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Sustainable Precision Agriculture: Research and Knowledge for Learning how to be an agri-Entrepreneur

SPARKLE

Sustainable Precision Agriculture: Research and Knowledge for Learning how to be an agri-Entrepreneur

Results of the Foresight Analysis

Rev. 3 - Update

WP 2.2

Erre Quadro

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DOCUMENT HISTORY

Version	Date	Author (Partner)	Remarks
1	2019-01-28	Erre Quadro	Draft
2	2019-02-20	Erre Quadro	Update due to partnership's requests
3	2019-03-29	Erre Quadro	Update due to partnership's requests
4	2019-06-19	Erre Quadro	Update due to external review

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1. SCOPE OF THE ANALYSIS

The foresight analysis is aimed to discover growing technological trends in the Precision Agriculture (PA) field. The study highlights which are the main technological clusters and their evolution in time; furthermore, for each technological cluster an in-depth analysis showing involved subjects, geographical areas of influence, and the most promising Research & Development (R&D) technical fields will be provided.

Through the usage of a double data source, both industrial and academic R&D outcomes are analysed, in order to inspect which are the last innovations which currently are (or will be in the future) on the market. Finally, results of the foresight analysis will be submitted for a final validation to a pool of experts in the field of precision agriculture.

2. SUMMARY

This document is aimed to introduce to the partnership of Sparkle the results of the technology foresight analysis focused on precision agriculture as part of WP2. After a methodological introduction (Chapter 3), the first layer of analysis is disclosed, comprising the number of analysed documents and the clustering activity (Chapter 4). In Chapter 5 and 6, for each technological cluster of viticulture and arable crops respectively, an in-depth analysis is shown. Furthermore, Chapter 7 introduces a synthetic view on obtained data and a comparison between technological clusters. Finally, Chapter 8 contains the conclusions, disclosing the main insights of the analysis.

The document has two annexes, related respectively to a glossary and a summary of Patent Offices' acronyms, and two annexes, in which, for each technological cluster, examples are displayed respectively of relevant patents and significant papers.

3. METHODOLOGY

3.1. DATA SOURCES

The foresight analysis has been conducted both on patents and on scientific literature. The analysis on patents has been carried out taking advantage of the Erre Quadro proprietary database, based on the data provided by the Patstat service, which is solely responsible for the accuracy and completeness of the data themselves. Patstat is a service of the European Patent Office (EPO) that supplies textual data and metadata (bibliographical, related to involved subjects and legal status data) about more than 110 million of patents, belonging to all the world patent offices[1]. The analysis has been conducted on the *"PATSTAT Global 2018 Autumn Release"* version, released in date 1st October 2018 and updated with documents published until 20th June 2018. Therefore, all the patent data present in this report are referred to said version of database.

Unlike the patent data source, due to the lack of a unique and complete source, it is not possible to perform a thorough analysis on scientific literature. Having this in mind, ScienceDirect has been chosen as a representative and statistically significant sample of the precision agriculture technological field. ScienceDirect, which is solely responsible for the accuracy and completeness of the data themselves, is operated by the publisher Elsevier and hosts over 12 million pieces of content from 3500 academic journals and 34000 e-books.

[1] For further information, visit the following web page: https://www.epo.org/searching-for-patents/business/patstat.html

3.2. BOUNDARIES OF THE ANALYSIS

In order to reduce the amount of documents to be processed and to focus on most significant ones, it is necessary to define a precise and shared set of characteristics. In accordance with the partnership, Erre Quadro gathered the opinion of all the partners and defined the boundaries of the analysis. Said boundaries have been reported in the document "*WP2.1 - Plan of foresight activities and expected results"* and validated by the partnership. In the following, a detailed definition of the applied boundaries. A document (patent or scientific paper) has been considered relevant for the analysis if its main object complies with all the following statements.

- Type of crops: The object of the document embraces the application of PA techniques on two main types of cultivation: **viticulture** and **arable crops**.
- Cultivation steps: The technologies object of the analysis are applied on the phases of cultivation going **from planning the field to harvesting**. No forward step (e.g. storage, transport, processing of crops etc.) has been analysed.
- Technology: No limitation within the definition of precision agriculture:
  ICT and mechanization aimed to treat different agricultural entities in accordance to specific needs, in order to enhance efficiency, productivity and environmental impact of the cultivation process.
- Geographical boundaries: No limitation
- Time boundaries: Selection of patents with filing date starting from 1990 and of scientific papers published not before 1985.

3.3. DESCRIPTION OF THE METHODOLOGY

In this paragraph, the description of the innovative methodology that Erre Quadro adopted for the foresight activities will be disclosed. The approach takes advantage of dedicated software tools that allow the massive analysis of texts and the clustering of the extracted information into meaningful patterns.

The following figure 1 shows a flow chart representing the methodology adopted for the execution of the foresight analysis.

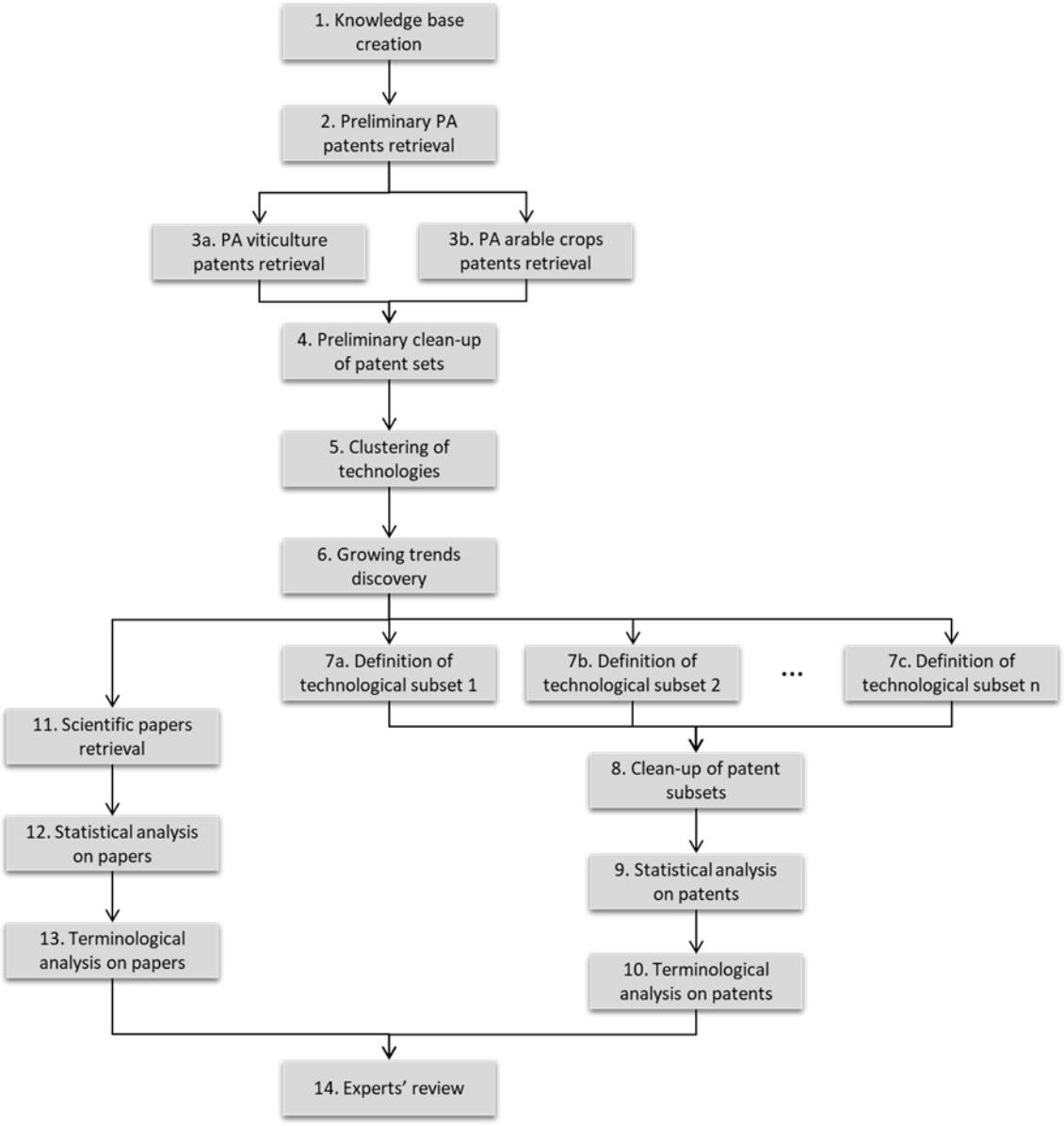

Figure 1. Flow chart of the methodology adopted for the execution of the foresight analysis.

