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TECHNOLOGICAL INNOVATIONS IN AGRICULTURAL TRACTORS: ADOPTERS' BEHAVIOUR TOWARDS NEW TECHNOLOGICAL TRAJECTORIES AND FUTURE DIRECTIONS

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Technological Innovations in Agricultural Tractors: Adopters' behaviour towards new technological trajectories and future directions

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ABSTRACT: Latest advancements in tractors engineering have allowed farmers to increase productivity, and simultaneously to reduce operator's *hazards*. However, little attention has been given to farmers' behaviour and attitude toward the adoption of technological innovations concerning agricultural tractors. The study explores farmers' behaviours on agricultural tractors current and future technological trajectories. A main case study concerning Italy is analyzed. Results show three different behaviours of farmers concerning tractors' technological innovations. These adopters' profiles would help developing new technologies that satisfy, more and more, farmers' needs and expectations, speeding up the adoption process, enhancing agricultural tractors' efficacy and efficiency.

Keywords: agricultural tractor, technological innovation, technological trajectories, adopters, farmers.

JEL Codes: Q16; Q55; O33

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SUMMARY

1. INTRODUCTION

Technological innovation plays a major role in agriculture sector (Sahal, 1981a, b; Coombs *et al.*, 1981; Coccia, 2005; Wright, 2012). Indeed, in the agricultural sector, research and technology development have been the foundation of main productivity gains (Ball and Norton, 2002). Agriculture is an area with significant application of high technology and, during the last century, exceptional advances in engineering knowledge have revolutionized farming (Sassenrath *et al.*, 2008). Technological systems and mechanical innovations have largely been developed and applied to agricultural tractors, enabling more efficient agricultural production and use of energetic resources, together with environmental impact reduction and improvement of drivers working conditions. The farm tractor holds a central role in farm operations and remains the most important machine in the agricultural market (Iftikhar and Pedersen, 2011). It pulls, lifts, powers, supports and often is the main status symbol of the agricultural enterprise. Hence, it is common to find individual farmers faithful to one particular brand (Day *et al.*, 2009). Technological advancements have the potential to increase farm productivity and to reduce costs associated with agricultural production (Korsching, 2001). Nevertheless, it is conventional that farmers do not adopt innovations simultaneously as they appear on the market. Adoption of a new technological machine, even when it shows obvious economic advantages, is often a difficult action (Rogers, 1995). The demand for agricultural machinery is strongly dependent on farms' income, which is influenced by external variables (i.e., agricultural policy, socio-economic environment, people attitude, weather and public policies). In recent years, structural changes in European agriculture affected income and investment behaviour, increasing the level of uncertainty and reducing farmers' propensity in new equipment investment with higher technological content (Vieweg, 2012). Nevertheless innovations require a long period from the moment they become available on the market, to the time when they are widely adopted; sometimes this is because technology advancements outpace the readiness of potential users, other times because there is a mismatch between technology solutions and end users desires, needs, and perceived usefulness of technology advancements (Bonati and Gelb, 2005).

A technology is considered useful when it improves production and profit, and when it satisfies users' needs. Therefore, it is paramount to gain knowledge of adopters' opinions when the manufactures are designing, developing and applying technological innovations to agricultural tractors. However, for a long time, farmers have been seen in a passive role, either adopting or not adopting the new technologies, without playing any significant role in their development (Douthwaite *et al.*, 2001). Technological determinism and science and technology studies, both in the soft and hard version, have overlooked the role played by end users in the process of technological development (Oudshoorn and Pinch, 2005). Nevertheless, over the past decade things have changed and the importance of consumers' role has emerged, demonstrating that end users of a technology influence technology's trajectory (Glenna *et al.*, 2010). Although in recent years consumers have received considerable attention in research on technological development, published studies analyzing the impact of farmers' perceptions in agriculture sector are rare. Among those stands out Adesina and Baidu-Forson's study (1995) supporting the hypothesis that farmers' perceptions of technology characteristics significantly affect their decisions, and Glenna and colleagues (2011) research reporting that people that ultimately use technologies influence their development and application.

The purpose of this paper is to analyze the adoption behaviours of farmers towards current and next technological innovations concerning agricultural tractors. This information can be important to pinpoint the vital farmers' behaviours and attitudes that could be useful to detect future technological trajectories that better satisfy the needs of agricultural tractors adopters.

Although some tractors manufactures undertake the effort of collecting information to understand their customers, this information remains restricted to internal use. Collecting data about real users requires efforts, takes time and costs money. To understand tractors users, it is important to determine who the targets are, their characteristics and demographics, and what they need and want to purchase. Their root motives can help manufactures to react quickly to users' needs, facilitating new product development and therefore the meeting of customer requirements in terms of products they subsequently purchase (Jeffrey and Franco, 1996; Dunk, 2004). As in other domains, knowing who the future users are, understanding their priorities and beliefs, what they know, what they are after, and how they get informed is vital (Nielsen, 1993). Nevertheless, only fragmented information is available on the attitude toward technological innovation recently introduced in agricultural tractors. This paper is an attempt to fill this lack of information, focusing specifically on the attitudes, beliefs, opinions and behaviours of Italian tractors' users towards new engineering technologies currently applied on agricultural tractors, as well as on technology advancements that could become available in the next future.

2. THEORETICAL BACKGROUND

The technology incorporated in a tractor has a considerable influence on tractors' production costs and on retailers' price. A global company, for example, sells the same basic concept of an 80-100 HP tractor in India for 150$/HP, in China for 250$/HP and in Europe and North America for 1400 $/HP. The remarkable difference is mainly due to the increasing complexity in safety, comfort, and environmental technical solutions adopted (Von Pentz, 2011). Current technological innovations in agricultural tractors are generating several technological trajectories to improve efficacy, efficiency and safety. Technological trajectories are, in general, driven by demand-pull and technology-push forces associated to learning processes (Dosi, 1982; Dosi, 1988; Nelson and Winter, 1982). In particular, demand and technological opportunities can affect the direction of technological advance in agriculture. The theoretical structure and process of these technological trajectories are underpinned in information and communication technology revolution and can be described by Teece (2008, p. 509, original emphasis):

> "Technological paradigms impose behavioural structures associated with 'normal' problem-solving activity. Paradigms imply the use of established problem-solving routines; they

> indicate where to focus resources and help identify blind alleys to avoid. . . . In short, technological paradigms fill a theoretical void by connecting the market to (at least some) technological possibilities."

According to Nelson (2008, p. 486 *passim*) a main role in the technological paradigm is the "conscious direction of efforts to advance practice, and recognition that efforts . . . are strongly oriented by the body of human know-how to advance practice". The analysis of Nelson (2008) is interesting because seeks to pinpoint the causes of fruitful scientific advances of technological paradigms in some fields in comparison to paradigms in other fields that have more scientific and technological infertility. Some determinants, according to Nelson (2008), are the economic and human resources invested to find a solution to "relevant problems" (*cf.* also Dosi, 1982 and Dosi, 1988 *passim*), and to a lesser degree " 'effective demand' " (Nelson, 2008, p. 487). As a matter of fact, advancements in some scientific and technological pathways are easier than others and an intensive scientific research activity can support a faster progress of some technological paradigm, though "relationships between the ability to advance practical know-how and the strength of scientific knowledge underlying that know-how are complex" (Nelson, 2008, p. 487). It is also important to note that the different technological pathways also depend on other elements in addition to economic resource, effective demand, institutional interest, needs of society and scientific research (Rosenberg, 1983). Nelson (2008) also argues that the evolutionary growth of knowledge and technology is supported by a process of accumulation based on the ability to identify, control and replicate practices, in other words the technological progress is based on "a certain amount of the 'routine' " (Nelson, 2008, p. 488; cf. also Nelson and Winter, 1982, *passim*). Nelson (2008) suggests that: "scientific understanding underlying a technology tends to be contained in the applications oriented sciences . . . . The paradigms they provide may, or may not, have a solid basis in more fundamental science (p. 489) . . . . broad paradigm was supported, but in most cases only loosely, by deeper scientific understanding" (p.491). In particular, engineering can be considered an *intermediate scientific field*, which links basic sciences (such as physics, molecular biology) to practical applications for societies (*cf.* also Nelson, 2008, p. 491 and p. 494).

The analysis of the relationship between the source and the users of technology, and of the recipient absorbing technology is important to evaluate both the type of adopter and their strategic behaviour. Technology transfer is important for firms' competitive strategy as well as growth and social development. Burkman (1987) presented the user-oriented development approach consisting of 5 adopter-focused steps:

- potential adopter identification;
- measurement of their relevant perceptions;
- user or adopter-friendly product design and development;
- informing the potential user or adopter of the product;
- support after adoption.

Other approaches recommend a complete analysis of educational need and user characteristics along with the identification of a new educational technology's relevant and appropriate features and factors (Stockdill and Morehouse, 1992). Carr (2001) stressed the need to analyse the environment in which the potential adopter is expected to use the technology, with a view to ensuring actual, correct and continual product use. This process includes identifying the relevant physical and use characteristics of both the instructional situation and the support system.

