Approaching to the Fourth Agricultural Revolution: Analysis of Needs for the Profitable Introduction of Smart Farming in Rural Areas

Stefania Lombardo[1], Daniele Sarri[1], Luigi Corvo[2], Marco Vieri[1]

[1]Department Agricultural, Food Production and Forest Management, University of Florence, Italy e-mail: stefania.lombardo@unifi.it
[2]Department of management and law, University of Rome, Italy e-mail: luigi.corvo@uniroma2.it

Abstract. Innovation in rural areas depends upon several factors. One of the most important of those is the technology transfer and how it takes place. Referring to the “long waves” theory on the technological revolutions, since the first agricultural revolution to the one we are experiencing today, some indicators, held together, can establish the relevance of innovations for each revolution. This approach, based on a comparison between agricultural systems, starts from a SWOT analysis to make a matrix table created and inspired to the smart specialization strategies on high technology farming of European Commission on research and innovation on the Agrofood sector. The aim of this work was to build a conceptual framework to understand if the frenzy period of precision agriculture could be a chance mostly in terms of sustainability. This paper highlights on a first approach to delineate some guidelines in order to provide feasible technological transferring for every kind of agriculture system.

Keywords: agricultural revolution, rural social innovation, precision farming, technology transfer, smart farming

1 Introduction

Nowadays it is possible to make an evaluation of what and how innovation and technologies in rural areas spread through industrializes centuries. There are different economic theories that explain the dissemination of innovation through industrial revolution, but it is difficult to find specific comparisons in the agricultural field.

Organize ideas and innovation and comparing different technologies for the same kind of agronomic activity, is an essential requirement to understand in this age and even in the future, where and how precision agriculture could help the agriculture systems. To deal with this challenge, on the one hand it is necessary to refer to conceptual framework known as the “Long wave” theory of Kondratiev (neo–Schumpeterian theory), which stated that radical technological revolutions influence innovation and markets above social and economic changes. On the other hand, we need to take into account the “Transition theory”, that try to explain technological

Proceedings of the 8th International Conference on Information and Communication Technologies in Agriculture, Food and Environment (HAICTA 2017), Chania, Greece, 21-24 September, 2017.

revolution emphasizing the spreading of niches. On these frameworks, it can be resume that the two conceptual frameworks have similar targets and adopt evolutionary economics with social change as a process of co-evolution of societal sub-systems but with different historical coverage. Lastly, it is also important to bear in mind that the Transition theory consider the sustainability, as opposed in the neo-Schumpeterian theory, therefore it could be important for future evaluations. In order to evaluate agricultural systems in their complexity, can be helpful the SWOT analysis that allows to evaluate ex-ante or ex-post systems or policy programs as Common Agricultural Policy (CAP) as well as to focalize points of strength or weakness and to underline opportunity or threats. This methodology is necessary to defining differences between agricultural systems, characterized by different innovations, and those which are now developing with the new approach named “precision agriculture”. In the larger part of agro industrial farms the high tech farming (HTF) is becoming a reality. The question to be resolved, therefore, is the following: is it possible to assert the same for other farming system? Farmers will have initial economical efforts, but for some agricultural operations, there are immediate effects for environmental and economic sustainability. There are severalexamples of technologytransferring to farmers in Europe inside Mediterraneanregionsasproject “Mare, Ruralità e Terra: potenziare l’unitarietà strategica” MARS + (Tirrò et al, 2013), “Vivaismo sostenibile” VIS (Recchia et al, 2013), “Valorizzazione della filiera vitivinicola attraverso la tracciabilità elettronica e le applicazioni della viticoltura di precisione.” TRA.PRE.VIT (Sarri et al, 2015) and “innovazioni per il miglioramento della viticoltura Toscana” IMVITO (Vieri et al, 2013). These projects documented that there are in addition initial barriers as in the learning in using the software or to understand the usefulness of collecting field data to deal with precision agriculture. Additionally, it must also be taken into account that precision agriculture solutions is becoming commercially achievable and is estimated that from 2014 to 2020 the precision agriculture market will grow every year by 12%, more less 50% in 4 years (EC, 2016a). Finally, it is important to measure the differences between old system and new one to let farmers choose consciously what type of system adopt in order of economic, social and environmental efforts and sustainability.

