, is based on the micro-economic theory of the firm with the explicit aim of providing support for farm management and contributing to the establishment of a scientific organization in agriculture. It has been developed first in the United-States, before the Second World War, and at the beginning of the fifties until the end of the nineteenth of the XXth century in Europe. This BM also attempts to describe the actual functioning of farms, with an aim in the background to analyze the functioning of the sector and to assess the impact of agricultural policies.

According to this type of model (Table 1), the farm is described as a business from a normative perspective. It seems difficult to give some precise empirical content to this type of

model. This group of BM has become more complex through the integration of the utility function of the farmer and taking into account the perception of risk in farmers' behavior. Nevertheless, it does not lead to a new concept of farming that simultaneously accounts for its environmental, social and productive functions.

In this model (Table 1), most of the value added is transferred to partners, downstream or upstream. For the farmer, the value he or she appropriates corresponds first of all to a patrimonial model: the value of the land estimated through its yield potential.

This second group of models (Table 2) claims an approach to farming as part of a larger economic and social dimension, the regulation of which does not depend only on market forces. The point of view is more structural. The farm is integrated in a set of farms more or less similar, which leads to business combination and divisions of labor. As for the previous model, work is conducted in a normative perspective. It is a model that meets the work of rural sociology. It puts the farm more into perspective which takes into account all the agricultural transformations. However, like the previous model, the articulation of environmental issues with economic and social dimensions remains limited.

This group of models (Table 2) incorporates the role of functions or material mutualization and therefore of cooperatives, which are at the same time partners, customers and suppliers. It is possible that the mutualization is a way of preserving the relatively small farms, maintained by the existence of cooperatives, whose activity is to pool a number of functions that are those of conventional enterprises. These cooperatives play an entrepreneurial role by mastering the logistics, the storage and in some cases the marketing and the transformation and thus position themselves as competitors of the private companies.

These models began to be developed during the 1970s and continued to expand until the late 1990s.

This third group of models (Table 3) stems, among other things, from the fact that farmers do not automatically adopt agronomic research proposals. They do not seem to behave like "rational actors" seeking to maximize profit or income. In these models, the point of view of the farmers on their actions and decisions is much more taken into account and even will be the most recommended. These models use the theory of the general system and postulates a limited rationality of the actors. Real agricultural practices are integrated and lead to the development of expert systems, their effectiveness in the face of hazards are evaluated. They open up the possibilities of understanding the multifunctional nature of farms, although they put non-agricultural activities out of the scope of analysis.

These models began to be designed and developed during the late 1970s and continued to expand until the late 1990s.

This fourth group of models (Table 4) analyzes farming by asking first and foremost the nature of farmers' organizational choices and their efficiency. Modeling is no longer built through the production function. The farm is considered as an organization that coordinates various activities. Like the first two sets of models, since the measure of efficiency is central, the designers' posture seems initially normative. The aim is to evaluate the economic efficiency of organizational choices, from the minimization of transaction costs and organizational costs.

There are crossing points between the third group and this one. The economic theories of the organizations are mobilized, the outsourcing choices are taken into account. Several different analytical approaches are used. The problems of natural hazards, including climatic hazards are taken into account. The diversification choices are studied, according to several approaches, including pluri-activity. Some approaches understand farming as an information and communication system.

This group of models (Table 4) is the most disparate, different theoretical fields are mobilized, the empirical work applied to farms being relatively rare. Finally, it turns out that this model group brings together different lines of research that come out of standard micro-economic models. This is not, despite the initial appearance, a normative stance; it is a research that tries to capture the new characteristics of farms in a context of change.

Synthetically, the first group of models tries to describe the articulation between the economic and agro-technical dimension. The second adds the social dimension, the third considers the strategic approach and the fourth anticipates the emergence of information systems, flow optimization and information processing. We can see the contribution of transdisciplinary and interdisciplinary in the agricultural world with the evolution of approaches. Implicitly, these models are bent on the agro-ecological and territorial integration, they lack both an integrated conceptualization and the right adapted tools (Berthet, 2014).