An adoption analysis approach considers the process from the broader perspective of both user-perception and organization attributes, resulting in a plan for carrying out the adoption of technology that is rooted in an organizational context and addresses issues of concern to the intended user (Farquhar and Surry, 1994). Product and application design and development are also significantly influenced by this approach.

Rogers (1995) shows that potential adopters of a technology over time through 5 stages in the diffusion process:

- learn about the innovation (*knowledge*),
- be persuaded of the value of the innovation (*persuasion*),
- decide to adopt it (*decision*),
- implement the innovation (*implement-ation*),
- reaffirm or reject the decision (*confirma-tion*).

The analysis of technological absorption of adopters also plays a paramount role in directing and monitoring the type of technology demanded by the economic system (Kingsley *et al.*, 1996). To analyse the adopters of technological innovation in agricultural tractors is important to support decisions of firms about the fruitful technological trajectories that satisfy the consumers' needs (Cohen and Levinthal, 1990). Cutler (1989) defines technology transfer as the situation when a subject, using the interpersonal channel (face-to-face) as a means of communication, acquires the knowledge of the source. Transfer is successful when the capability related to the transferred knowledge and technology, which the source possesses, is assimilated by the adopter, consciously or unconsciously constructed through the interpretation of information (Daft and Lengel, 1986; Rullani, 1994). In general, the users link the technological knowledge to the ease of acquisition, comprehension and application of the same. Next section describes the research design to analyze adopters' behaviour of technological innovation concerning agricultural tractors.

3. RESEARCH DESIGN

A survey was conducted during the 5 days of the 37th edition of the International Exhibition of Agricultural Machinery (EIMA), investigating farmers' attitudes, opinions and beliefs towards technological innovation in agricultural tractors. EIMA is a biannual international exhibition of agricultural machinery and it the most popular event in the field of machinery technologies for agriculture in Italy. The fair was supported by over 1600 national and international exhibitors, attracting a great number of national and international visitors.

The survey involved over 300 owners and/or users of agricultural tractors, randomly selected during the exhibition opening hours among the people visiting the pavilions.

In this study opinions on a set of technological innovations available on the market, as well as on advancements that could become available in the next future (table 1), were investigated.

Table 1 – Technological innovations investigated.

Technological innovations on the market	Future technological innovations
[CVT] Continuously Variable Transmission **[GPS]** Assisted guidance system **[NCfuel]** Alternative fuels	**Virtual terminal** refers to the possibility to control all implements from different manufacturers through one single terminal and display, eliminating the need for separate controls. Tractors will ultimately have just one monitor instead of multiple devices to control sprayers, spreaders and other implements
[POWER] Overpower/Power-Boost	**System integrated** into the tractor allowing access to internet, e-mail, and corporate network on an agricultural machine
[RD] Remote diagnostics system **[ISO]** ISOBUS/CAN-BUS	**Safety and warning system** enables driver identification, prevents risky manoeuvres, gives information to the driver about dangerous situation, and communicates any incidents to a business centre or an emergency service
[Speed] Speed greater than 40 km/h **[ABS]** Assisted Braking Systems **[FLEET]** Fleet Management **[ELECT]** Electric actuators	**CVT for power take–off** (PTO). The PTO is a splined driveshaft, generally on the back of the tractors, designed to be easily connected and disconnected, and to provide power to operate. Adoption of CVT solutions for PTO allows the speed of the PTO to be independently set to the engine speed, allowing implement's operations to use the lowest possible engine speed, saving fuel. Case IH presented the first application of CVT-PTO on a tractor's prototype at the SIMA exhibition in 2011

3.1 Agricultural technological innovations

Most of the emerging technologies are referred to the increasing electronic content in agricultural equipment and its accelerating trend. The natural consequence of this tendency is to enhance data interchange between machines, machine and people, and among people, to improve functionality, productivity, performance, safety and comfort. A certain number of solutions are already developed and applied by manufacturers, others exist but are not ready yet to put forward for tractors and could be available for farmers in the next future.

Generally, tractors are equipped with mechanical transmissions that offer a fixed number of gear ratios. CVTs (Continuously Variable Transmission) can change steplessly through an infinite number of effective gear ratios between minimum and maximum speeds. CVTs provide better fuel economy, enabling the engine to run at its most efficient revolutions per minute (RPM) for a range of vehicle speeds. Alternatively, CVTs can be used to maximize tractor's performance by allowing the engine to turn at the RPM at which it produces peak power making possible to improve productivity, work precision, energy efficiency, environment protection and driver comfort (Renius and Resch, 2005). The most known CVT is the "Vario" transmission developed by Fendt and produced since 1996. Its outstanding success motivated competitors to follow and design CVTs solution for their tractors.

In agricultural tasks, tractors usually need to follow a trajectory equidistant to a previous pass. This action can be easily accomplished when the tractor is equipped with an assisted global positioning system (GPS) (Yao *et al*., 2005), a guidance system that controls the tractor along a predetermined trajectory (Bell, 2000). The system uses a combination of a positioning system, tractors' onboard sensors, a computer to process the information and mechanisms to control the trajectory, relieving the operator from many of the tasks involved in guiding a vehicle. Two main types are currently in use: a simple "light bar" system where the operator sees tractor's position on a screen and corrects the trajectory steering accordingly, and a sophisticated "hands free" type. Both are available as after-market control systems or built-in systems integrated in the tractor.

Since 1970s global fuel crisis, considerable attention has been paid to alternative renewable liquid fuels production (Hansen *et al*., 2005). Biodiesel is the most relevant for tractors because it doesn't require modifications in existing diesel engines (Patterson *et al*., 2006) and can be used directly or as blends with Diesel fuel (Demirbas, 2009) and only a small decrease in performances is reported compared to mineral Diesel (Bozbas, 2008). Biodiesel is derived from edible and inedible vegetable oil, animal fats, used frying oil and waste cooking oil, contributing less to the global warming and environmental degradation.

Overpower/Power-Boost make possible to deliver additional engine horsepower in specific working conditions, such as high-power PTO applications and road transport operations, improving the tractor's productivity. Valtra (2012) first presented it during Agritechnica in 1997 and the introduction of electronic management on engines helped to spread its diffusion.

In tractors, vehicle maintenance strategies generally consist of corrective (the vehicle is maintained on an "as-needed" basis, i.e. after a fault has occurred) and preventive (replacing components and fluids based on a conservative schedule to "prevent" possible failures) maintenance approaches, or a combination of these. Recent advances in remote communications and embedded system technologies have led to share in-vehicle sensors and diagnostic information with remote computers, enabling remote vehicle diagnosis, communicating when maintenance is necessary (You *et al*., 2005). Some manufacturers have made these systems currently available on their tractors, while others are working on it.

ISO 11783 is a Standard for electronics communications protocol for agricultural and forestry equipment (ISO, 2007) based on the Controller Area Network (CAN) data bus developed by Bosch in the late 1980s (Cox, 2002). This Standard has been developed to meet the needs for electronic communication among sensors, actuators, control elements, and information-storage and display units embedded in tractors, implements, and other self-propelled agricultural machines, supporting precision farming applications, operator interfaces, and communications with an off-board management information system. The system can be used to coordinate machine components, to allow information to be shared among components of a machine and to be distributed across components of a machine (Stone *et al*., 1999). Since John Deer presented it at Agritechnica in 2009, many tractors and several implement manufacturers offer it (Renius, 2009).

Since 1994, responding to customers' demands to increase tractors' transport performance, manufacturers started to offer tractors with a maximum speed higher than 40 kph. All major tractor manufacturers are now offering tractors at 50 kph. No European common legislation governs the standards to which they are engineered, although local legislation, such as German National Regulations for road going vehicles, does exist.

Assisted braking system had gained great popularity in agricultural tractors. Compressed air and hydraulic brakes system are integral parts of the tractors or available as retrofitting components. Recently the anti-locking system (ABS), almost universal on passenger cars, is offered on tractors by some manufacturer: JCB equips its Fastrac with ABS since 2001, and lately also CNH (New Holland and Case IH branded tractors) and AGCO (Fendt models of tractors).

Compressed air and hydraulic brakes systems (Assisted Braking Systems) are integral parts of the tractor or available as retrofitting components. Recently the anti-lock braking system, almost universal on passenger cars, has been offered on tractors by some manufacturers as JCB, CNH and AGCO.

Fleet Management is a tool commonly adopted in transport and construction business to improve fleet of vehicles operational measures (Sørensen and Bochtis, 2010). Agriculture application of fleet management systems permits to have better timing of field work and co-ordination of available equipment, resulting in less traffic and number of trips, more adequate co-ordination of transport vehicles and site-specific accumulation of goods, machinery use and decrease in energy and labour costs (Auernhammer, 2001).