2 Materials and Methods

2.1 Technological Revolution Models

A first approach to delineate some guidelines in order to provide feasible technological transferring to the different kind of agriculture systems requires an initial reference to the theories that have been point out about technological revolutions. Kondratiev wave theory describes technology revolutions and how innovation irrupts through economy and markets. The also called “long wave” theory, revised and discussed by many economist has many contact points with the “Transition” theory that mainly analyses processes of radical change in society connected with big changes in socio-technical system. Kondratiev theory (neo-Schumpeterian theory) is not usually associated with sustainability instead, "Transition" theory is it and is limited in its debate of how to influence social and economic opportunity. Within this theory, "the advantages of the new technology are so great that policy and institution accompany the development of the new industry" (Köhler, 2012). There are several modern economist which have been tried to describe long waves as Freeman and Louçã (Freeman and Louçã, 2001) that have summarized in six phases the life cycle of a techno-economic paradigm i.e. 1, the laboratory/invention phase, 2 decisive demonstration(s) of radical technical improvement and commercial feasibility, 3 Explosive, turbulent growth, characterized by heavy investment and many business start-ups and failures., The phase 4 refers to continued high growth, as the new technology system becomes the defining characteristic of economy, with impacts on most, if not all sectors of the economy. The 'regulatory regime' is therefore reconfigured to support the new technologies and industries' products. Then the 5 step "Slowdown" as the technology is challenged by new technologies, finally the 6 stage "Maturity" leading to a (smaller) continuing role of the technology in the economy or slow disappearance. Therefore, the innovation trajectories in long waves theory for technological revolutions defined by Perez (Perez, 2010) are based on the diffusion of the technological revolution and time and can be identified in four phases defined by a first irruption phase followed by a frenzy period then by a synergy period and finally a maturity period (figure 1).

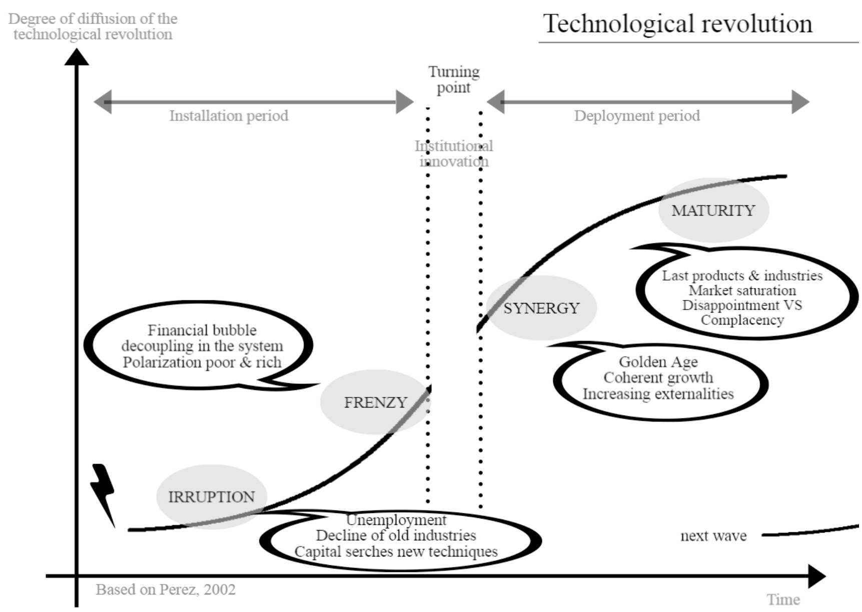

Fig. 1. Graphic of technological revolution, based on Perez (2002).

Generally, the discussion on technological revolution is on industrial field, but it can be borrowed also on agricultural revolutions that usually deduce from industrial ground.

Lastly, if the larger part of economist agree with the "Schumpeter-Freeman-Perez" paradigm that identify five waves for agricultural sector, innovations that bring new waves can be compared with industrial revolution waves as showed in the table 1.

Table 1. Comparison between industrial revolutions and agricultural revolutions.

Technological revolution	Popular name for the period	Big-bang initiating the industrial revolution	Year	Big-bang initiating the agricultural revolution	Year	Agricultural revolution
First	The Industrial revolution	Arkwright's mill opens in Cromford	1771	First theory on reversing plough*	1774	First
Second	Age of steam and railways	Test of the Rocket steam engine for the Liverpool–Manchester railway	1829	First gasoline tractor engine**	1890	Second
Third	Age of steel, electricity and heavy engineering	The Carnegie Bessemer steel plant opens in Pittsburgh, PA	1875	-	-	-
Fourth	Age of Oil, the Automobile and Mass Production	First Model-T comes out of the Ford plant in Detroit, MI	1908	*Fordson*tractor based on T model**	1915	Third
Fifth	Age of Information and Telecommunications	The Intel microprocessor is announced in Santa Clara, CA	1971	ICT and digital systems in agriculture management***	1997	Fourth

*AA.VV, (2008).
**Zoli, M., Vieri, M. (1998).
*** I[st]European conference on precision agriculture (1997).