The Transformation of Agricultural Activities and the Need of Digitalization

What emerges from the article by Laurent et al (2003) is that, since that date, both society's expectations of agriculture and the practices of farmers have changed. In 2017, all researchers studying the evolution of agriculture are convinced, even if the models of the farm of tomorrow remain uncertain.

Ten years after that article, Marraccini et al (2013) confirmed that farmers are still, and increasingly asked, to fulfill several functionalities and services (basic food production, energy save and production, waste recycling, landscapes management, economic vitality of rural communities' maintenance, protection of sensitive biotopes, biodiversity blooming, etc.). Farmers also seek a balance of their activities either by pluri-activity or by diversification. All of this combined, it appears a completely new model that leads to reconsider the analysis of the operation at varying spatial scale, depending on the point of view considered and usually largely exceeding the farm (Munroe et al. 2014).

The requirement of traceability of the sectors associated with landscape and biotope conservation, and also Carbon Dioxide (CO₂) caption and storage, generates new constraints far exceeding the scope of the farm. Furthermore, the need for precision farming to save inputs while optimizing production can also provide the means for increased traceability of actions. Combining precision, digital tracking and traceable action are technically similar goals, thanks to digitalization. It is of course necessary to define the economics of such developments.

Farmers diversify their production and develop pluri-activity. It is important for any type of statistics about agriculture that the farms managed by such farmers be accounted for in agricultural activities. It is even more important that they are also digitized in a similar way.

Any study or benchmark corresponding to scale levels beyond the activity of the farm must be able to be based on the activities of all farms included in the referenced higher scale.

The references of agricultural production methods have been transformed: organic farming, conservation agriculture, agroforestry, sustainability requirements, peri-urban and urban agricultures. In terms of quality, we have attended the multiplication of quality labels and protected designation of origin (mostly in Europe). If production optimization tools in each cultural context and for each cultural itinerary are digitally monitored, it will be possible to follow the production and guarantee its traceability. We can imagine that this will provide tools for monitoring and productivity improvement. The whole question will be to have the right sensors corresponding to the criteria that will have to be followed.

At the same time, a still growing surge of connected objects, Big Data, Artificial Intelligence and robots is taking place. The number of smartphones in the world has reached 2.3 billion, farmers becoming one of the most equipped social groups (Beza et al. 2017). The number of connected objects has exceeded the number of human beings and its exponential growth continues. The number of industrial robots increases by nearly 700,000 per year, and now they reach agriculture. Connected objects means connected tools; any type of existing tool or new tools or new sensors could offer the possibility for collecting and monitoring precise information.

Faced with the complexity of agricultural activity, now at the crossroads of agro food chains and controlled regions that can be revitalized by the bio-economy, it is much more than just a simple economic model that is to be accomplished. We have to build the concepts and the tools for the various and integrated models that will emerge. It appears that digitalization could offer the possibility to accumulate precise data for two different and complementary aims: traceability and improvement of efficiency. Both of these goals should be pursued far beyond the agricultural parcel and farm levels.

Internet of Things Business Models: A New Opportunity for Farmers?

The new situation in the development of a multifunctional agriculture and in the enlargement of farmer's activities has some heavy consequences. First, this situation could result in the need to separate the farmer from the farm, which could lead to a change in farm businesses law. This may lead to another revolution, as this modification will have to be made taking into account other modifications of the current general context.

Second, it leads to asking who are the customers of the farmers who participate to functionalities which go beyond the perimeter of their own farm? (Hansen et al. 2014). It can be about biodiversity, even relatively local, protection of the grounds and water, landscape maintenance, CO₂ capture, etc. Indeed, it seems hard to imagine that a farm manager would invest time, skills and money in activities whose benefits revert to different collectives and at different levels of scale and yet this is taking place (Bühler and Raymond, 2012; Raymond et al. 2015; Primdahl et al. 2013). He must be paid and his service should be evaluated. The evaluation of farmers' services requires various tools (Digitalization) that will indicate, on the one hand the actions actually undertaken and on the other hand the measured effects (Everard, 2011). It will be necessary to move also towards outcomes guarantee. And it will require data to build the relationship between means and outcomes. So, the farmer could be paid as his

service is evaluated, and the payers could be satisfied to go beyond the only guarantee of means.