In the first step (Knowledge base extraction), a knowledge base necessary to validate the results of the subsequent activities has been created. The automatic research tools have been calibrated in compliance with analysis' requirements. The creation of a knowledge base consists in the iterative

running of software tools for the automated extraction of patterns from texts and in the validation of the obtained outputs through structured and semi-automatic algorithms. These steps are necessary for a substantial reduction of textual ambiguities.

On the basis of the created knowledge base, in the step 2 (Preliminary PA patents retrieval) all the patent documents related to PA have been retrieved and gathered in a preliminary patent set by means of a complex no-sql query on Erre Quadro's proprietary search engine. In the following steps 3a (PA viticulture patents retrieval) and 3b (PA arable crops patents retrieval), starting from the preliminary PA patent set, two subsets respectively on application of PA in viticulture and arable crops have been identified and isolated.

In step 4 (Preliminary clean-up of patent sets), an iterative cleaning process is aimed to eliminate the not relevant documents from the two patent sets on arable crops and viticulture. These documents have been possibly captured due to textual ambiguities or to wrong relations between keywords contained in query of step 2 (Preliminary PA patents retrieval), therefore the two patent sets have been preliminary treated in order to increase the precision parameter while minimizing losses in terms of recall (for further details, see the paragraph 3.4).

Successively, the two patent sets have been processed in order to clusterise the technologies disclosed in the documents (step 5: Clustering of technologies) of the two patent sets according to the textual contents. In step 6 (Growing trends discovery) the documents of each cluster have been explored in order to identify patterns of growth; then these signals, potential tendencies of growth in technology, have been verified.

For each technological field selected in the previous step, the relevant patent documents have been isolated in independent subsets (steps 7a-7c: Definition of technological subset 1…n) on which, in step 8 (Clean-up of patent subsets), other iterations of the cleaning process have been be run, with the aim of obtaining a high degree of reliability of the final data. Therefore, each single technological subset has been processed through Erre Quadro's automated tools in order to extract statistics from metadata (step 9: Statistical analysis on patents) and textual information from documents (step 10: Terminological analysis on patents).

At the same time, after the discovery of growing technological trends, a parallel analysis on papers has been conducted in order to validate on scientific literature the information retrieved in patents. At this purpose, in step 11 (Scientific papers retrieval), the queries created in the previous steps for the collection of patents have been adapted for searches on ScienceDirect. As well as for patents, metadata and abstracts of papers have been analysed in order to generate statistical information (step 12: Statistical analysis on papers) and extract terminological patterns (step 13: Terminological analysis on papers).

Finally, in step 14 (Experts' review), results of the foresight analysis will be submitted for a final validation to a pool of experts in the field of precision agriculture.

3.4. CONTROL PARAMETERS

Completeness and reliability of the analysed data are ensured by constantly monitoring *"recall"* and *"precision"* parameters. These two indicators allow the measurement of the quality of a patent set and are respectively defined as follows:

- Recall: This parameter indicates the completeness of a set. For its estimation, a statistically significant sample of patents (set R) is independently defined: the value of the recall parameter is calculated as the ratio between the number of documents belonging to R that are included in the set under examination (set A) and the total number of patents contained in R.

$$Recall = \frac{\#(R \cap A)}{\#R} \%$$

- Precision: This parameter indicates the precision of a set, namely it provides an estimation of the percentage number of significant patents contained in the set of interest (set A). For its estimation, a random and statistically significant sample of patents (set P) is defined as a properly dimensioned subset of the set A. For each patent belonging to P, the pertinence respect to the research topic is evaluated and, finally, the parameter is calculated as the ratio between number of relevant documents and the total number of patents contained in set P.

$$Precision = \frac{\#(P \cap A)}{\#P} \%$$

Set A: It is the set object of the evaluation; e.g. in this analysis, one of the patent sets on precision agriculture.

Set R: It is a statistically significant set representative of the analysed technological field. The set is generated in an independent way respect to the methods of definition of set A.

Set P: It is a subset of A; randomly extracted and statistically significant.

∩: It is a symbol referred to the intersection operator

#: It is a symbol referred to the cardinality of a set

At the end of the data clean-up process, the parameters' estimation has confirmed the completeness of the patent sets and a level of precision greater than 90% for each analysed patent set[2].

[2] Since the part of analysis led on scientific literature has been performed on an external source and only the papers' abstracts are available, Erre Quadro is not able to estimate the level of precision and recall reached on scientific literature.

3.5. PATENTS AND PATENT FAMILIES

The process of analysis takes advantage of the distinction between **patents** and **patent families**; hence, in the following chapters, the text often refers alternately to both of them. In this sense, it is important to highlight that a patent family can be considered approximatively equivalent to an invention; hence, the numerical count of patent families estimates the quantity of inventions/R&D projects of a certain subject and/or in a certain interval of time. The definition of patent family adopted by Erre Quadro is the so-called DOC-DB family[3]. The patent family is composed by a patent (priority patent) and, possibly, by more documents generated as status change or extension to another patent office of the priority patent.

Therefore, references to number of patents are necessary when it is desired to examine the characteristics of whole patent portfolios, e.g. the capacity of exploitation of the inventions or the geographical distribution of patents. On the contrary, the consideration of patent families is useful when the interest of the analysis is directed at the measurement of the R&D effort in a certain technological field or of a certain subject.

[3] The European Patent Office (EPO) provides the following definition of DOC-DB patent family: "Generally speaking, if two applications claim exactly the same prior applications as priorities (these can be e. g. Paris Convention priorities or technical relation priorities […]) then they are defined by the EPO as belonging to the same DOCDB simple family."; Source: Data Catalog – Patstat:
http://documents.epo.org/projects/babylon/eponot.nsf/0/31eb8d4926355d3fc1257833003c2225/$FILE/patstat_data_catalog_v_5_03.pdf

4. SELECTION OF DOCUMENTS AND CLUSTER ANALYSIS

In the first level of analysis, the research has been focused on patents as source of information; patents of interest regarding precision agriculture (PA) in both viticulture and arable crops have been collected.

	Patent families	Patents
Viticulture	**1475**	**6766**
Arable Crops	**16043**	**62458**

Table 1. Number of documents in PA applied on viticulture and arable crops

On these documents, a cluster analysis on patents has been conducted in order to gather documents related to similar topics and, in this way, discovering the main technology/application fields in which organizations' R&D effort is focused. The analysis has highlighted the presence of 5 clusters in viticulture and 7 clusters in arable crops.

Viticulture

Data Processing: Algorithms and proceedings for data elaboration, computing systems etc. aimed to process several kinds of data deriving from variables detected on the vineyard.

Measurement and data collection**:** Systems for detecting variables and parameters related to vineyards such as distance, temperature, pressure etc.

Data transfer: Telecommunication systems aimed to transmit between two or more sources collected data and information. This cluster includes aerials, wireless communication systems, networking solutions etc.