In 2007 John Deere presented the E Premium in series production tractors with high voltage system, providing power to electrical driven engine auxiliaries and to 230/400 Volt sockets available for external power supply for implements. Since then, implement manufacturers presented machines with electrical driven actuators: trailed sprayer from Amazone, mechanical and pneumatical fertilizer spreaders and pneumatic seed drill from Rauch. The benefits are the optimized controllability and distribution of power flows across and between agricultural machines, real “plug & play” for implements, increased flexibility in arrangement of components, enhanced productivity and operator comfort, and reduction of input costs (Buning, 2010).

3.2 Questionnaire

A computer-assisted personal interview was used to administer to the study’s participants a questionnaire, designed using web-based survey software (www.surveymonkey.com). The innovative method has undoubtable advantages over traditional paper-and-pencil questionnaire (Greenlaw and Brown-Welty, 2009) and was judged more appropriate considering that the survey focused on innovations and the data collection was made in a noisy and crowded environment.

Data were collected on a group of mobile devices (iPad) and trained interviewers administered the questionnaire, speeding up the process and assisting respondents when needed. The use of iPad as a survey instrument provided to be a new and engaging way to gather information.

The questionnaire was divided into several sections, containing from factual questions (objective content) to attitudinal/opinion questions (subjective content) (table 2).

Table 2 – Questionnaire variables grouped by their objective or subjective content.

A	**OBJECTIVE CONTENT**	***active variables***

A.1 Farms characteristics

A.1.1 Dimension		A.1.2 N° of agricultural tractors		A.1.3 Geographical origin	
<5ha	*Less then 5 hectares*	1-3TR	*Between 1 to 3*	Central	*Central Italy*
5-20ha	*Between 5 - 20 hectares*	4-6TR	*Between 4 to 6*	N_E	*North-east Italy*
>20ha	*More then 20 hectares*	7-9TR	*Between 7 to 9*	N_W	*North-west Italy*
		>9TR	*More then 9*	South-Islands	*South Italy and islands*

A.2 Tractors characteristics **A.3 Work characteristics of survey respondents**

A.2.1 Tractor state		A.3.1 Respondent's activity		A.3.2 Respondent's years of work	
Out_TR	*Outdated*	Farmer	*Farmer*	W<3y	*Less then 3 years*
Old_TR	*Old*	FarmW	*Farm worker*	W3-10y	*Between 3 - 10 years*
Mod_TR	*Modern*	Contr	*Independent contractors*	W<10y	*Less then 10 years*
Mod_Old_TR	*Modern and old*				
Mod_Out_TR	*Modern & outdate*				

A.4 Characteristics of survey respondents

A.4.1 Respondent's gender		A.4.2 Respondent's age		A.4.3 Respondent's study title	
F	*Female*	18-25	*Between 18 and 25 y.o.*	Elementary	*Elementary*
M	*Male*	26-35	*Between 26 and 35 y.o.*	JHS	*Junior high school*
		36-45	*Between 36 and 45 y.o.*	HS	*High school*
		46-55	*Between 46 and 55 y.o.*	University	*University*
		>55	*More then 55 y.o.*		

B	**SUBJECTIVE/OBJECTIVE CONTENT**	***active variables***

B.1 Ownership/desire of technological innovations already available on the market (10 innovations)

OWN_[*XXX*]	Owns/works with a tractor equipped with [XXX]
Next_[*XXX*]	Wishes to own/work with a tractor equipped with [XXX]
NO_[*XXX*]	Doesn't own/work and doesn't desire to own/work with a tractor equipped with [XXX]

C	**SUBJECTIVE CONTENT**	***supplementary variables***

C.1 Knowledge & perceived utility of technological innovations already available on the market

Know_[*XXX*] +	High perceived usefulness of a specific innovation know [*XXX*]
Know_[*XXX*] —	Low perceived usefulness of a specific innovation know [*XXX*]
Know_[*XXX*] ?	Lack of knowledge related on a specific innovation [*XXX*]

C.2 Validity/utility of the information channels

INFO[*XXX*] +	The use of a specific [*XXX*] information channel is perceived to be highly useful	[press] agricultural & technological dedicated press [internet] internet
INFO[*XXX*] —	The use of a specific [*XXX*] information channel is perceived to be not useful	[sellers] sales networks [fair] fair and events
INFO[*XXX*] ?	Not use of a specific [*XXX*] information channel	[colleague] colleagues [e&rINST] research and/or education centers [prof_ass] professional associations

C.3 Brand considered innovative

Open answer on the name of the tractor brand they consider more innovative

In particular, participants were asked to report some data on their current machine(s), their source of information on technology innovations applied to tractors, and their knowledge and perceived usefulness of technological innovations, the aspects considered important in agricultural tractor usage and their propensity toward technology advancement investigated. Respondents used a 4-point Likert scale (1932) to express their opinions. The survey ended with a set of background and demographic questions.

3.3 Statistical Analysis

Data analysis was conducted on 228 questionnaires, accounting for 75% of the total number of questionnaires collected. Students, people working in the agriculture machinery trade or service sector, and people whose primary work activity was not related to agricultural sector were removed from it.

Analyses have been conducted exclusively on subjects who affect directly the tractor market sector, being those who make the actual purchase of the machines.

Univariate and bivariate analyses was performed in order to know the relationship between and among the variables investigated. Gender differences were not investigated, being not conclusive (only nine women participated to the study). As reported in table 3, chi-square test (χ^2) and Spearman's rank correlation coefficient (r_s), a nonparametric measure of statistical dependence between two variables, were calculated. Considering that χ^2 value is affected by both the strength of the association between the two variable and the size of the sample, it was decided to calculate also the Cramer's V. Indeed, Cramer's V removes the effect of the sample size, leaving a measure of the strength of the relationship between two variables.

Additionally, a multiple correspondence analysis (MCA) was conducted using R software. In particular FactoMineR (Escofier and Pagès, 2005) and CA (Greenacre, 2007) packages were applied. The variables listed in A and B of table 2 were considered as active variables - the variables directly used for computing the factorial plane - while C variables were added as supplementary information. The percentage of explained variance of the first two factors was re-evaluated using the Benzecri (1973) method.

4. RESULTS AND DISCUSSION

The analysis is applied considering the Italian case study. In 1945, Italian farms had about 52,000 tractors, a number that rose to 1.75 million by 2008 (Unacoma, 2008), assigning to Italy the 3rd place in tractor fleet after USA and Japan (World Resources Institute, 2012). Italy is a world leader in tractor production (Unacoma, 2008) and its agricultural machinery manufacturing industry is made out of large globally active groups and small and specialized companies that are closer to their clients and better placed to know their needs (Vieweg, 2012). Specific information on the production of the two groups are not available, however large companies dominate the tractor market and roughly 80% of the vehicles are manufactured by 20% of the manufacturers (i.e., Pareto principle) (Vieweg, 2012). In 2008 and 2009 the Italian agricultural tractors manufacturers assembled more than 27,000 vehicles. By 2011 this number decreased to 23,500 units, as a consequence of the global financial

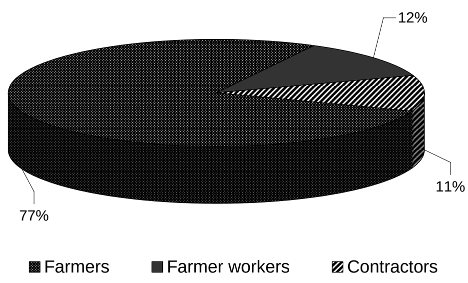

Figure 1. Sample distribution

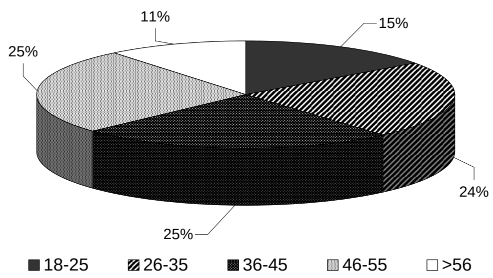

Figure 2. Sample age distribution

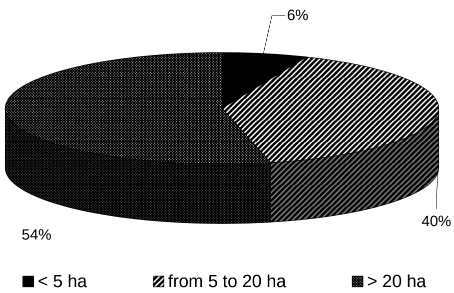

Figure 3. Farms size distribution

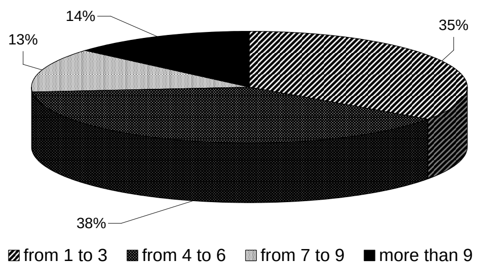

Figure 4. Number of tractors owned or used

crisis (Federunacoma, 2012). Approximately 1,729,000 farms are operative in Italy, utilizing an area of 12.7 million hectares (Istat, 2005). Based on recent data 80% of the farms are smaller than 5 hectares and their average dimension is 7.6 hectares (Istat, 2009). Moreover, any of the Italian farms has a tractor and tractors' density is approximately 138 every 1000 ha; very high if compared with 85.8 for Germany, 64.5 for France and 26.8 for USA (World Resource Institute, 2012).