All data provided by connected objects must be shaped and analyzed by cognitive models derived from scientific knowledge to be transformed into measurement tools and decision support tools. Only then can data make sense. As noted by Corentin Cheron (in Caroux et al. 2018, p. 103), the raw data collected must be analyzed and transformed locally because it is first a question of defining relevant interpretation and acting directly. It is after this first stage that the aggregations at different levels can become interesting. In the same parcel, and on the same farm, data comes from various connected objects that contribute to new significant data. While it is important to maintain raw databases for traceability purposes, it may be important to know what is useful for integrations at larger scales.

Used as results' proofs but also as tools for improvement, data may belong only to those who produced it. However, this may not always be the case. For the study and the follow-up of functionalities which can only be followed beyond the farm, it seems logical that data can be the property of the bodies funding the data collection at the larger scale.

We can conclude that, even if it is still a question of research, it now seems possible to design and implement specific BM built from IoT. It can be a real opportunity for farmers to obtain adequate financing for their production of non-marketable features.

AN EXAMPLE OF FARMING DIGITALIZATION: THE FIRST AGRILAB® BOOTCAMP

Farming digitalization is considered to require high skills in new technologies. Workshops and open labs can facilitate the appropriation of such technologies by farmers. In this perspective, UniLaSalle organized its first bootcamp – an intensive participative workshop – about the IoT in smart farming (UniLaSalle, 2017).

Goal and Organization of the First Bootcamp

This first bootcamp aimed to provide an open learning environment hindered on the farmers' needs to enhance their decision-making by connected sensors. It lasted two days and a half (24-26 November 2017), with the participation of six voluntary farmers (members of UNEAL, NORIAP and Agora cooperatives), 39 master degree students (mostly in agriculture and agroindustry), ten experts in digital technologies and agronomy, and some observers. The perspective was to start a free and open knowledge base shared under Creative Commons license (AgriLab 2017). Experiences like Open Source Ecology (<http://opensourceecology.org/>) and its French homologue Atelier Paysan (<https://www.latelierpaysan.org/>) show the interest for boosting grassroots innovation path drawing upon free access to others' experiences.

The bootcamp was coordinated by AgriLab®, a collaborative innovation center for agriculture based in Beauvais (northern France), and part of the sustainable development UniLaSalle program, whose main aim is to promote digital innovation and open source

involving all stakeholders. The bootcamp was backed by the Chaire “Agro-Machinisme & Nouvelles Technologies” together with by the Region Hauts-de-France through the INS’Pir regional program for digital and social innovation. In addition, the Wolfram Company and RS Components provided their technological expertise.

Farmers were prompted to address their main current needs for farming management, namely by exploring the use of connected sensors to improve the monitoring of physical environmental variables and for decision-making support. They can choose among the latest cheap and open source technological “building blocks”: Grove sensors, Arduino and Raspberry Pi, gateways and LoRa radios, a 3D printer, etc. In addition, they had access to a cloud data repository (Wolfram DataBin, InfluxDB time-series database) and to Wolfram technology data analysis software (Mathematica and Wolfram Cloud).

The first half-day started with the introductory conferences dealing with data, IoT and project examples. In particular, CongDuc Pham (LIUPPA, University of Pau, France) provided a wide array of examples concerning the use of low-cost antenna technology for low-power wide-area network IoT in rural applications (Pham et al. 2017) issued from the WaziUp H2020 research project (<http://www.waziup.eu>). Afterwards, four farmers formed each a group with the students, starting to define their work issues through a design thinking approach.

On the second day, each farmer group kicked-off the connected sensor prototype by addressing the physical variables that they wish to monitor. In the afternoon, the participants split into learning thematic sessions about the key prototype components: sensors and electronics, 3D printing and packaging, digital network interfaces, data collection and processing. In particular, the data session focused on the farmers’ expected human-machine interface and the decision support system. The third day the groups continued and completed the prototyping. Finally, in the afternoon, each group presented its concept prototype to the other participants and a conclusive debate allowed to wrap-up the main workshop outcomes and perspectives.