Harvesting and pruning**:** Systems having function of interaction with plants in order to pick grapes or to prune the vineyard.

Vineyard care**:** Systems having functions of planting, cultivating, irrigating or protecting the vineyard.

Arable crops

Data processing**:** Algorithms and proceedings for data elaboration, computing systems etc. aimed to process several kinds of data deriving from variables detected on the fields.

Measurement and data collection**:** Systems for detecting variables and parameters related to crops such as distance, temperature, pressure etc.

Data transfer**:** Telecommunication systems aimed to transmit between two or more sources collected data and information. This cluster includes aerials, wireless communication systems, networking solutions etc.

Harvesting and manipulation**:** Systems for harvesting the crops from the field and/or for their successive handling, e.g. automatic systems and robots.

Planting and soil working**:** Systems having functions of supporting each agricultural operation before and during the positioning of new seeds or plants in the field.

Agricultural vehicle**:** Vehicles and related accessories or their subsystems aimed to support every step of agricultural process.

Irrigation and fertigation**:** Systems for distribution of irrigating or fertilizing substances on a field.

In the following tables a summary of the number of documents that every technological cluster contains.

VITICULTURE	Patent families	Patents	Papers
Data Processing	**179**	**629**	**668**
Measurement and data collection	**319**	**1327**	**82**
Data Transfer	**128**	**491**	**82**
Harvesting and pruning	**133**	**580**	**106**
Vineyard Care	**332**	**1239**	**450**

Table 2. Number of documents for each cluster in PA applied on viticulture

ARABLE CROPS	Patent families	Patents	Papers
Data Processing	**961**	**3396**	**1703**
Measurement and data collection	**1581**	**5539**	**513**
Data Transfer	**530**	**2046**	**365**
Harvesting and manipulation	**2250**	**7439**	**113**
Planting and Soil Working	**1963**	**4537**	**1186**
Agricultural Vehicles	**640**	**2570**	**1095**
Irrigation and Fertigation	**504**	**1413**	**1970**

Table 3. Number of documents for each cluster in PA applied on arable crops

It is important to highlight that the clusters are not independent: a single document could belong to more than one cluster; e.g. a patent can describe a soil-working vehicle: in this case the patent belongs both to “agricultural vehicle” and to “planting and soil working” clusters.

In the following chapters the technological clusters for both viticulture and arable crops will be analysed in detail.

5. IN-DEPTH ANALYSIS - VITICULTURE

In this chapter, an analysis of precision agriculture technologies applied on viticulture is disclosed. In the following sections, every identified technological cluster will be introduced and examined.

5.1. DATA PROCESSING

In this section, the technological cluster relating to data processing in viticulture is analysed. The cluster gathers documents in which the main object concerns algorithms and proceedings for data elaboration, computing systems etc. aimed to process several kinds of data deriving from variables detected on the fields. In the next paragraphs, analyses on patents and papers are respectively disclosed.

5.1.1. PATENT ANALYSIS

The patent set on data processing in viticulture is composed by 629 patents belonging to 179 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

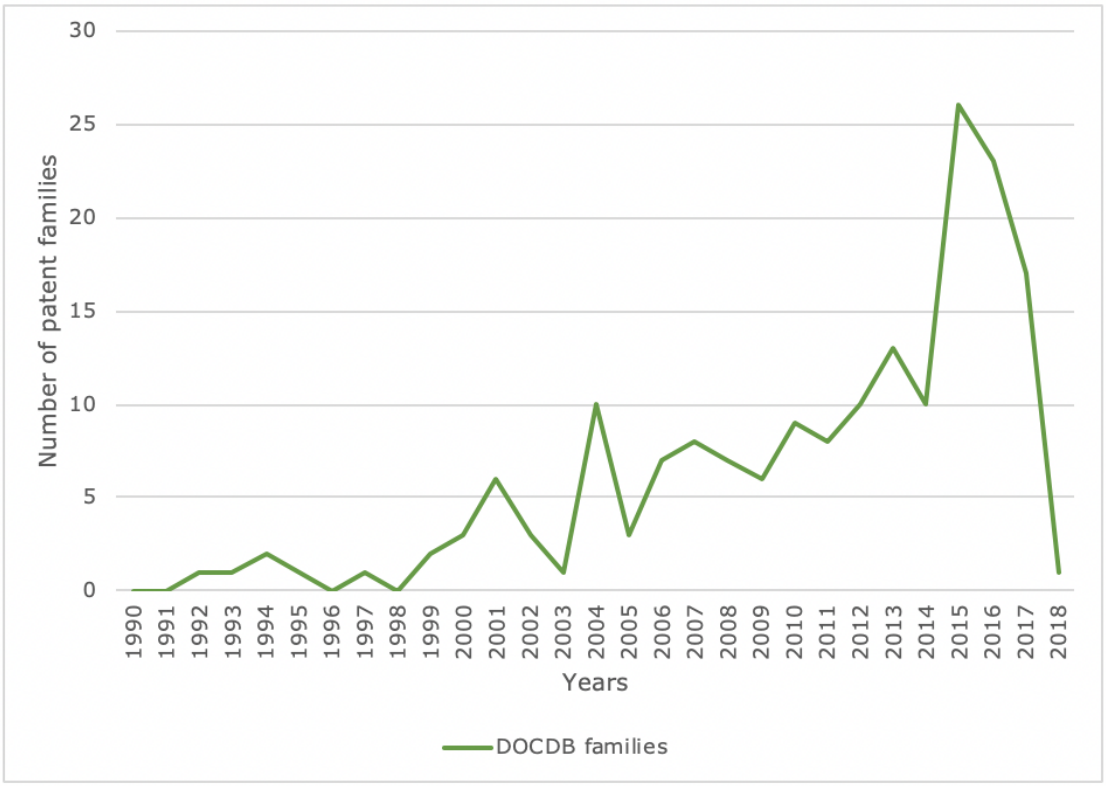

Figure 2. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field, especially in 2015. The increasing trend, in combination with the small number of filings per year, suggests that data processing in viticulture is an **emerging technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

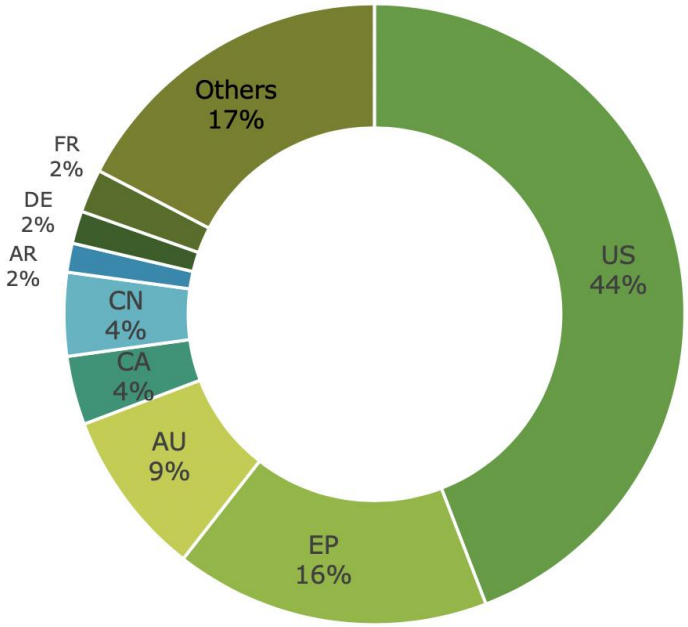

Figure 3. Percentage distribution of patents in the patent offices

USA is by far the main filing country (US), followed by the European jurisdiction (EP). Relevant the presence of the Australian (AU) patent office.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.