In the study only data related to farmers, farm workers, and independent contractors (n=228), accounting for 75% of the total number of respondents, were analyzed. More than three quarters of the sample were farmers (figure 1). Respondents' age ranged between 18 and 75 years. Participants were grouped into three ten-years age classes, plus a class aged between 18 and 25 (youngest) and one aged between 56 and 75 years old (elderly)(figure 2).

As shown in figure 3 and 4 the majority of the sample owns or works in a farm larger than 20 hectares and deals with a number of tractors between 4 and 6.

4.1 Trends and relationships between variables

Descriptive statistics showed that in agriculture tractor usage the aspect considered most important was safety (76,7%), followed by ease of maintenance and assistance (67,5%), and comfort (66,2%). Just over half of the sample (53,1%) gave a score of 4 on the Likert scale – meaning "very important" - to environmental impact reduction. Less than a third of the respondents considered very important tractor technological content (30,3%) (figure 5).

Table 3 reports all significant relationships

Table 3 – Significant relationships between sample characteristics and questionnaire statements.

#	Variable 1	Variable 2	χ^2	df	p	r_s	df	p	Cramer's V
		Important aspects in tractor usage							
1	Environmental impact	Age	27.532	12	.006	.171	226	.010	.201
2	Environmental impact	Years of activity	23.015	6	.001	.225	226	.001	.225
3	Comfort	Farm size	16.069	6	.013	.477	226	.004	.270
4	Safety	Job title	15.209	6	.019	---	---	---	.183
5	Technological content	Geographical origin	22.971	12	.028	---	---	---	.183
		Source of information on new technologies							
6	Internet	Geographical origin	27.193	16	.040	---	---	---	.173
7	Edu. & research centers	Job title	20.179	8	.010	---	---	---	.210
8	Agricultural press	Years of activity	16.878	8	.031	.220	226	.001	.192
		Useful technologies innovations							
9	Speed > 40 Km	Geographical origin	32.758	16	.008	---	---	---	.190
10	Alternative flues	Geographical origin	27.187	16	.039	---	---	---	.173
11	Assisted Guidance System	Age	29.010	16	.024	-.200	226	.002	.178
12	Assisted Guidance System	Farm size	15.961	8	.043	.176	218	.009	.190
13	CVT-VARIO	Farm size	17.020	8	.030	.183	218	.006	.197
14	Overpower / Power Boost	Farm size	17.415	8	.026	.214	218	.010	.199
15	Remote diagnostics	Farm size	16.012	8	.042	.187	218	.005	.191
16	Alternative flues	Farm size	16.381	8	.037	-.168	218	.013	.193
17	Remote diagnostics	N° of tractors owned	21.701	12	.041	.141	226	.034	.178
18	Fleet management system	N° of tractors owned	24.177	12	.019	.167	226	.011	.188
		Useful aspects of technologies innovations							
19	Increase flexibility	Age	21.064	12	.049	.129	218	.050	.178
20	Increase flexibility	Job title	14.655	6	.023	---	---	---	.182
21	Increase safety	Job title	13.673	6	.034	---	---	---	.173
22	Increase safety	Years of activity	14.774	6	.001	.222	226	.001	.180
23	Increase reliability	Years of activity	18.880	6	.004	.219	226	.001	.203
24	Reduce environ. impact	Years of activity	22.537	6	.001	.181	226	.006	.222
25	Increase driving comfort	Geographical origin	35.950	12	.000	---	---	---	.229
		Future interesting technologies innovations							
26	Safety and warning	Years of activity	14.711	6	.023	.206	226	.002	.182
27	PTO infinite number	Geographical origin	21.625	12	.042	---	---	---	.182

between sample characteristics and questionnaire statements. A significant association emerged between age and importance given to environmental impact reduction in the use of agricultural that younger people are more environmentally concerned than older people (Olli *et al.*, 2001). On the contrary, the analysis showed a weak but statistically significant positive correlation between age and importance of environmental impact reduction (#1r_S), indicating that those who assigned the highest score to the importance of reducing the environmental impact were people aged between 46 and 55 (figure 6).

Similarly, higher education is in general positively associated with environmental concern (Eckersley, 1989), and therefore it was expected that highly educated participants would have judged environmental impact reduction very important in agricultural tractors usage. However, any significant

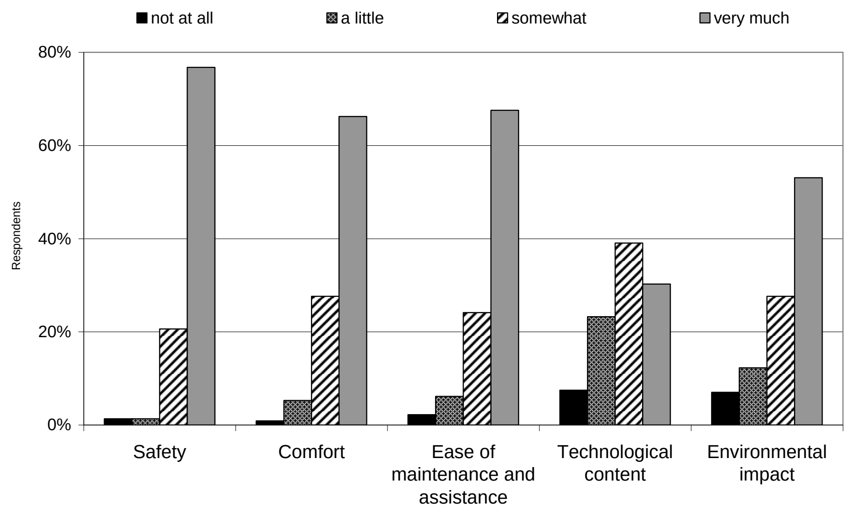

Figure 5. Aspects considered important in tractor usage.

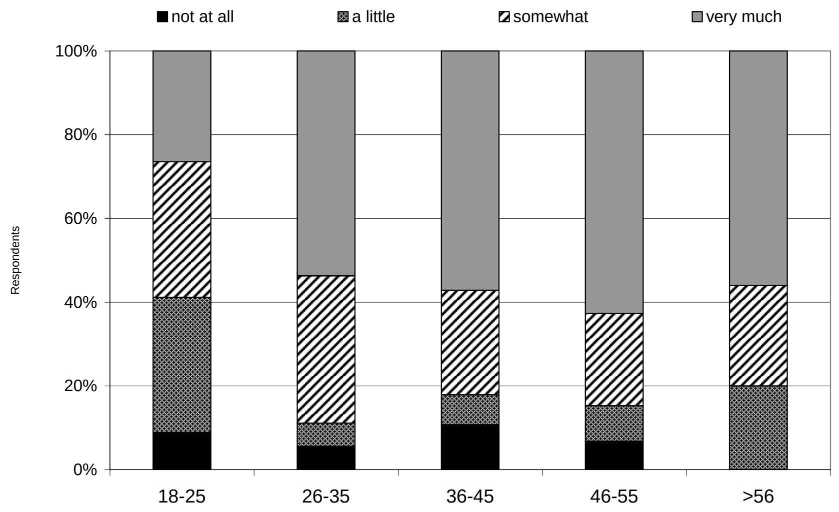

Figure 6. Importance of environmental impact reduction according to respondents' age.

correlation between school degree and importance given to this aspect was found. Nevertheless, a significant association was found looking at the years of activity (#2χ^2). Respondents who were working in this sector for more than 10 years were more likely to consider it very important (#2r_S) (figure 7).

At the same time, the more years they had spent working in this field, the more they believed that technological innovations of agricultural machines enabled environmental impact reduction (#24$\chi^2 r_S$).

A significant strong association with a Cramer's *V* of .270 was found between farm size and importance given to the aspect of comfort (#3χ^2); the bigger the farm, the more important is agricultural tractor comfort. In addition, job title (i.e. farmer, farm worker or independent contractor) was significantly associated with the importance given to safety

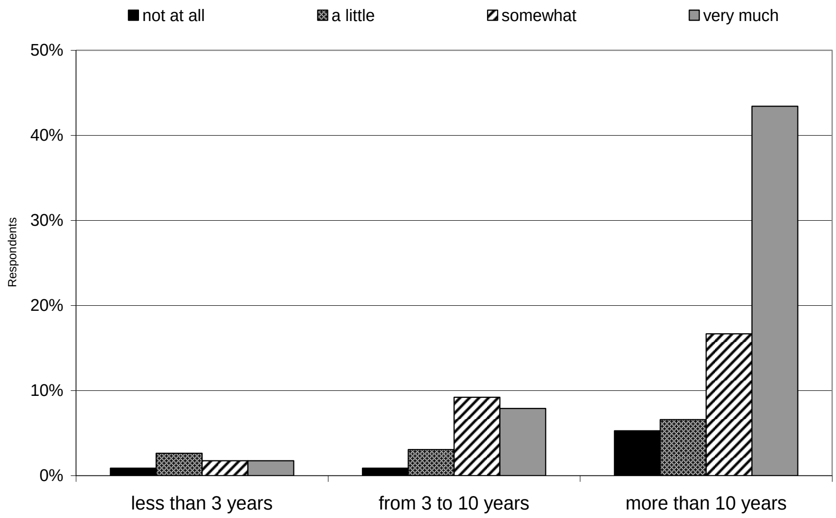

Figure 7. Importance of environmental impact reduction according to respondents' years of work.