Technological revolutions in the industrial sector and also in the agriculture sector occurred along the same years. Nevertheless, it must be noticed that for the main tool of the green revolution i.e. the tractor, and specifically for the T tractor have elapsed only few years, while it is just a fact to find the first microprocessor on tractor have spent many years. Consequently, the first approach with CAN-bus was made only in 1988 (Biondi, 1999).

2.2 SWOT Analysis Method

In order to evaluate each agricultural revolution that generated different agricultural systems, a SWOT analysis was carried out to assess ex-ante or ex-post the systems with the objective to focalize points of strength or weakness from internal and to underlines opportunity or threats from external (Table 2).

Table 2. SWOT matrix model

	Helpful (to achieving the objective)	Harmful (to achieving the objective)
Internal origin	Strengths	Weaknesses
External origin	Opportunities	Threats

2.3 A Matrix to Compare Technological Revolutions in Agriculture

A matrix that compares agrarian revolution with a system based on the precision agriculture method was made with the target to make order in this frenzy period and in order to compare it with other known systems. This system, inspired to the smart specialization strategies on high technology farming of European Commission on research and innovation on the Agrofood sector, splits different mechanized/not-mechanized field operations divided in technology oriented (eyes, touch, arms, mind) and in service oriented (memory, experience, identity) (table 3). Under each operation are shown the unit used (Vieri, 2016).

These operations were defined for the precision farming (but they can be explained also for the others technological revolution) as follow:

- EYES & TOUCH to monitor the single element on wide area (sensors and digital layer) and recognise the effects in each element treated (on board, proximal and remote sensors)
- ARMS to do huge and precise tasks (automation, robot)
- MIND to be aware of what, where and when to act in each single productive step (Modelling and Decision Support Systems)
- MEMORY to be aware on what has been done (telemetrics, traceability, data store)
- EXPERIENCE (Data Management & Prescriptions)

- IDENTITY of agricultural resources and sustainable use at Local & Regional level (territorial complexity, TRL of tools & services, Know-how, CoPs).

Table 3. Comparison between agricultural revolutions in terms of field operations technology oriented

Agricultural revolution	Operation			
	EYES ha/year/man	TOUCH ha/year/man	ARMS h/ha/man	MIND surface
First	2-3	2-3	From 800 to 80	subsistence farm
Second	scheduled andprescribed application		From 80 to 10	levelling out methods and practices
Third	200-300	200-300	From 10 to 2	farm
Fourth	300-500 (multiparameter)	300-500 (multiparameter)	From 2 to ~ 1	global level

Table 4. Comparison between agricultural revolutions in terms of field operations service oriented

Agricultural revolution	Operation		
	MEMORY data	EXPERIENCE farmer	IDENTITY farmer
First	oral	oral/personal experience	family
Second	levelling out methods and practices		
Third	oral/written/data	local level/farms	farms
Fourth	big data	global level	local level

In the tables 3 and 4, clearly show how technology have influenced since the first to the fourth agricultural revolution the different operations. Moreover, it is possible to highlight as in the green revolution, (the second agricultural revolution) farmers did not carry on decisions on many operations.

3 Discussion & Results

In the first agrarian revolution thanks to innovations in the design and efficiency of ploughs, human strength increased even though there were less people employed in farming because of industrial revolution and wars. In the second agrarian revolution mechanization played a key role allowing everyone, more profits and production. Thanks to this, although the increasing number of people, the born of agroindustry resolved the hunger problem, with mechanization and chemicals. On the other hand, the system loses its complexity in terms of territorial knowledge and peculiarity. In the third agrarian revolution, times of innovation reduced in bias of more complexity of systems and technologies used. Knowing this, a first approach, committing the neo-Schumpeterian theory of technological revolutions and applying the SWOT analysis to the fourth agricultural revolution can be discussed and resumed as follows: (Table 5).

Table 5. SWOT Analysis on the fourth agricultural revolution

	Helpful (to achieving the objective)	Harmful (to achieving the objective)
Internal origin	Strengths • knowledge – based agriculture • augmented capacity • multidisciplinary	Weaknesses • speculative business model • digital divide of rural communities • limited access to data and innovation
External origin	Opportunities • innovative value chain • circular economy • social cohesion • empowerment of rural communities • antifragility	Threats • business as usual value chain • inequality • exploitation of rural communities • fragility

The table above summarize the state of the art of what is the fourth agricultural revolution.