#	IPC Class	Class description	# patent families	# patents
1	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING*	60	204
2	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES*	40	147
3	G06K	*PHYSICS || RECOGNITION OF DATA; PRESENTATION OF DATA; RECORD CARRIERS; HANDLING RECORD CARRIERS.*	31	78
4	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING.*	30	83
5	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL*	27	82
6	G06Q	*PHYSICS || DATA PROCESSING SYSTEMS OR METHODS.*	24	59
7	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING.*	21	72
8	G06T	*PHYSICS || IMAGE DATA PROCESSING OR GENERATION, IN GENERAL*	19	53
9	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES*	18	37
10	G01C	*PHYSICS || MEASURING DISTANCES, LEVELS OR BEARINGS; SURVEYING; NAVIGATION; GYROSCOPIC INSTRUMENTS; PHOTOGRAMMETRY OR VIDEOGRAMMETRY.*	14	24

Table 4. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

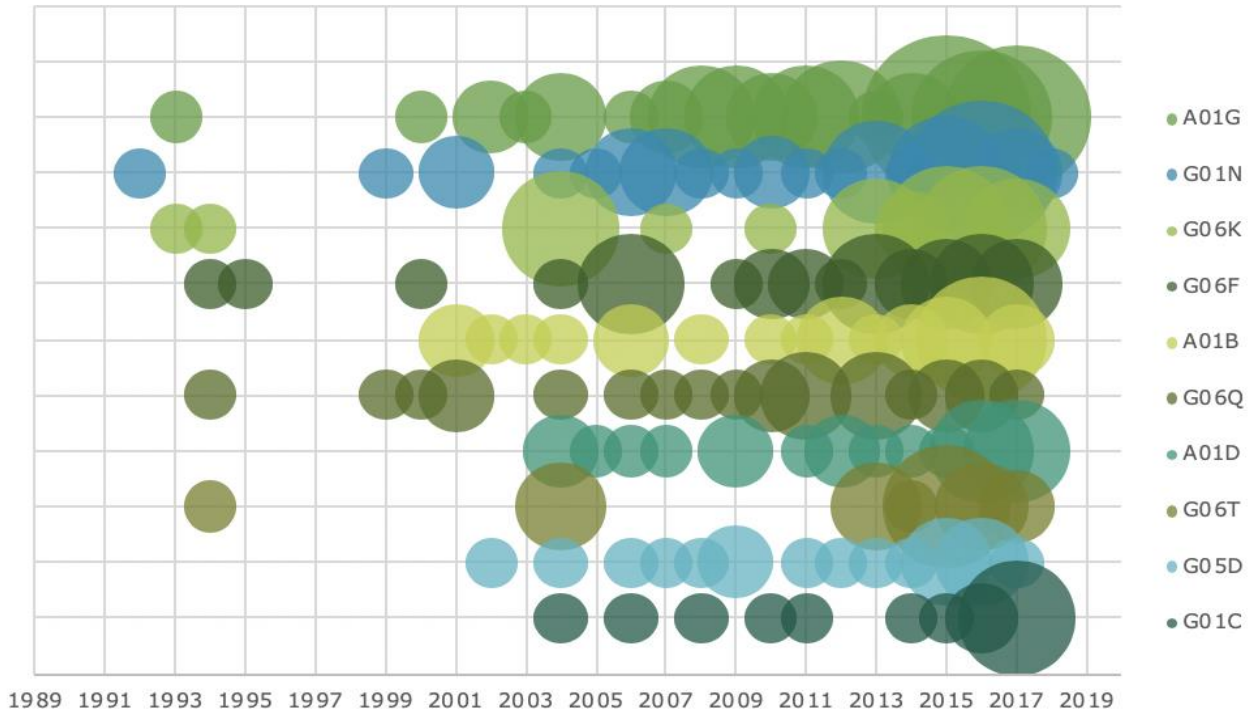

Figure 4. Evolution in time of main IPC classes

A01G is a very general class about agriculture; hence, its presence is expected for each analysed cluster. It is interesting to highlight classes G06T and G01C, related respectively to image data processing and navigation of devices.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

Figure 5. Tag cloud 2000-2010

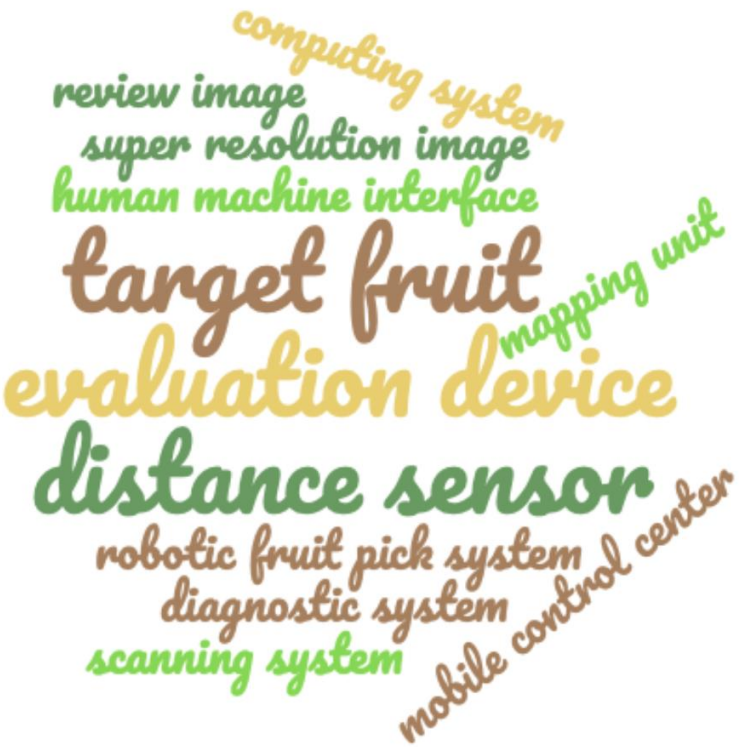

Figure 6. Tag cloud 2011-2018

In the first tag cloud, among the others, there are several expressions referred to autonomous machines and machine control. In the second one, the focus is shifted from machine control to human machine interface, diagnostic systems, and image analysis.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# Patent families	# Patents	% Patent families
1	John Deere	13	46	7,3
2	Ge	4	6	2,2
3	Agerpoint	4	15	2,2
4	Michigan State University	3	6	1,7
5	Zhejiang University of Technology	3	4	1,7
6	Harvest Croo	3	7	1,7
7	Oxbo International Corporation	2	17	1,1
8	The Invention Science Fund	2	4	1,1
9	Julius Maximilians Universitaet Werzburg	2	10	1,1
10	Max Planck Gesellschaft	2	10	1,1
11	Carnegie Mellon University	2	5	1,1
12	Csiro	2	2	1,1
13	Monsanto Company	2	17	1,1
14	Pellenc	2	18	1,1
15	Ibm	2	18	1,1

Table 5. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent Families	# Patents
1	Anderson Noel Wayne	6	22
2	Mcpeek K Thomas	4	12
3	Reid John Franklin	4	9
4	Pitzer Robert	3	7
5	Aivazian Bryan L	3	5
6	Jia Tingmeng	3	4
7	Xun Yi	3	4
8	Mas Francisco Rovira	3	6
9	Zhang Qin	3	7
10	Didomenico Dale Martin	3	5

Table 6. Top inventors

5.1.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about data processing in viticulture is composed by 668 documents; the number is comparable to the number of patents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