(#4χ^2), while respondents' geographical origin showed to be significantly associated with the importance of agricultural tractor technological content (#5χ^2). In both cases, the Cramer's *V* of .183 indicates that the relationship was moderately strong.

Most of the respondents obtained information on technological innovations primarily from exhibitions or conferences (96,9%), through colleagues (95,6%) or by direct experience (94,7%). Only a reduced number used internet as a source of information on new technologies, and a moderate association between respondents' geographical origin and usefulness of the information on technologies innovations obtained through the use of internet was found (#6χ^2).

Likewise, obtaining information through educational and research centers showed to be significantly associated with the position held in the farm (#7χ^2). Similarly, obtaining information through agricultural press was significantly associated with years of activity (#8χ^2); the more respondents had been working in the sector, the more they found agricultural press to be a useful source of information on technological innovations (#8r_s).

The innovations most known were the speed higher than 40 kph and the brake assisted systems, while the ISOBUS/CAN-BUS technology resulted as the less known (figure 8).

All participants who had knowledge about a particular technological innovation, were also asked to report how useful they believed that innovation was. ABS and possibility to reach speed greater than 40 km/h were considered the most useful ones (figure 9). Interestingly, a significant moderate relationship was found comparing respondents' geographical origin and opinions on speed (#9χ^2). Again, respondents' geographical origin and opinions on alternative flues showed a slightly less strong relationship (#10χ^2).

No statistical significant differences were found in the usefulness of ISOBUS/CAN-BUS technology, while a significant association emerged between age and usefulness of assisted guidance system (#11χ^2). Younger farmers resulted slightly more informed about this technology, and compared to older farmers they considered it to be more useful (#11r_S).

Farm dimension resulted statistically significant associated with knowledge and believed usefulness of almost all technological innovations investigated in the survey. The bigger the farm size, the more useful the technological innovation was believed to be (i.e. assisted guidance system (#12), CVT-Vario (#13), overpower/Power-Boost (#14), and remote diagnostics system (#15). The only exception to this positive trend was related to the opinions on alternative flues (#16).

Remote diagnostics system (#17) and fleet management (#18) resulted significantly associated with the number of tractors in the farm, showing that the more tractors were in a farm, the more farmers needed support for their management.

A ternary diagram (figure 10) was created to

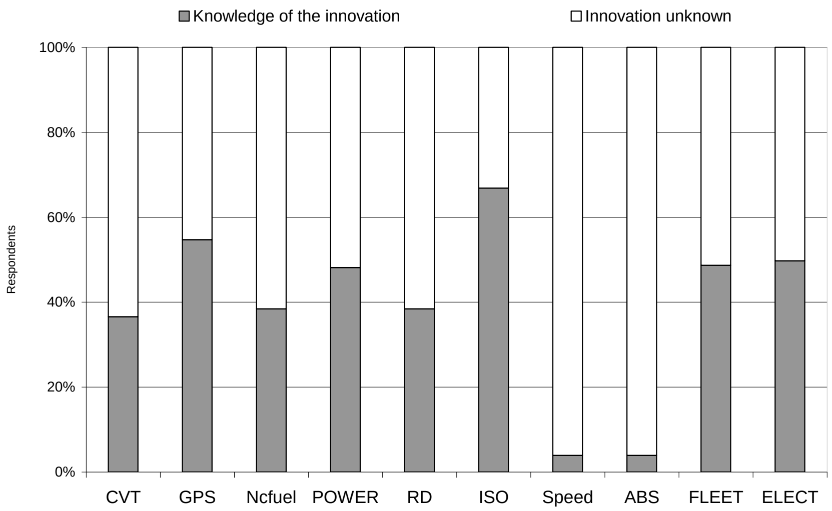

Figure 8. Respondents' knowledge of agricultural tractor technological innovations.

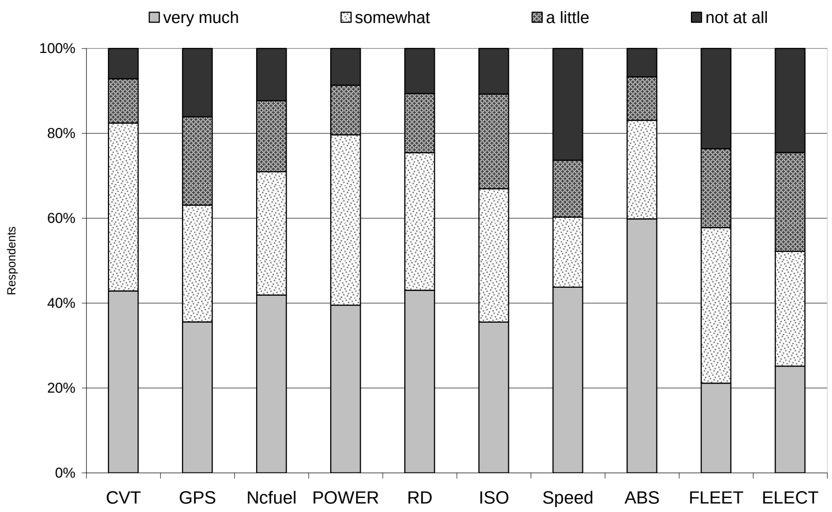

Figure 9. Importance of different technological innovations in agricultural tractors.

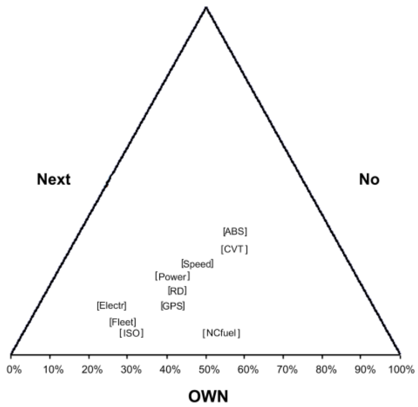

Figure 10. Distribution of technological innovations according to the percentages of respondents who have (OWN), who wish they have (Next), and who don't have and don't want to have them (NO).

visually represent the distribution of the set of innovations according to the percentages of respondents who actually have them (OWN), who wish they had (Next), and who don't have and neither want to have the innovation (NO). In the diagram, each label distance from each side of the equilateral triangle proportionally to the percentage of the item indicated on the side. For example, ABS and CVT resulted the technologies the more available among the sample (in the figure they are at the farthest location from the OWN side). Similarly, electric actuators, fleet management system and ISOBUS/CAN-BUS technologies were very little available and desired, while alternative fuels resulted little available and highly desirable.

More than half of the respondents believed that technological innovations applied to agricultural tractors increased very much the comfort of the machine and its safety (figure 11). Beside, a significant correlation was found between the belief that technological innovation increases machine flexibility and respectively respondents' age (#19χ^2) and job title in the farm (#20χ^2). At the same time, respondents' job title was found significantly correlated with the opinion that technological innovation raises machine safety (#21χ^2). This statement showed to be significantly correlated also with respondents' years of activity in the field (#22χ^2). Farmers working in the agricultural sector for more than 3 years believed that technological innovation increases very much agricultural machine safety compared to farmers who recently (less than 3 years) started working in this field (#22r_S). Similarly, years of activity was significantly related to the opinion that technological innovation amplifies machine reliability (#23χ^2), showing that the more years farmers have been working in the agricultural field, the more they considered that technological innovation increases machine reliability (#23r_S). Regarding the aspect of driving comfort a significant correlation was found with respondents' geographical origin (#25χ^2).