Main Bootcamp Outcomes

The four projects shared the same general workflow architecture (Figure 1), except for the specifications concerning the sensors for the physical data collection and for the desired DSS (Figure 2).

The implied physical variables may be temperature, CO₂, humidity, distance, etc. Sensors are directly connected to an Arduino Printed Circuit Board, which acquires data and then sends them to a database via a network, which may be a wired network or a wireless network (e.g. Wifi, Lora), depending on the needs. Databases and data mining processes may either be installed locally or in the cloud.

Four open source prototypes of connected sensors/DSS were designed based upon the farmers’ needs (Table 5) and tested in simulated environment. Each project consisted of two main steps. First, the specification that includes the definition of the context, and of the input and output variables. Second, the implementation, which consists in sensor choice & packaging, connectivity and data collection and processing.

All the participants to the bootcamp agreed that it is relatively easy to design and implement the most appropriate connected solutions suited to the farmers' needs. Through this process, we show that farmers should be involved in the agriculture digitalization, and even more that they may participate to a problem-solving approach to broaden their skills. In addition, relating this to the students' training, by project learning, can help to raise their confidence in their capabilities to acquire new knowledge and new know-how and to develop new solutions.

Such an open innovative model farmer-oriented can benefit from the involvement of students and experts in agronomy and in digitalization technologies. In the end, this approach to innovation leads to a large range of new BMs, among which the creation of a start-up becomes just one of the multiple possibilities through which the involved actors can create a new activity. For instance, the farmer-oriented concept prototypes can be adopted by established industries for the development of improved solutions.

TOWARDS A NEW TYPE OF MODEL: SUSTAINABLE INTERNET OF THINGS OPEN INNOVATION MODEL

The fifth BM should take into account different levels of analysis:

- 1. Pure open innovation with open data, and open software. It means the emergence of an economy of functionality. The utility of data acquires value and can be rapidly expanded at different scales.
- 2. Control on some data which could be useful for different levels. The data acquired by farmers whose activity is completely digitalized can be aggregated at different levels that are not all hierarchical. This may concern territorial levels, and also institutional levels. Local innovation can come from a recovery of innovations from various locations worldwide (open software travels very fast ...). These local innovations can then expand in an ascending way, by aggregation.
- 3. Partially closed innovation for specific tools that can be crucial for competitiveness. Some process innovations can lead to open innovations in terms of products. The sale of the process can be implemented in different ways (intellectual or industrial property, production of specific parts, etc).
- 4. Multiple levels of customers. As the farmers are producing a lot of pluri-level functionalities, their customers are at all the scales mentioned above. All these features correspond to various societal demands that may seem contradictory and who's only practical application will be to disentangle these possible contradictions (protect the soil, capture CO₂, protect aquifers and arable crops, increase biodiversity, protect endangered species, improve taste quality and sanitary quality, increase the volumes produced and their diversity, etc. These various supplies of new services and products are addressed to private structures, territorial authorities, geographical areas, national or regional institutions, rural areas or agglomerations, cooperatives, food chain operators, etc.

All these activities have a cost for farmers, and at the same time nobody is able to conceive the integration of all these demands addressed to them neither to compute their real values.

How to monetize the immaterial produced by agriculture? This question is studied in the field of ecosystem goods and services.

To capitalize farmers' knowledge and skills, accumulated knowledge, techniques and processes, they must be shared by farmers and at the same time be financed, because no farmer will invest without hope of return. How can farmers sell this knowledge and know-how? To answer, we must find a solution to the weakness of farmers' power due to the low relative weight of each farm.

It is conceivable that this increase in power goes through the construction of cooperatives. However, the loss of farmers' power in cooperatives, as soon as they develop, shows that the farmer's BM needs to be reconsidered.