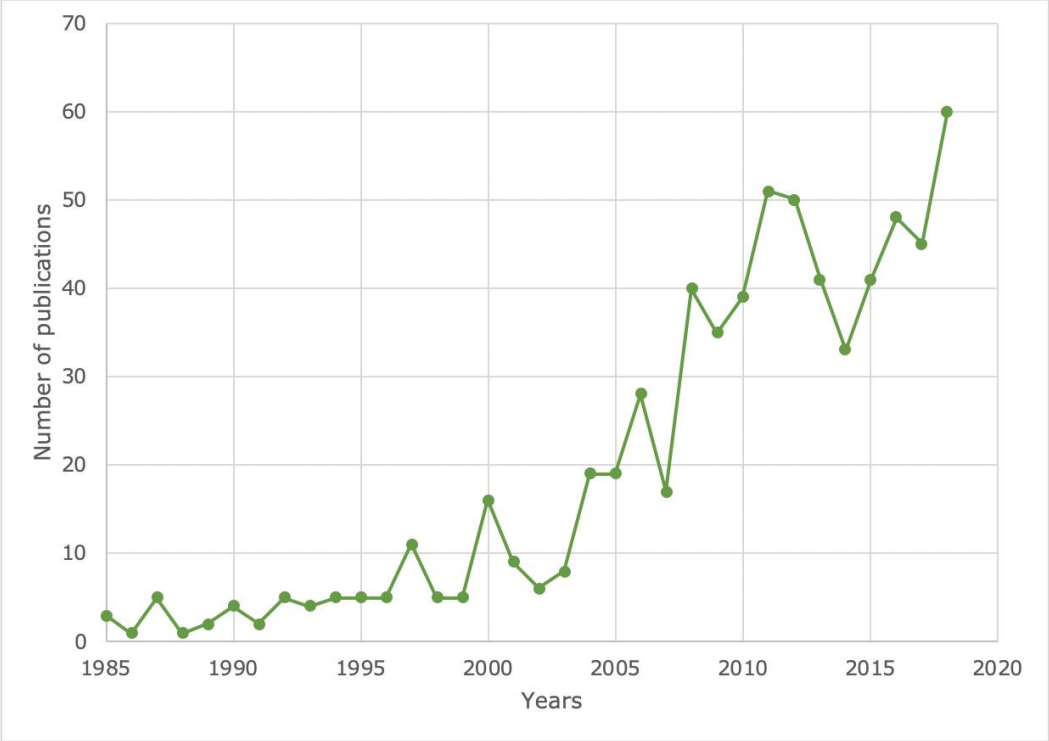

Figure 7. Distribution of the scientific literature according to publication dates

In accordance to the patent analysis' trend, the graph shows a growing technological field.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

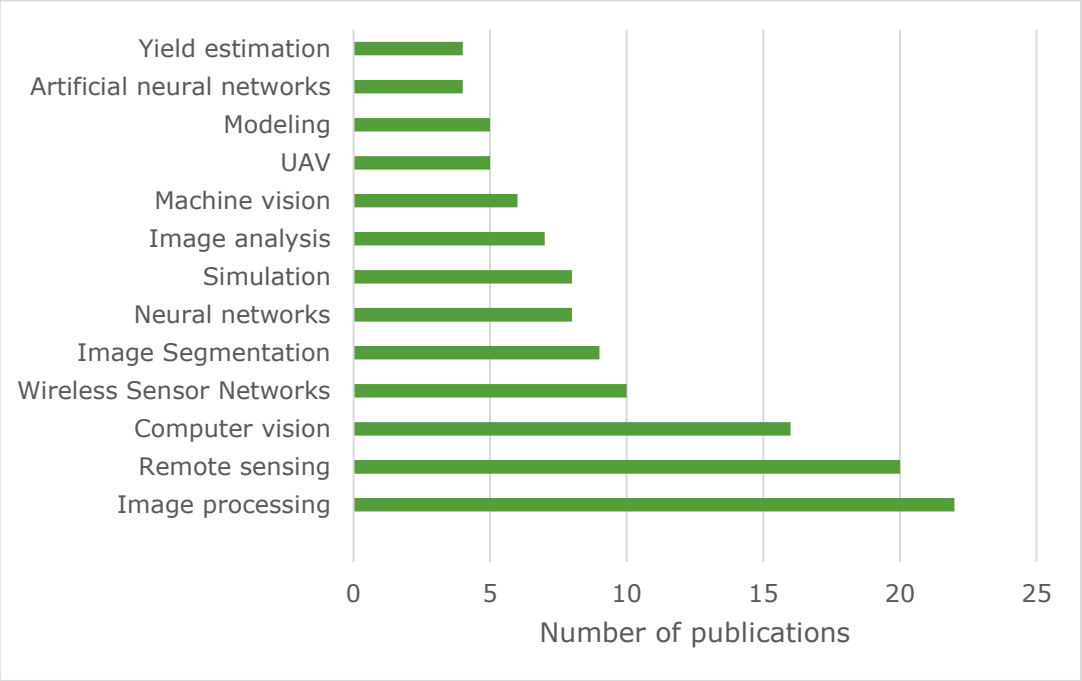

Figure 8. Papers' tags histogram

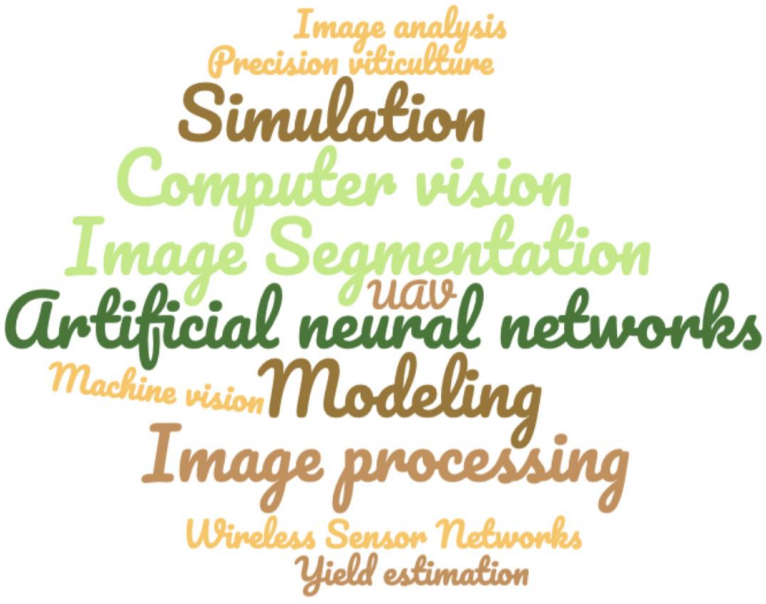

Figure 9. Papers' tag cloud

Several expressions among the main tags are referred to image processing. Other recurrent patterns regard wireless sensor networks, and neural networks.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