According to respondents' opinions two technological innovations could be very useful in the future, such as 1) safety and warning system that enables driver identification,

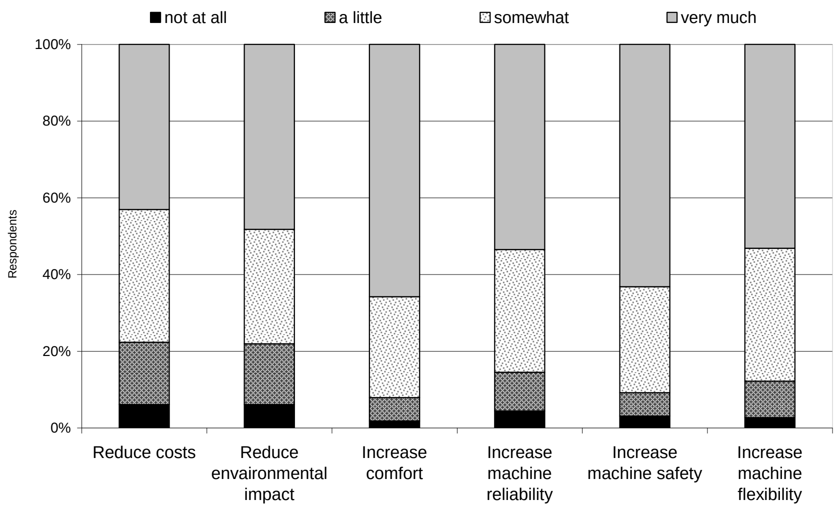

Figure 11. Respondents' opinions on the possible results of the application of technological innovation to tractors.

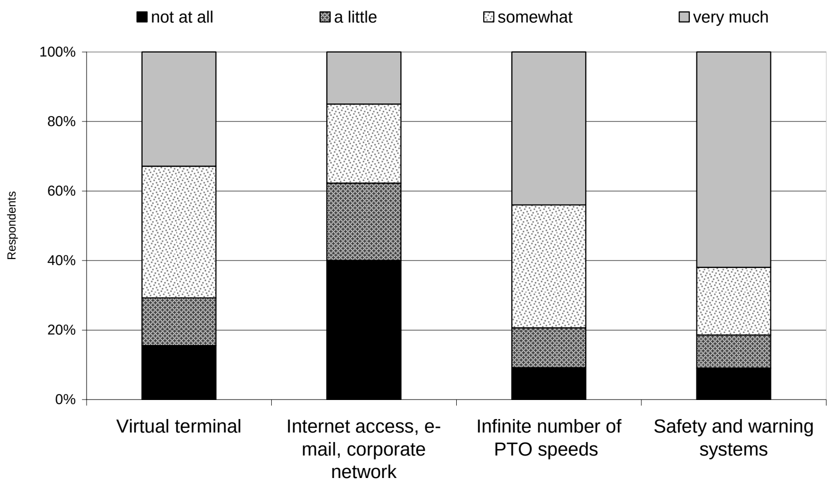

Figure 12. Respondents' opinions on the usefulness of possible future technological innovations.

prevents risky manoeuvres, gives information to the driver about dangerous situation, and communicates any incidents to a business centre or an emergency service (60,1%) and 2) a system providing infinite number of power take-off speeds independently from those of the engine (42,1%) (figure 12).

A significant positive correlation was found between years of activity and safety and warning system (#26), and between the geographical origin the system providing infinite number of power take-off speeds (#27χ^2). The possibility to have access to e-mail, internet and corporate network on an agricultural machine was considered not at all useful by the 38,6% of the sample.

4.2 Multivariate analysis

A graphical representation of questionnaire active variables is reported in figure 13. The variables with some objective content were directly used for computing the factorial plane, while variables with only subjective content were added as supplementary information. A significant contribution to the interpretation of the MCA output was given by users' ownership/desire of technological innovations.

This question had both an objective and subjective content. The objective content was related to the fact that participants reported which one of the technological innovations available on the market they had or not on disposal (variables labelled OWN_[*XXX*] and NO_[*XXX*]), while the subjective content referred to those innovations they wished their tractors were equipped with, or, in other words, the technological innovation they "*desired to have*" (see variables labelled Next_[*XXX*]).

The availability of technological innovation on agricultural tractors, spread on the right side of the factorial plan (dark gray boxes), giving significance to the horizontal dimension (first factor).

Indeed, a dichotomy appeared between participants positioned on the left side of the quadrant (those who don't own/work with tractors equipped with technological innovations) and those on the right side (who have innovative tractors). A similar situation was found looking at farm size and fleet dimensions (see solid arrows).

The smaller farms, both in terms of size and

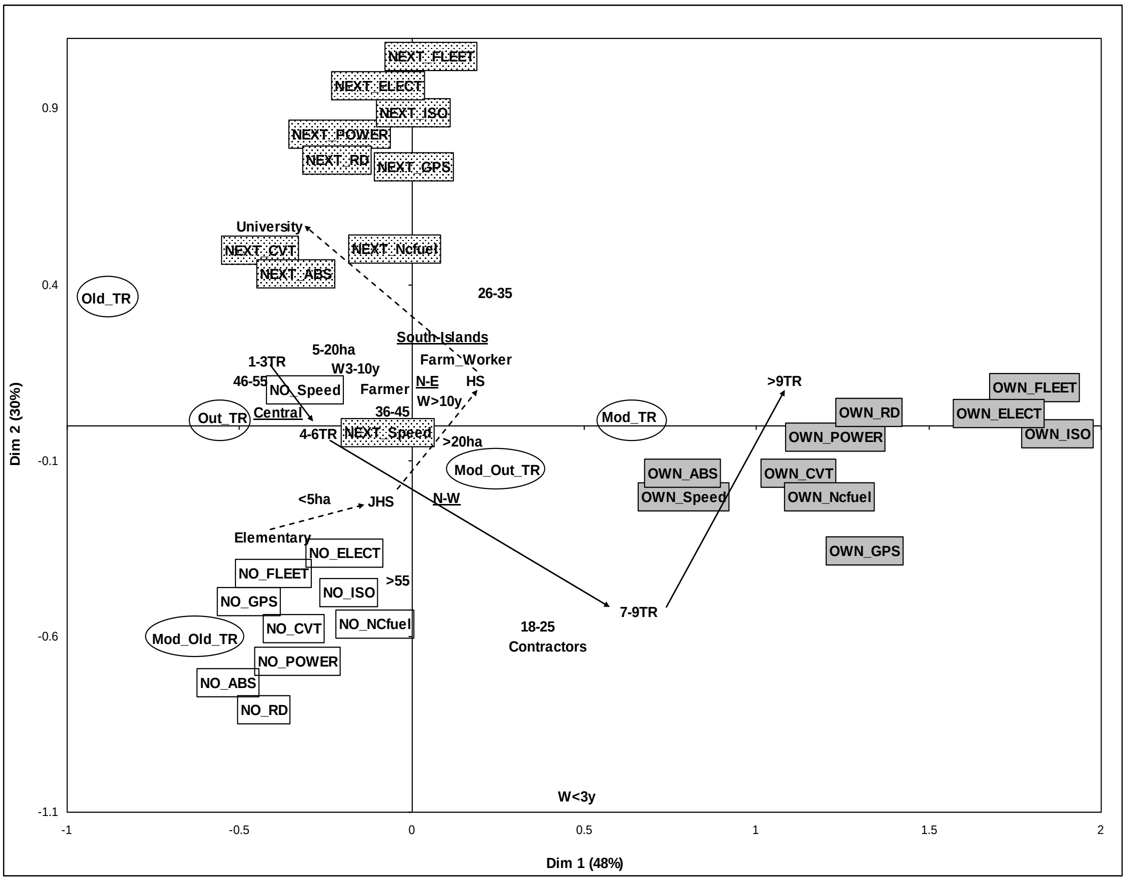

Figure 13. Multiple correspondence analysis. Projection of active variables (see Table 2)

fleet, were positioned on the left side of the graph (the less technological), while moving to the right-hand side of the factorial plane (the more technological area) we find bigger farms (both in terms of size and fleet). Again, the technical state of the tractors used by the respondents (see circular shapes) followed the same path from left to right, according to a classification that goes from prevalent use of old tractors (very left), to outdated tractors, then to tractors in part outdated and in part modern, and finally to modern tractors (right). According to participants' geographical origin (underlined in the figure), the less technological area resulted located in the centre of the peninsula, while the other main Italian areas showed higher averages of technological innovation; in the inhomogeneous south-islands area (located just in one point of the map to represent a greater number of respondents), the south appeared less technological. According to the professional role, moving from the left-hand side we encounter agricultural farmers with less opportunity to dispose of modern tractors, then agricultural farm workers and finally independent contractors, who show more opportunity to work with tractors equipped with technological innovations. Hence, the first dimension (horizontal) has an objective explanation, opposing real presence of technological innovation on agricultural tractors (right-hand side) to its absence (left-hand side).

Differently, the second dimension is explained mainly by subjective opinions related to the desire of technological innovations. In the area on the left of the axes origin - the less technological area - the factorial plan shows again a distinct polarization: at the top are positioned respondents who don't have technological innovations on their machines and wish they would have them in the future (grey boxes), while at the bottom we find respondents who don't own/work with technological machines and don't have the desire to dispose of those innovations (white boxes). Respondents of this last group appeared to be over 55 years old or to have a low degree level (elementary or junior high school degree). Either the technological state of their tractors was old or the new tractors were plain models with a low hi-tech profile. On the contrary, respondents with a university degree (see dash arrows) were more frequently between respondents of the upper pole, those who don't dispose of technological innovations and wish they would.