Thebiggest difference between the fourth agricultural revolution and the others is that the former happens during the era of the digital revolution. This opens to the opportunity of changing radically the value distribution and allows the re-thinking of the local products (and local producers) as the core of a new value system based on the triple bottom line approach (people, planet, profit). This paradigm has been defined "rural social innovation", and is aimed at investigating the pathways for a Mediterranean social innovation initiative (Giordano, A. and Arvidsson, A., 2015). Referring to the SWOT analysis, this means that threats can become opportunities for medium and small agricultural companies and this represents a challenge for the territories in which these companies play a significant role for the social and economic development of the communities.

Trying to realize it, we should also consider that there are different actors turning in this system, discovering who exactly they are and how they act.

The main actors of this system are:

- government (local or central), as the actor in charge for the policies
- farmers, as the actor in charge for the supply
- people, as the actor in charge for the final consumption demand

In this scenario, policies should take in consideration the real need of rural communities, taking care of the important role played by them for maintenance of landscape, water regulation, traditions, food quality and finally, of all the dimensions that can generate positive social and environmental impacts.

The last European Policies (CAP) and the Declaration of Cork 2.0 claim this path well signed (EC, 2016b).

Table 6. Perspective of possible evolution of technological shifting in agricultural contest

	Empowerment of rural communities		
Speculative as usual business model	Traditional technology transfer	CSA Digital innovation hub	Innovative value chain
	Top- Down policies	Marketing of local products	
	Exploitation of rural communities		

Furthermore, the SWOT analysis risks realizing a static vision of the reality. In fact, it is not possible to effect on strengths and weaknesses but it is possible to have a deeper vision of the SWOT analysis working on and convert treats in opportunities. In this case, referring to the table 5 there are two key variables, the value chain (strength-weaknesses related) and the level of empowerment-exploitation of rural communities and we intend to show how guidelines can influence the evolution of the new agricultural paradigm, in terms of technological shifting, and their related effects. This dynamic framework can develop (if the factors on the axis go to the upside and the right) in a Community Supported Agriculture system (CSA), a digital innovation hub, or other online and offline networks that fulfil the rural social innovation approach, which include a digital approach (Lombardo, 2017 in press).

Every action took by actors, in other directions, cannot realize completely the innovations needed in rural areas for farmers. In fact, turning threats in opportunities means that the access to technology allows little and medium companies to use environmental peculiarities (i.e. biodiversity or landscape) as levers for marketing. For this reasons instead, those peculiarities can be the lever of a new value distribution.

3.1 A First Approach to Comparison Between Precision Agriculture and Other Agricultural Revolutions

Whilst it has been considered the policies and a different innovation approach in rurality, on the other side arises the necessity to compare operational data in order to understand that filling the gap of technologies innovation in agriculture is a real need. As an evaluation example of agricultural working stages, the ploughing was considered. The reference unit analysed was the working capacity expressed as $m^3 h^{-1}$ ploughed considering a soil furrow slice with a 0,2 m deep and 0,4 m width, for a total surface of 8 dm^2 worked by a man with a shovel. The time required was set to 800 hours per hectare as documented by CosimoRidolfi (Faucci, 2008) and further a yard efficiency of 0,85 was set. In view of these parameters, it follows that the amount of soil to plow was 2000 m^3 per hectare and that a man with a shovel was able to work around 2,5 m^3 per hour. This reference unit yard was compared with the horse with plough, to the tractor coupled with single plow, a tractor with a five ploughshare plows and finally with a tractor equipped with a five ploughshare plows and automatic drive. The yard working capacity was calculated multiplying the forward speed by the soil furrow slice surface. Then the resulting value was multiplied by the yard efficiency.

Table 7. Work needed for a furrow slice of 8 dm^2 for different yard typologies representing diverse technologies revolutions.

Yard				Working capacity $m^3 h^{-1}$
Man + Shovel	Volume/h	$m^3 h^{-1}$	2,5	
	Yard efficiency		0,85	2
Horse + Plough	Forward speed	$m h^{-1}$	3600	
	Yard efficiency		0,8	230
Tractor + Single Plough	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,7	336
Tractor + five ploughshare	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,7	1680
Tractor + five ploughshare + Automatic Drive	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,9	2160

The results showed, referring to the unit $m^3 h^{-1}$and taking as reference unit the man work, the huge differences between the productivity of a tractor (like that one of the 2ndth and 3th agricultural revolution and the more used kind of tractor), compared to the productivity of a tractor with automatic drive. The difference encountered between the productivity of the tractor with ploughshare 336 $m^3 h^{-1}$ and the tractor with five ploughshare 1680 $m^3 h^{-1}$ is attributable to the increasing number of ploughshares and not to the technology used. It is important to underline, the relevant difference if the technology used changing. In fact, a tractor with five ploughshare has a productivity of 1680 $m^3 h^{-1}$, but a tractor with five ploughshare and automatic drive has a productivity of 2.160 $m^3 h^{-1}$ that is 1,3 times more.