This fifth model (Table 6) describes a change of attitude for farmers. The land holdings are no longer a source of value, yet they are the whole complex of digitalized knowledge and know-how. Indeed, the technical mastery of this complex creates value that relies upon the knowledge of its digitalized features.

The agro-ecological knowledge is also a value, a place-based value that depends though on the data usage skills, which is to say by digitalization.

Given the widespread context of knowledge, know-how digitalization, and the identification, monitoring and tracking of real practices, the data control master is the final owner. Yet, this ownership is its value, perhaps the basis of negotiation, which is to say of monetary exchanges, in a multi-scale framework. This market of agricultural knowledge is not necessarily a traditional market since the status of buyers depends on the scale at which these data are valued. These buyers can be enterprises, territorial or political institutions, and the value can be fluctuating and dependent on political choices at different levels.

Farmers will therefore have data whose value will depend on the level of data integration. They will have to share innovation with the peers. They will have to foster solutions even in the case of open innovation and to participate in monitoring and data integration platforms. As everything is traceable, it will be possible to move from collective valuation to individual valuation. In the cases of very advanced data integration, it is conceivable that the value of data and the sharing of value will derive from the collective recognition that it is a common good.

CONCLUSION AND PERSPECTIVE

Digitalization is finally a general concept that encompasses all innovations currently under development and using digital tools. For example, the evolution of Artificial Intelligence has the consequence that they will be quickly portable and that anyone could have these tools, including farmers. As the use of Artificial Intelligence will be relatively easy (which is not true of its conception), one can conceive very profound changes of professional relations and thus of BM. Farmers who will master the use of tools with Artificial Intelligence and Deep Learning could have the means to analyze data, to create value and to preserve his or her autonomy.

Among the large trends in food and agriculture, digitalization appears to be a dominant one, as it is far more than a tool. It can adapt together to large production in a changing environment and to specific and diversified products. Evermore, digitalization could be the necessary tool to meet the agro-ecological challenges and the general needs for a more efficient agriculture. The innovator farmer could find some new ways to better food security, better optimization of inputs in agriculture, and methods to be better paid for their actions.

The presentations of this chapter focus on a new innovative BM's type. It could offer to the farmers the possibility to be empowered through mastering the use of all digital based tools. Special cases of this BM model can be built as part of partnerships between farmers, engineering school, students and experts in digitalization technologies. Nevertheless, this global BM leads to a large range of new BMs. The Start-Up approach is one possibility through which a new activity can be created. In addition, this experience interests some project sponsors for the development of new activities. It means that this new type of BM integrates the possibility of the emergence of multiple SMEs, with local and specific activities (Chiappini and Toccaceli, 2013), most of them controlled in part by farmers, who will act in the agricultural sector. Large groups may also have interests in these SMEs, although there is no guarantee that a large industrial group will have the agility to be present at the multiple interfaces generated by digitalization.

Digitalization arrives in agriculture later than in any other economic activity, because the added value is small. In fact, the tools that will develop in agriculture would often be reframing or reconstructing technologies already tested elsewhere.

It can therefore be inferred that the digitalization of agriculture can revolutionize agricultural practices. We believe that one of the keys to the success of such a revolution is farmer's mastery of the technological innovations. Open IoT is a very significant way to achieve this. Indeed, thanks to AgriLab® approach, farmers will be enabled to develop their own "custom" solution; proposed solutions are not expensive due to the low cost of the equipment; conception cost can be low and integrated in apprenticeship training; and finally, open IoT favors collaboration between farmers, scientists, experts and students.

The AgriLab® project falls within Sustainable Development approach and aims to promote digital innovation and open source involving all stakeholders. Through this process, it can be shown that the farmers can be involved in the agriculture digitalization, and even more that they can participate in a problem-solving approach to broaden their skills. The students' training, by project learning, serve to raise their confidence in their capabilities to acquire new knowledge and new know-how and to realize new solutions. All of this should be built upon and improved for future experiments or farmer's project.