Beyond this general trend, it is interesting to note that some features, such as fleet management systems, electronic actuators and ISOBUS/CAN-BUS systems were generally recognized as the most attractive. Indeed, they were positioned slightly higher compared to other features, both in the high left side of the factorial plane (the area targeting individuals who would like to have on disposal technological innovations; they were more interested on the features positioned below in the graph), as well as in the low left side of the factorial plane (the area targeting individuals less interested to tractors technological innovations; in particular considering the features positioned higher up in the graph). Otherwise, the trend found for these two groups (those who are interested in the innovations and those who are not)

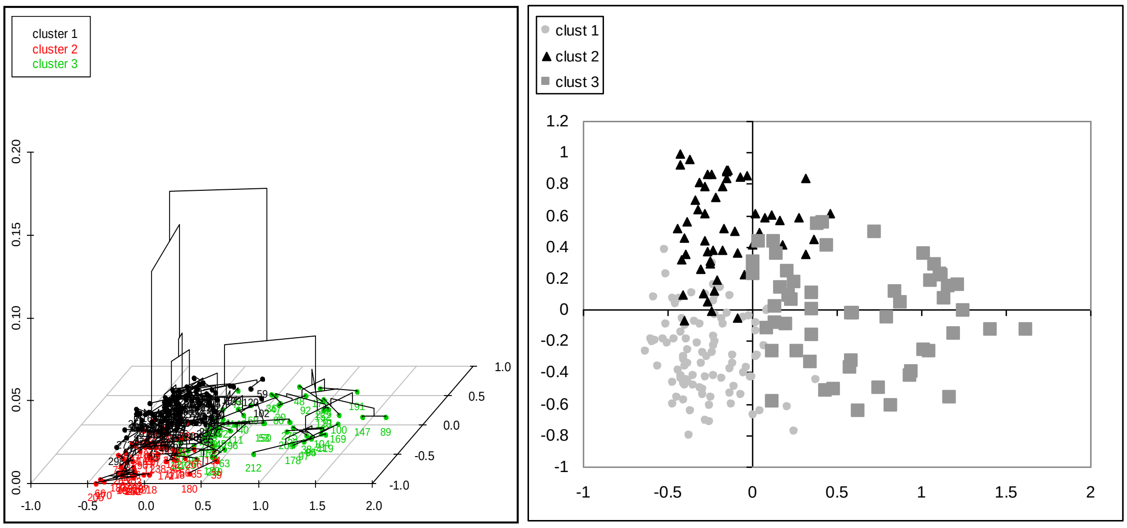

Figure 14. Cluster analysis on first five factors resulting from the MCA of figure 13.

repeated itself even for the remaining features, such as the speed greater than 40 km/h, positioned very close to the abscissa.

In order to confirm MCA result, a further analysis was conducted with the use of cluster analysis (Ward hierarchical method was used on the first five factorial axes) grouping participants by response affinity. A good fit was reached considering a three cluster partition, as shown in figure 14.

The three groups of respondents are quite separated in the planar representation and correspond to the three categories already identified in the MCA factorial plane. Cluster 3, positioned on the right side of the plane, represents respondents who have more opportunities to dispose of technological features; at the top left cluster 2, consisting of respondents who - while not working in technological environments, feel the lack of technological features; and finally at the bottom left cluster 1, presents respondents who neither use, nor would like to dispose of tractors equipped with technological features. Also, the cluster analysis allowed the numerical evaluation of the three groups, showing that just over half the respondents (53%) had on disposal or wanted to work with technological innovations, while the actual availability of technological innovations on tractors was represented by one quarter of cases (26%).

Moreover, results of supplementary variables to the so-called active variables, were positioned on the factorial plane and are presented in figure 15 (perceived usefulness of different information sources on technological innovation) and figure 16 (level of knowledge and appreciation of technological innovations).

At the bottom of figure 15, characterized by a low education level, were gathered responses linked to the non-use of the different media information channels (INFO[*XXX*]?).

The shift in perception from low benefit (INFO[*XXX*]-) to high usefulness (INFO[*XXX*]+) of media information channels followed a bottom-up trend. This trend matches with a general cultural development that resulted usually accompanied by a greater appreciation for technological features.

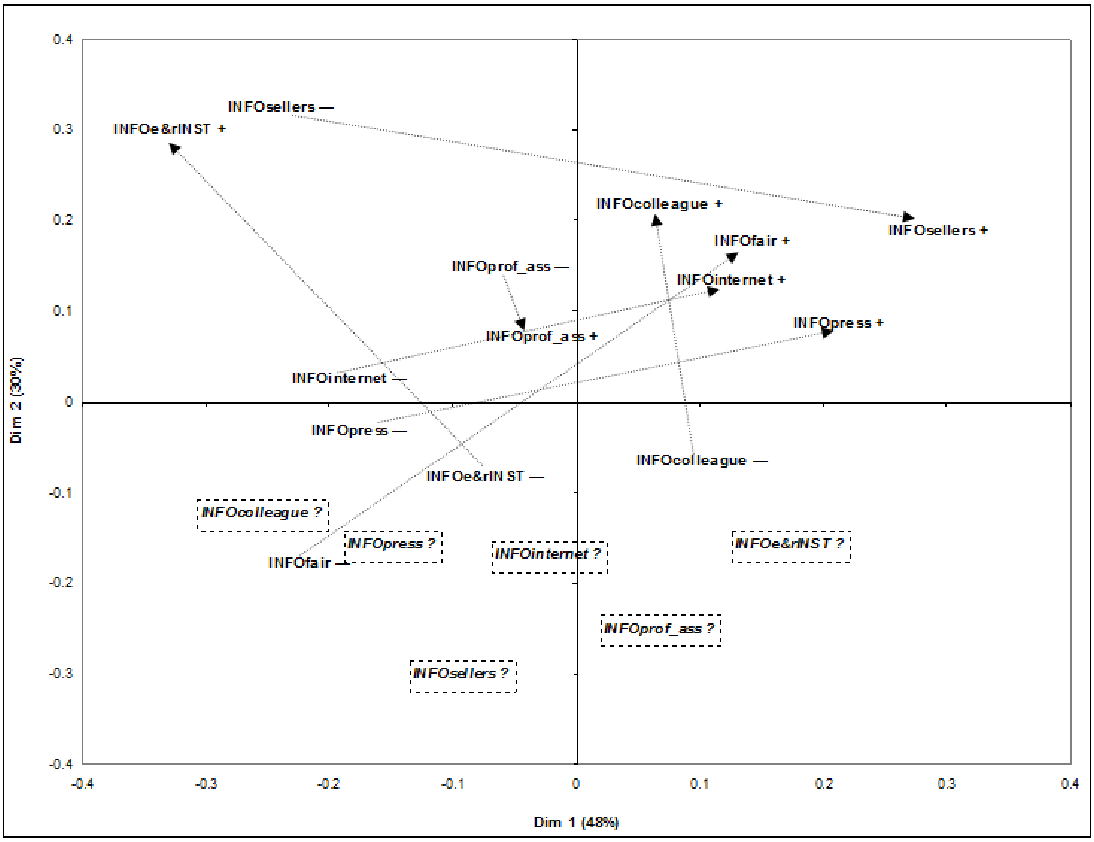

Figure 15. Multiple correspondence analysis. Projection of supplementary variables (perceived usefulness of information channels). See Table 2 (C.2)

Opposite to this general trend, is the quality of the information perceived from sales networks and especially from professional association, to whom respondents with the lowest educational levels turn to get informed on agricultural machines technological features. At the same time, the arrows in figure 15 follow mainly a left-to-right direction, indicating that the level of interest and benefit gained by the use of the different media information channels increased according to the advancement knowledge on technological innovations and the disposal of tractors with high technological features. Instead, a right-to-left direction was found for the respondents who turn to colleagues or to research and/or education centers, making up for the information they do not have acquired yet.