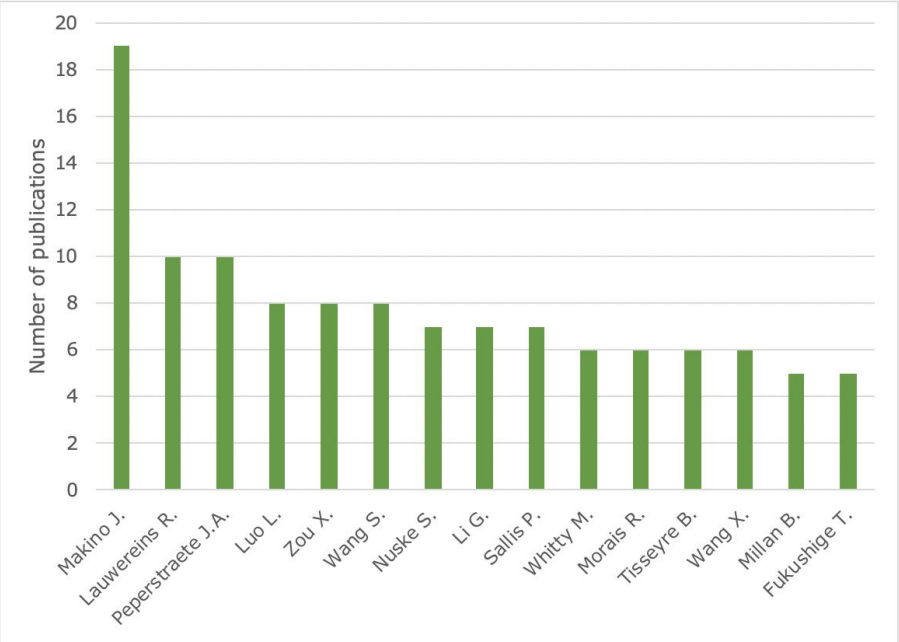

Figure 10. Top 15 authors

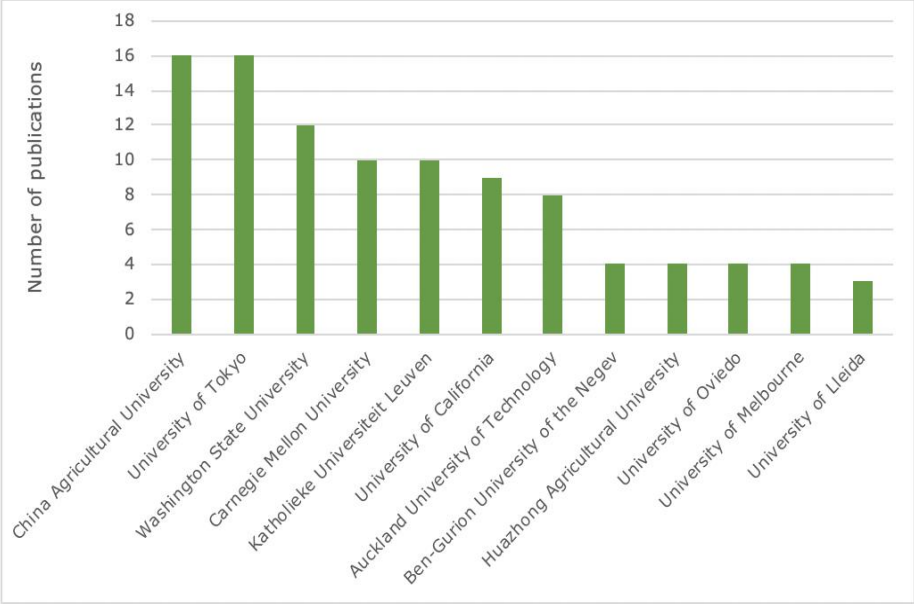

Figure 11. Top affiliations

The main authors' affiliations are in Chinese, Japanese, American and Belgian Universities. Furthermore, is remarkable the presence of Universities having headquarters in Israeli, New Zealand and Australia.

5.2. MEASUREMENT AND DATA COLLECTION

In this section, the technological cluster relating to measurement and data collection in viticulture is analysed. The cluster gathers documents in which the main object concerns systems for detecting variables and parameters related to vineyards such as distance, temperature, pressure etc. In the next paragraphs, analyses on patents and papers are respectively disclosed.

5.2.1. PATENT ANALYSIS

The patent set on measurement and data collection in viticulture is composed by 1327 patents belonging to 319 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

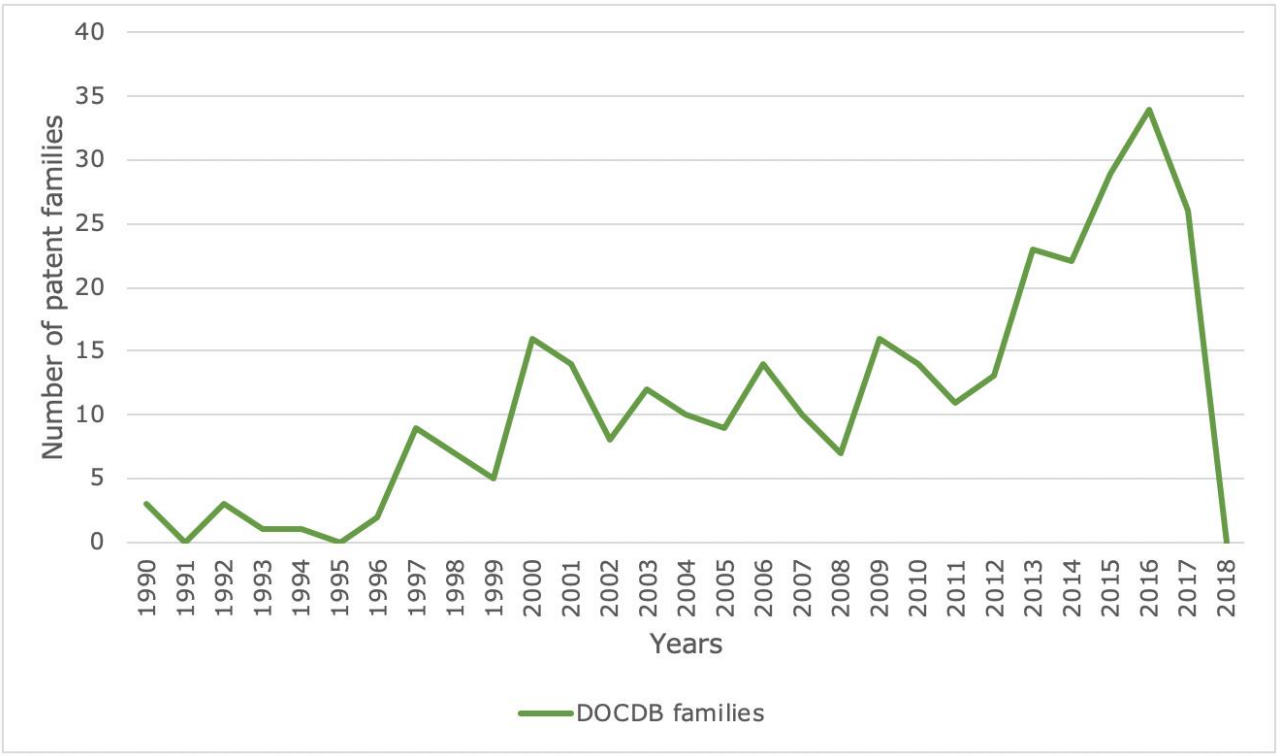

Figure 12. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The growing trend, in combination with the small number of filings per year, suggests that measurement and data collection in viticulture is an **emerging technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

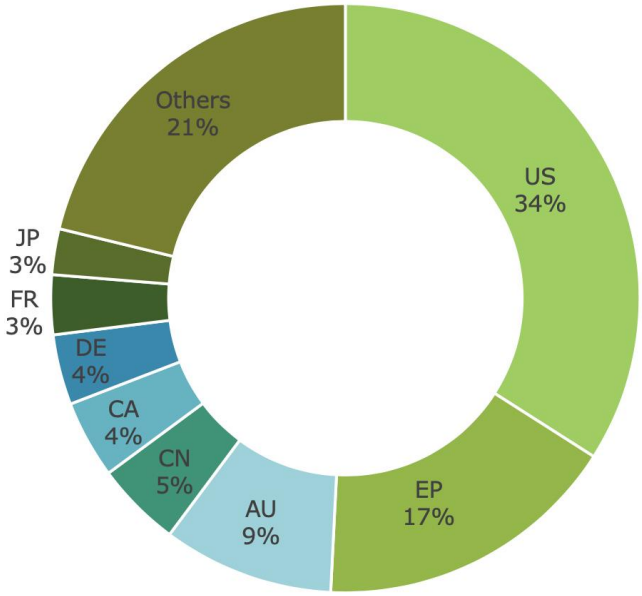

Figure 13. Percentage distribution of patents in the patent offices

USA is the main filing country (US), followed by the European jurisdiction (EP). Relevant the presence of the Australian (AU) patent office.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.