This new and open innovative BM involves farmers, engineering schools, students and experts in agronomy and Information and Communication Technology (ICT). Nevertheless, this fifth model leads to a large range of specific BMs. What are the barriers to open the 5th BM via IoT technologies in order to promote sustainability? A benchmarking with different types of FabLabs, in agriculture and in other domains, could be very useful.

In the process of digitalization of agriculture, three different axes appear:

- i) An agronomic axis: low-cost sensors, mobiles or fixes, are expected to enable farmers to better monitor the environment, thus to facilitate the implementation of

precision farming. This possibility to follow in real time many parameters leads to the possibility of optimizing and simplifying the technical cultural itineraries. For instance, the main outcome of the AgriLab® bootcamp was to improve the farmers understanding of sensor technology and data management. They were eventually helped to clarify their expectations from the new technology providers and advisors. More in general, from the agronomic point of view, we can stress that digitalization will require farmers to ask more and more precise questions, then to consider how the novel monitoring tools will enable new practices to finally build models allowing anticipation, follow-up and decision-making in complex situations.

- ii) An economic axis: digitalization could provide added value; this can explain why farmers, or their children, adopt such new technologies. The implementation of AgriLab® platform can play a part on the adoption and the dissemination of technology by farmers, students and experts in digitalization technologies. For the farmers, the challenge is to be able to own, adopt and adapt the 5th BM.
- iii) A technological axis: proposed indicators are still descriptive data. It will be necessary to develop predictive analyzes (Artificial Intelligence and Deep Learning), which will require bigger data sets, sometimes involving data collection over several years. It could be necessary to validate the different sensors, may be to define some other, to define some others, and to think about the needs of sensors according to the scales of integration of the data.

We can first mention the fears and desires of farmers, and the necessity of a culture of innovation and entrepreneurship. As a result, the level of education and information of farmers will become crucial. For this, AgriLab® will play also as training and learning center.

The digitalization of agriculture can have profound consequences. The traceability of actions and their results can be built by integrating pedo-climatic factors, agro-ecological choices and societal criteria (protection of the environment, pollution, biodiversity). The new drivers of digital agriculture could depend on a multi-scale societal demand policy.

Depending on political choices defining the role of agricultural activity in each agricultural region or sub-region, as well as in peri-urban or urban agriculture, it could become possible to ensure stable incomes that will no longer be subsidies but service payments to the community. This has already begun, however, without digitalization, the traceability of actions and effects is far from complete. Today, it is trivial to attribute without evidence the effect of farmers' actions on environmental or food security issues. One can imagine that with the general digitalization of agriculture it could become possible to carry out such follow-ups.

The digitalization of agriculture can also change the status of farmers who could become experts for the actual evaluation of any new variety, even before the variety is registered. Digitalization and complete crop monitoring can turn any field into a potential field trial. Farmers could be able to sell the data of a well traced production in real conditions to the breeder of the variety. The plant breeder will realize the integration of the data.

These challenges require farmers to expand their knowledge to be able to master these innovations such as digital machine control, embedded sensors, big data management, etc. Thanks to the lowering cost and miniaturization of advanced technologies, farmers are pushed and eager to shift from intuitive to fact-based farming practices. Any decision in agricultural production could be controlled and accounted for at the intra-field level (Bencini et al. 2012; Aqeel-ur-Rehman et al. 2014). The increased data collection and monitoring capacities can be

a good answer to the need for a better use of natural resources to reduce farming trade-offs, thus meeting the society expectations for sustainable development. Yet, the fast-increasing amount of harvested data remains largely unexploited because the first users - farmers - are still poorly involved in the development of processed information relevant for their decision making and often poorly equipped.

Innovation in training and educational programs, as well as new forms of knowledge transfer could be a solution. Digitalization can lead to innovation processes that would change the way of farming, with a focus on the impacts and expectations for the agricultural knowledge and information systems. Indeed, digitalization, through web platforms, could allow experienced farmers to maximize the value of their know-how, help other farmers who need reliable and operational information, and also for all farmers to acquire knowledge and know-how for the success of their business. Such farmers could obtain some value from their knowledge and from the data they could be able to produce.