4 Conclusions

Approaching to the fourth agricultural revolution and trying to understand emerging needs, in both operational and policies it could be a chance to introduce profitable innovations in agriculture to have a sustainable managing of the natural resource. The highlight on one field operation, comparing through different kind of technology used, is the first step to underline the necessity of a technology introduction also for small and medium agricultural enterprises. In this contest, it is important to remember the feasibility of a technology and the cost to effort for every kind of company. The challenge for the policy makers in the framework of a technological revolution, such as precision farming, is boosting knowledge and technological transfer also for those farmers who can't have all the capital needed.

For this reasons, it is desirable to design and implement an economic and social ecosystem able in supporting this kind of policy. Only in this way, it will possible to shift from a extractive business as usual value, to a community supported agriculture system (CSA), where the value generation and redistribution is coherent with the effective value contribution given by the actors involved in the process.In conclusion, these kind of policies allow us to consider a new SWOT analysis that faces the challenge of the rural social innovation approach.

References

1. Biondi, P. (1999) Le macchine agricole UTET, 3, p.76-78.
2. EC, (2016a) Precision Agriculture and the Future of farming in Europe - Technical Horizon Scan; Study, Science and Technology Option Assessment. http://www.europarl.europa.eu/RegData/etudes/STUD/2016/581892/EPRS_STU(2016)581892_EN.pdf. Accessed October 1 2017.
3. EC, (2016b) Cork 2.0 Declaration A Better Life in Rural Areas. Luxembourg: Publications Office of the European Union. http://enrd.ec.europa.eu/sites/enrd/files/cork-declaration_en.pdf. Accessed May 13 2017.
4. Faucci, R. (2008) Centro studi sulla Civiltà Toscana fra '800 e '900, serie di storia del pensiero economico 48/1, Cosimo Ridolfi - Scritti scelti.
5. Freeman, C. and Louçã, F. (2001) As Time Goes By: From the Industrial Revolutions to the Information Revolution. Oxford University Press, http://EconPapers.repec.org/RePEc:oxp:obooks:9780199241071.
6. Giordano, A. and Arvidsson, A., (2015) Il manifesto della rural social innovationhttp://www.ruralhub.it/manifesto-rural-social-innovation/ .
7. Köhler, J. (2012) A comparison of the neo-Schumpeterian theory of Kondratiev waves and the multi-level perspective on transitions. Environmental Innovation and Societal Transitions, 3, p.1-15.
8. Lombardo, S., Sarri, D., Vieri, M. and Baracco, G. (in press). Proposal for spaces of agrotechnology co-generation in marginal areas 2017. Atti della Società Toscana di scienze Naturali, Serie B.
9. Perez, C. (2010) Technological revolutions and techno-economic paradigms. Cambridge Journal of Economics, 34, p.185-202.
10. Recchia L., Sarri D., Rimediotti M., Vieri M., Cini E., (2013) Environmental benefits from the use of the residual biomass in nurseries. Resources, Conservation and Recycling, 81, 31-9.
11. Sarri, D., Lisci, R., Rimediotti, M., Vieri, M. and Storchi, P. (2015) Applications of the precision viticulture techniques in the Chianti district. Paper presented at the 1st Conference on Proximal Sensing Supporting Precision Agriculture - Held at Near Surface Geoscience 2015, p.121-25.

12. Tirrò, G., Lisci, R., Rimediotti, M., Sarri, D. and Vieri, M. (2013) The cross-border project between France and Italy MARS+ sub-project - innovative technologies for the mechanization of the areas hard to reach. Journal of Agricultural Engineering, 44, 425-30.
13. Vieri M. (2016) S3 Platforms for High Technology Farming pillars of the Scoping Note [PowerPoint Presentation]: EU Kick-off Event of the Smart Specialisation Platform on Agri-Food, Florence, 6 December 2016, Available at: http://s3platform.jrc.ec.europa.eu/-/kick-off-event-of-the-smart-specialisation-platform-on-agri-food?inheritRedirect=true .
14. Vieri M., Sarri D., Rimediotti M., Perria R. and Storchi P., (2013) The new architecture in the vineyard system management for variable rate technologies and traceability).
15. Zoli, M. and Vieri, M. (1998) Storia del XX secolo, Istituto della Enciclopedia Italiana fondata da Giovanni Treccani, Roma. Tecnologie I, (III), VII, p.7-19 .