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1	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING*	116	431
2	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES*	69	246
3	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING*	54	237
4	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL.*	47	174
5	A01M	*HUMAN NECESSITIES || CATCHING, TRAPPING OR SCARING OF ANIMALS; APPARATUS FOR THE DESTRUCTION OF NOXIOUS ANIMALS OR NOXIOUS PLANTS*	32	151

#	IPC Class	Class description	# Patent families	# Patents
6	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES*	30	97
7	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING*	25	52
8	G06K	*PHYSICS || RECOGNITION OF DATA; PRESENTATION OF DATA; RECORD CARRIERS; HANDLING RECORD CARRIERS*	25	49
9	G06T	*PHYSICS || IMAGE DATA PROCESSING OR GENERATION, IN GENERAL*	21	43
10	A01C	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING.*	21	51

Table 7. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

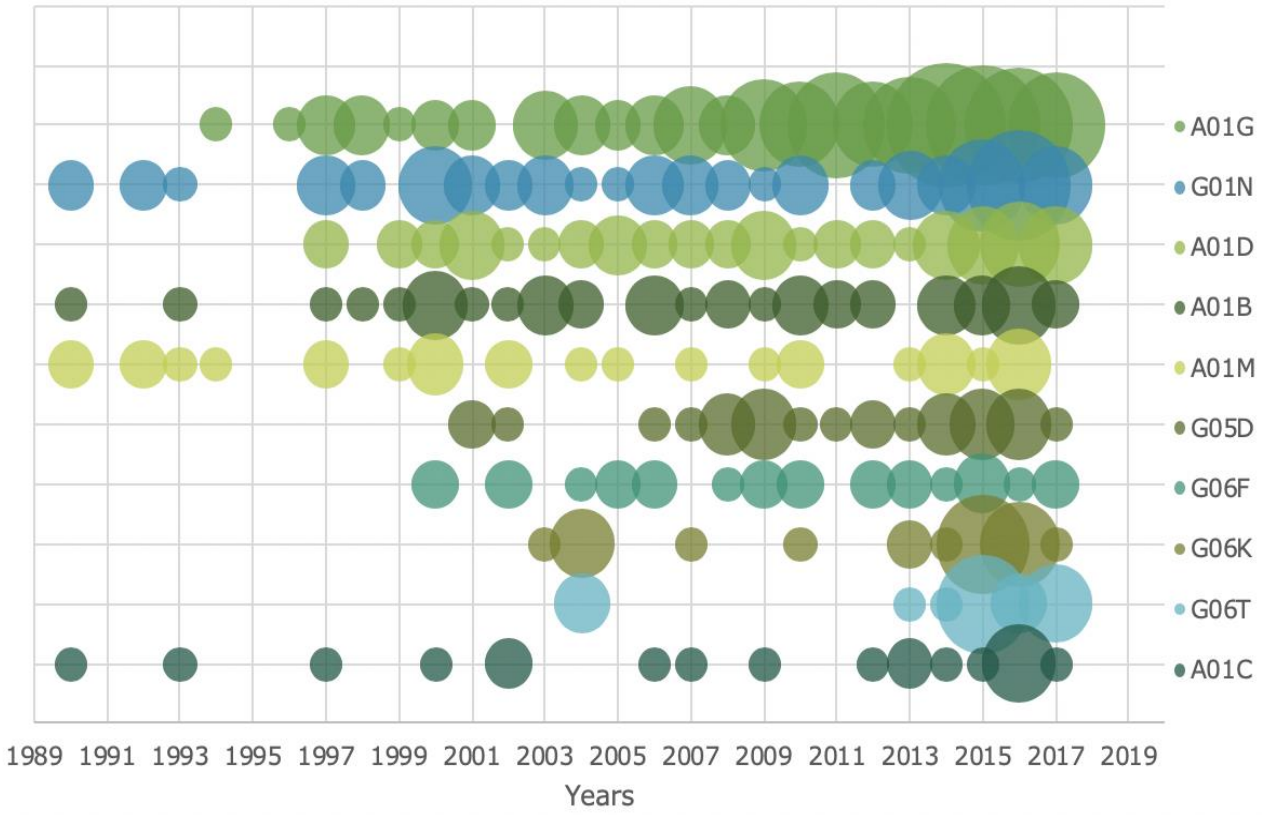

Figure 14. Evolution in time of main IPC classes

A01G is a very general class about agriculture; hence, its presence is expected for each analysed cluster. Several classes are, more or less, constant over time. It is interesting to highlight classes G05D, G06F, G06K and G06T, not present until the begin of 2000s and increasing across years.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

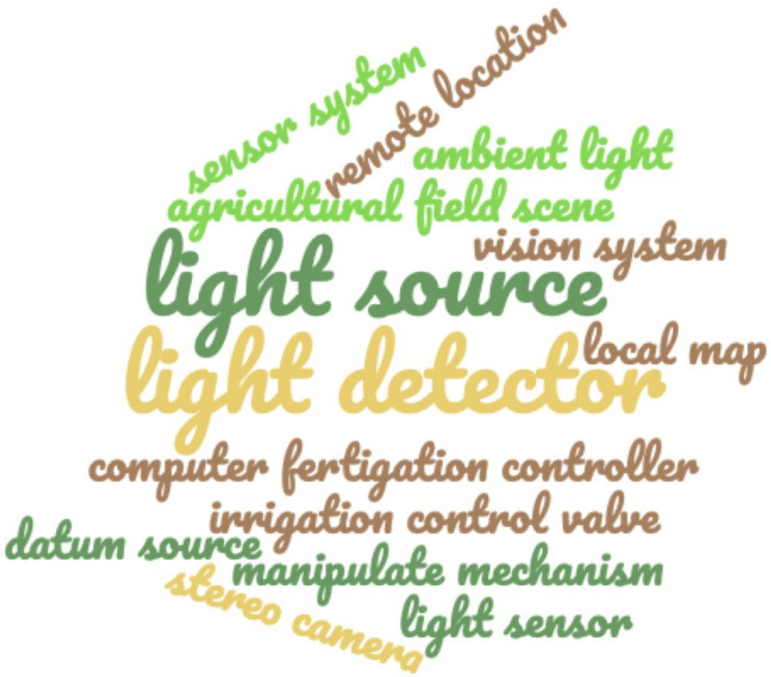

Figure 15. Tag cloud 2000-2010

Figure 16 Tag cloud 2011-2018

In the first tag cloud, there are several expressions referred to optical systems and irrigation/fertigation. In the second cloud, vision systems are still present and some references to vehicles appear, comprised aerial vehicles.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# patent families	# Patents	% Patent families
1	John Deere	18	102	5,5
2	Cnh	12	51	3,7
3	Pellenc	11	110	3,4
4	Philips Electronics	6	24	1,8
5	Trinamix	4	7	1,2
6	Vito	4	18	1,2
7	The United States Of America As Represented By The Secretary Of Agriculture	4	6	1,2
8	Guerrieri Gonzaga Aliana	4	11	1,2
9	Aguila Corporation	3	8	0,9
10	Zim Plant Technology	3	19	0,9
11	Trimble Navigation	3	8	0,9
12	Fmc Corporation	3	10	0,9
13	Csiro	3	3	0,9
14	Washington State University	2	10	0,6
15	Harvest Croo	2	5	0,6

Table 8. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Pellenc Roger	11	99
2	Anderson Noel Wayne	8	32
3	Gialis Jean-Marc	5	34
4	Miller Deborah L	4	4
5	Miller John C	4	4
6	Colburn Jr John W	4	4
7	Guerrieri Gonzaga Edoardo	4	4
8	Valouch Sebastian	4	7
9	Send Robert	4	7
10	Bruder Ingmar	4	7

Table 9. Top inventors

5.2.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about measurement and data collection in viticulture is composed by 82 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