Digitalization can therefore become a general tool for diversifying agricultural services to businesses and institutions. The greater the number of services and their financial weight, the less farmers will be sensitive to market fluctuations.

Table 1. 1st model: Farm as “a micro-economic unity”

Partners Upstream/ downstream agencies	Activities Crop and livestock production	Value for the farmer Family patrimony	Customer Relationship Logistic Stock	Customer segments Companies (private, trading)
	Resources Scarce, soil		Channels B to B	
Costs Production unit			Revenues Agricultural raw materials	

Table 2. 2nd model: Farm as “a component of social system”

Partners Upstream/ downstream agencies Other farmers Financial institutions	Activities Crop and/or livestock production Specialization Division of labor	Value for the farmer Family patrimony Investment in equipment. Improved productivity.	Customer Relationship Logistic Stock	Customer segments Cooperatives Companies (private, trading)
	Resources Soil Labor force		Channels B to B	
Costs Set of production units			Revenues Return on investment	

Table 3. 3rd model: Farm as “a controlled system”

Partners Upstream/ downstream agencies Other farms Financial institutions	Activities Different production “workshops” Various marketing channels Marketing	Value for the farmer Family patrimony Investment in equipment. Improved productivity.	Customer Relationship Logistic Stock Products for consumption	Customer segments Companies Cooperatives Consumers

Development organizations Public institutions	Logistics Social function Resources Soil Labor force Vision of the situation	Variety of the production flows Efficiency	Channels B to B/ Distribution B to C	
Costs All factors contributing directly to production including some processing and sales.		Revenues Sales/ return on investment, sales, processing Subsidies		

Table 4. 4th model: Farm as “a complex organization”

Partners Upstream/ downstream agencies Other farms Financial institutions Development organizations Public institutions Consulting	Activities Production Marketing Logistics Information and communication systems Resources Natural Information Other activity	Value for the farmer Family patrimony Investment in equipment (hardware and software). Improved productivity. Variety of the production flows Efficiency Life quality ...	Customer Relationship Logistic ERP Web services ... Channels B to B Distribution B to C	Customer segments Companies Cooperatives Consumers ...
Costs All factors contributing directly to production and sales, including software, robots, internet connection, distribution		Revenues Sales/ return on investment/ transformation		

Table 5. Overview of the outcomes from the first AgriLab® bootcamp

Project name	Issue	Specifications		Digitalization perspectives
		Physical data	Output	
iPatate	Quality monitoring of potato stocks	Temperature CO2 Humidity phyto-hormones	Intervention of the operator	Remote management of separated stocks
SiloTeam	Monitoring of the filling level of poultry food storage silos	Height of food remaining in the silo	Exact tonnage of food remaining in the silos	Automation of the supply management
VegData	Early rot detecting in salads	Air, foliar and soil temperature and humidity	Raising soil moisture to warn the farmer when the moisture reaches a threshold that requires	Creation of a territorial network with neighbors and test of an artificial intelligence approach

Project name	Issue	Specifications		Digitalization perspectives
		Physical data	Output	
			irrigation	
Decisio	Soil moisture monitoring to identify best time for: (i) sowing flax; (ii) harvesting potatoes	Soil moisture and temperature Moisture and air temperature Foliar development Rainfall	Concerning flax: knowing the best period for sowing. Concerning potatoes: predicting the stoppage of vegetation growth and thus the harvest	Simplification of monitoring through multipurpose sensors.

Figure 1. Workflow architecture of the bootcamp prototyping activity (source: adapted from Dantan et al. 2018)