Similarly to figure 13, in figure 16 the lack of knowledge on the innovations proposed was grouped in the bottom-left area (Know_[*XXX*]?), marked as "Unknowing area". Moving from the central area to the top-right one, participants opinions on innovations usefulness increased, going from low (Know_[xxx]--; Uselessness area) to high (Know_[xxx]+; Usefulness area). All the arrows in figure 16 are left-to-right and bottom-up oriented, showing a positive disposition toward technological innovations as respondents possibility to use or own tractors equipped with technological innovations rise (horizontal dimension) and their cultural level increase (vertical dimension). Differently, the perception of usefulness of some innovations, such as those related to the use of alternative fuel or to electric actuators (see white boxes), showed only a bottom-up direction, thus being more related to the cultural development rather than d to the possibility of using innovative tractors. Affected to a lesser extent by the opportunity of using innovative tractors, a more consistent pattern with cultural development was shown by the appreciation of ABS and remote diagnostics systems. Indeed, a close vertical direction of the arrows, as well as some tendency from left to right, can be noticed. Instead, more consistent with the possibility to be exposed to the use of innovative tractors was the appreciation for the opportunity to reach speeds above 40 km/h (gray boxes). In figure 16 is also reported a list of brands[1] that respondents considered the most innovative in terms of technological content. Landini brand (bottom left) positioned with respondents lacking of knowledge on technological advancements and not having on disposal innovative tractors (see figure 13). Follows Same, positioned more to the right (alike respondents who were

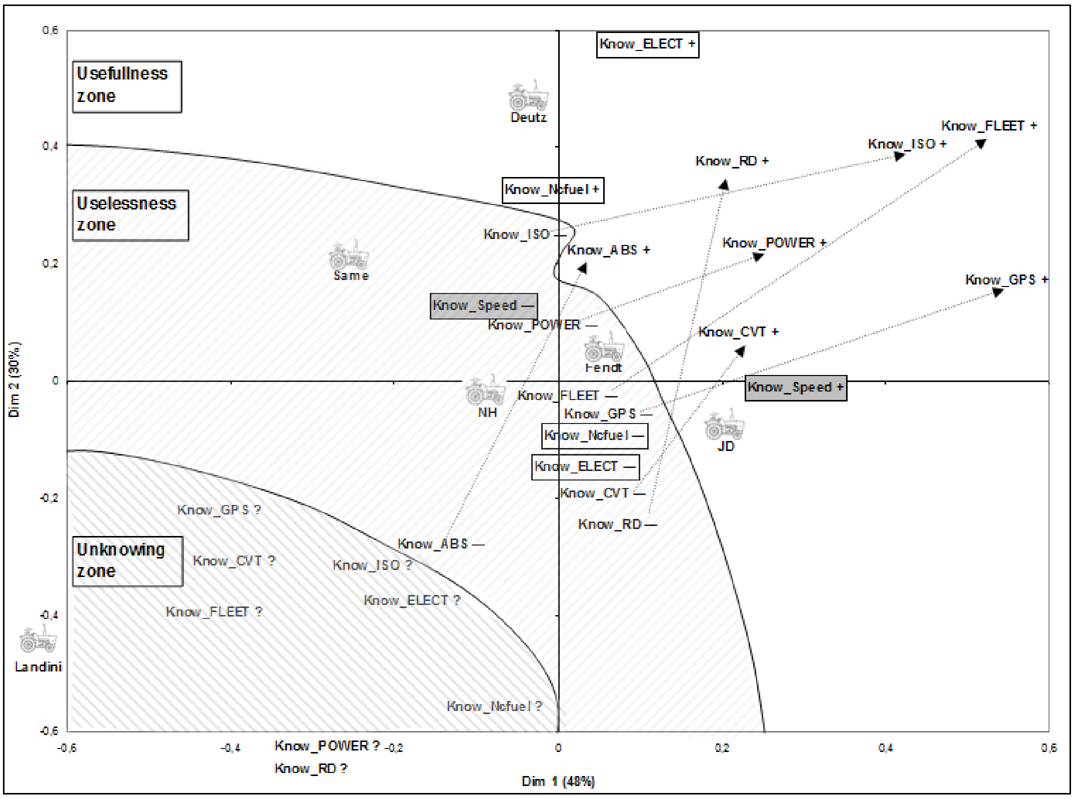

Figure 16. Multiple correspondence analysis. Projection of supplementary variables.*
See Table 2 (C.1 and C.3)

* Know_POWER and Know_RD have a y-value lower than it appears in the map; see also “Landini” which has a lower x-value

1 The figure reports different brands of tractors manufacturers (i.e. SAME Deutz-Fahr manufacturer appears as Same and Deutz-Fahr brands).

more experienced with technological advancements and higher (alike respondents with higher cultural level). Located further right, similar to respondents with a higher expertise in technological features, are New Holland, Deutz Fahr and Fendt that gain a higher appreciation as innovative brands in terms of technological advancements. At the far right hand side is positioned John Deere, acknowledged especially by those respondents who had more experience with technological innovations applied to agricultural tractors.

5. LESSONS LEARNED AND CONCLUDING REMARKS

In Europe the past decade trend has led to provide the development of sophisticated technology and the introduction of electronics into all areas of agricultural machinery (Vieweg, 2012). Nevertheless, several tractor users have not moved toward technological innovations, showing that it is important to investigate and understand how people respond to new trends and innovative concepts.

While economic benefit is recognized as the primary reason to adopt new agricultural technologies, other attitudes play important roles. The way an individual perceives the new technology is critical to whether they will eventually adopt it. Gaining knowledge on who the tractor users are, on their perceptions toward technological innovations, and on their aims is paramount to those agricultural machinery stakeholders who are looking for new opportunities to increase their income and expand their business, as well as to those who are responsible for the agricultural policy regulations. Indeed, knowing the preferences, expectations and needs of tractors operators could improve the allocation of human resources, budgets of innovative projects, and founding for agricultural subsidies. It also means improving the probability of success.

To this end, a questionnaire was designed and applied to draw a picture of Italian tractor users' beliefs, opinions and behaviours on technological innovations currently applied to agricultural machines, as well as on those innovations which could become available in the next future.

The survey reveals that technological innovation is relevant for Italian large farms and contractors. Large farms are managed professionally, requiring more efficient and sophisticated machineries. New highly technological products are targeted to these professional farmers, where manufacturers can capitalize on these trends (Richenhagen, 2009). On the other hand, tractor technological innovation content is not the main aspect taken into consideration when agricultural operators are using it. Nevertheless, more than half of the study's participants indicated that technological innovation is fundamental, recognizing its role in improving comfort and safety. In particular, comfort resulted important especially for larger farms, where higher is the number of hours that a worker has to spend dealing with the machines.

Differently from the literature (Olli *et al.*, 2001), results show that the older the tractor users are and the longer they have been working in agriculture, the higher is their commitment to environment protection and safe working conditions. This result suggests that more energy should be use in agricultural education on these two topics, and that young farmers' population should be further investigated on these aspects.

Nevertheless, the study reveals a general interest on environment protection, especially when alternative fuels were considered. Indeed, they resulted to be one of the less available and highly desirable among the innovative technologies investigated.

Also, operators use different strategies to collect information on tractors technological innovation according to their age. Generally, older respondents prefer to gain information from magazines, professional associations and sale network. Internet is not deemed as an important source of information by almost all respondents and its access from the tractor cabin achieved limited interest. Use of information from scientific sources are limited to the group of people that manage a large number of tractors and - or - have a higher education.

Some technological innovations such as ABS and speed higher than 40 kph are well known and resulted the most required, meeting a precise need of modern agriculture. Indeed, tractors above 100 hp spend a large amount of time in transport related activity, moving from one part of a farm to another or carrying implements, such as crop sprayers or fertilizer spreaders. In farms with reduced dimensions and fragmentation of the surface, which characterize Italian agriculture, it is crucial to reduce road travelling time. This allowed to predict the success of the ABS system to tractors. It is a more efficient braking systems that permits to achieve safer braking performance, to increase tractors size and speed, and of the heavy trailers and implements they are expected to pull or carry.

Differently, some technological innovations are far to be known to the great public. That is the case of the virtual terminal, where co-operation among tractors and implements suppliers is required to develop a successful system.

The survey highlights some geographical aspects. The request of technology is generally greater in north of Italy, especially in the North-West, where most of the bigger farms are.

Survey results indicate that farmers, farm workers and contractors recognize safety as a priority and that enhancement of tractor technology content is highly desirable. Indeed, those who run tractors often work alone with powerful machinery in conditions that can be hazardous. Solutions that enable driver identification, prevent risky manoeuvres, give information to the driver about dangerous situations, and communicate any incidents to a business centre or an emergency service, have already been proposed by manufacturers.

Such systems intend to increase the adoption of safe practices, the respect of the safety regulations, and consequently the reduction of accidents. Nevertheless, until now, none of those solutions have been able to satisfy real users' needs, being therefore unsuccessful.

Additionally, the survey allowed to discriminate the respondents' behaviour toward innovations. Three different respondents' profiles, presenting different cultural levels and working positions, emerged from questionnaire results.

These distinctive adopters' behaviour, which can easily represent sketch of *personas* applied in user-centred design methods (Carroll, 1995; Cooper, 1999), are the following:

1. *Unwilling*: lack of information retrieval, technological innovation lack of use and lack of desire;

2. *Cultural*: information seeker, unavailability of technological innovation, as well as desire to have them on disposal;
3. *Owner*: availability of technological innovations and positive attitude towards future innovations.

Tractor users with a more positive attitude toward technological innovations are those who have a higher degree and have reached a certain work maturity, without having moved to the oldest age ranges yet.

Moreover, a high level of culture and the availability of technological innovation, settle the prevalent source used to gain information on new technology, such as the web, specialized press, and national and international fairs.

It is also interesting to note that the three identified profiles can be combined with different tractors brands, according to their predisposition toward technological innovation, and whose results are appreciable in terms of numbers of innovative solutions awarded in different contexts and made available on mass production.

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