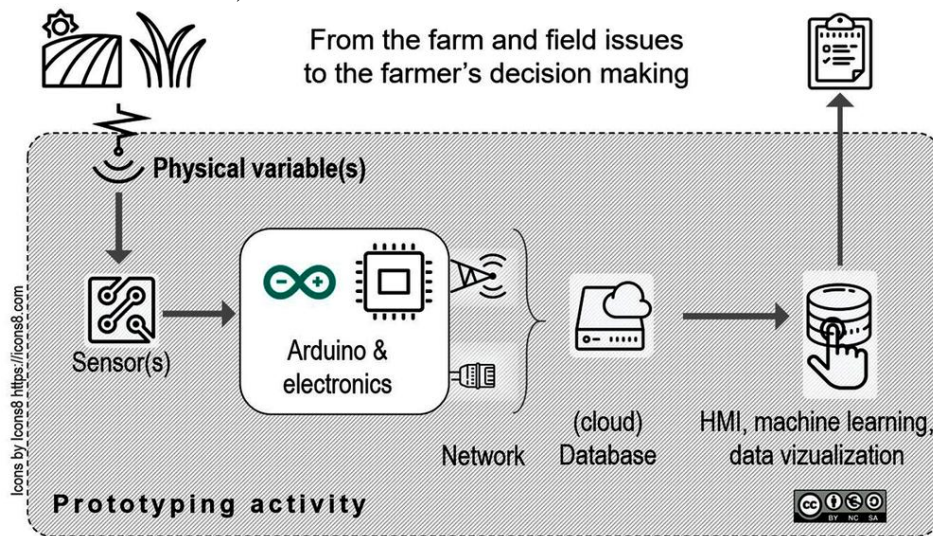


Figure 2. Decisio sensor-to-DSS package (source: adapted from Dantan et al. 2018)

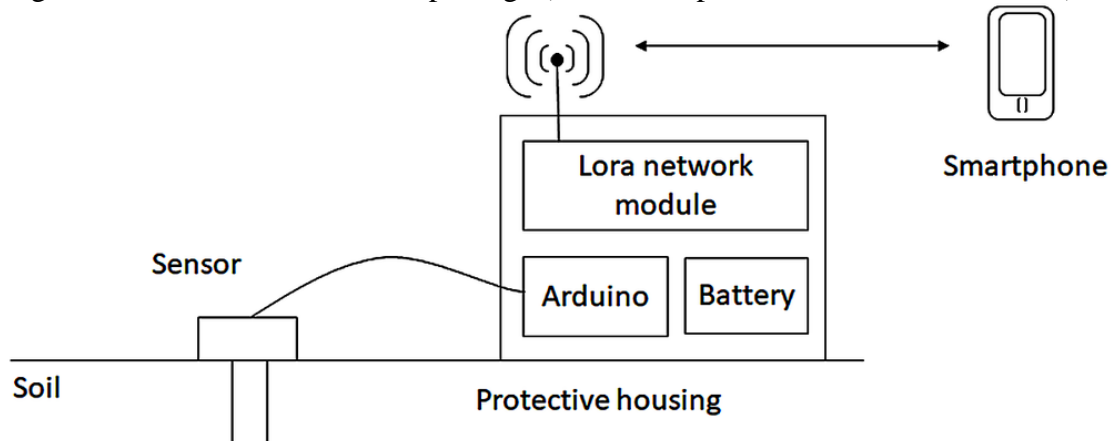


Table 6. 5th model: Pluri-activity Farm as “a connected organization”

Partners	Activities	Value for the farmer	Customer Relationship	Customer segments
Upstream downstream agencies Other farms Financial institutions	Diversified (Tourism, renewable energies, environmental features, material innovation...)	Processing Data Information and knowledge sharing The knowledge of the soil, the	Comparative Websites CRM solutions	Cooperatives « Locavores » Companies Startup (distribution,

Development organizations Public and territorial institutions « AgriLab® » type, FabLab Teaching and research institutions Startup	Resources Mechanical - mechatronics Data Hardware and software All FabLab, AgriLab® included.	climate, his agronomic choices, etc. Technical itinerary, markets, ...,	Channels B to B Distribution B to C Short B to C Direct business on farm	sales, platforms) Consumers
Costs All factors contributing directly to production and sales, including software, robots, internet connection, distribution, etc.		Revenues Sales/ return on investment/ transformation Valuation at several levels of scale (sale corresponding to territorial requirements) Data Hacking (Collaborative Platforms) Grants considered not as aid but as compensation for “intangible property sales”		

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