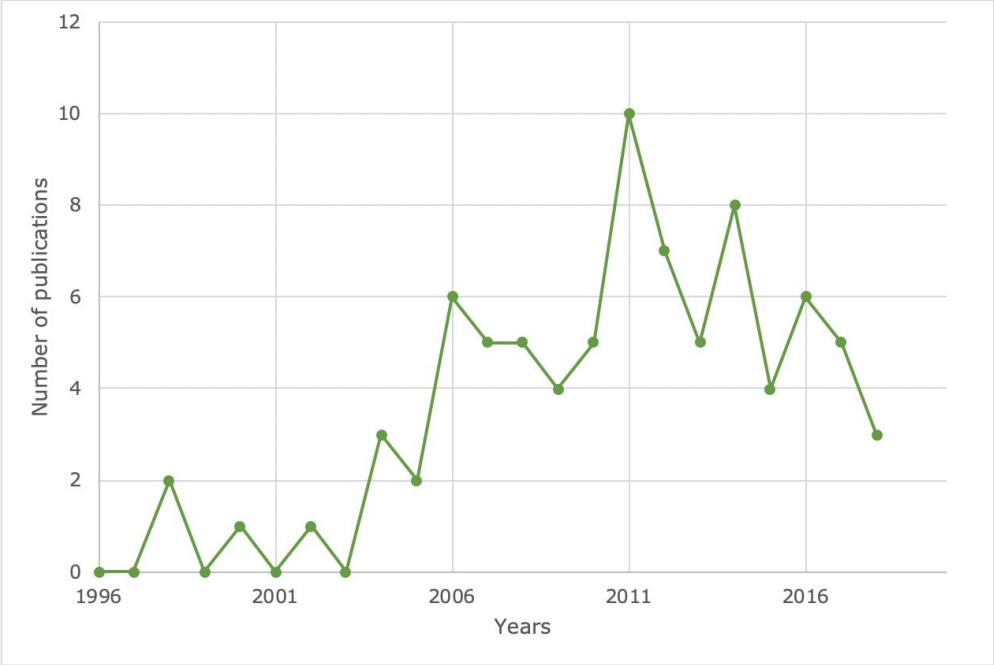

Figure 17. Distribution of the scientific literature according to publication dates

The small number of publications per year does not allow a reliable statistical interpretation of the tendency.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

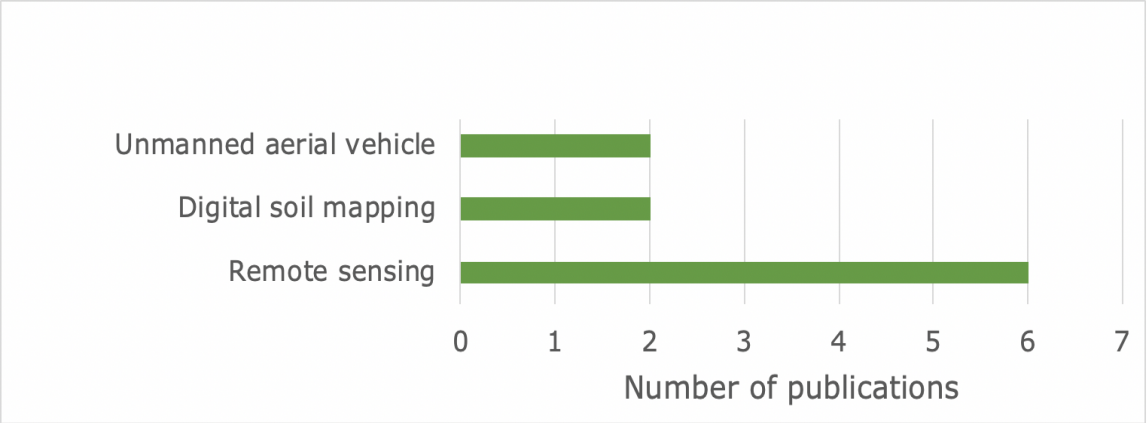

Figure 18. Papers' tags histogram

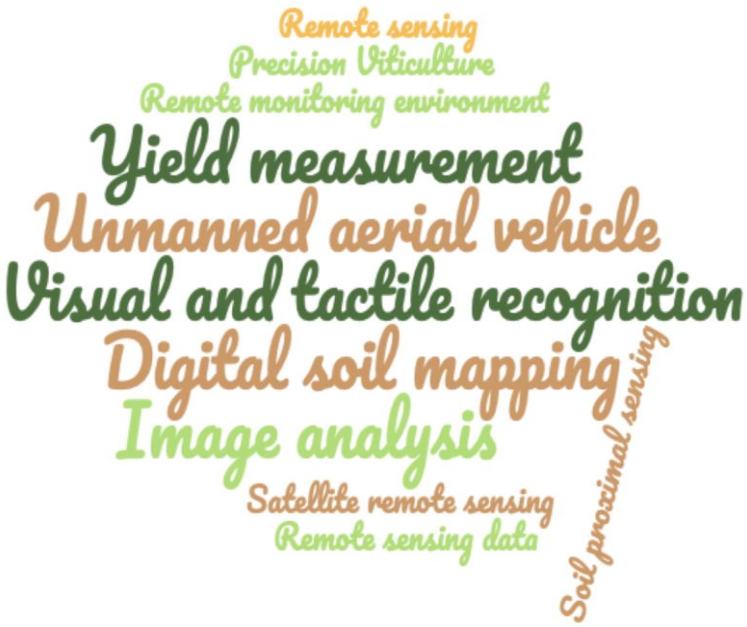

Figure 19. Papers' tag cloud

The main topic retrieved in the data set regards remote sensing.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

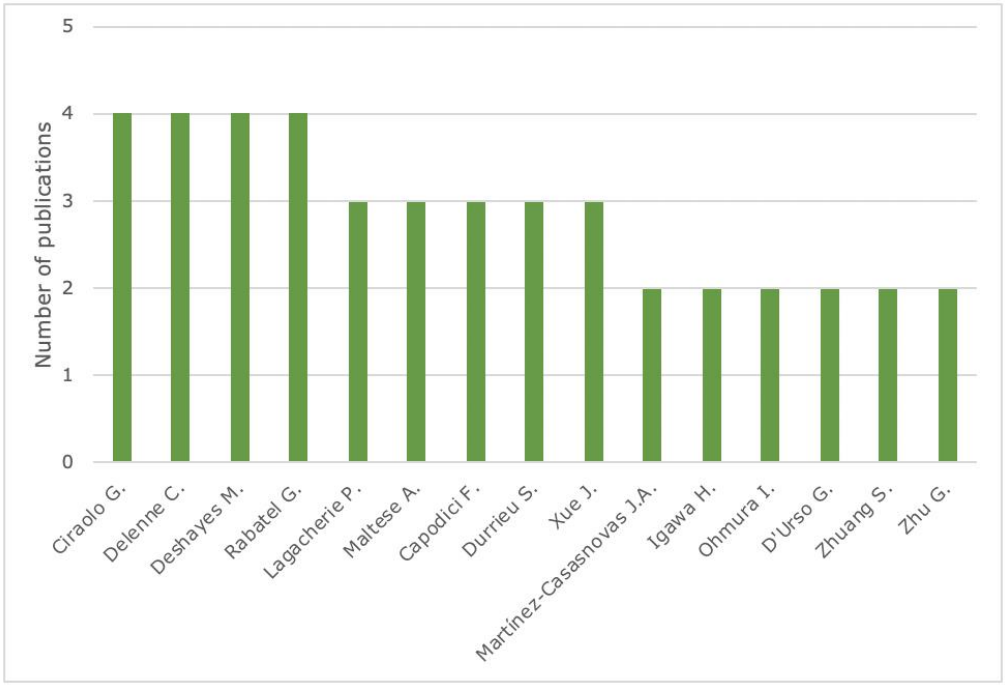

Figure 20. Top 15 authors

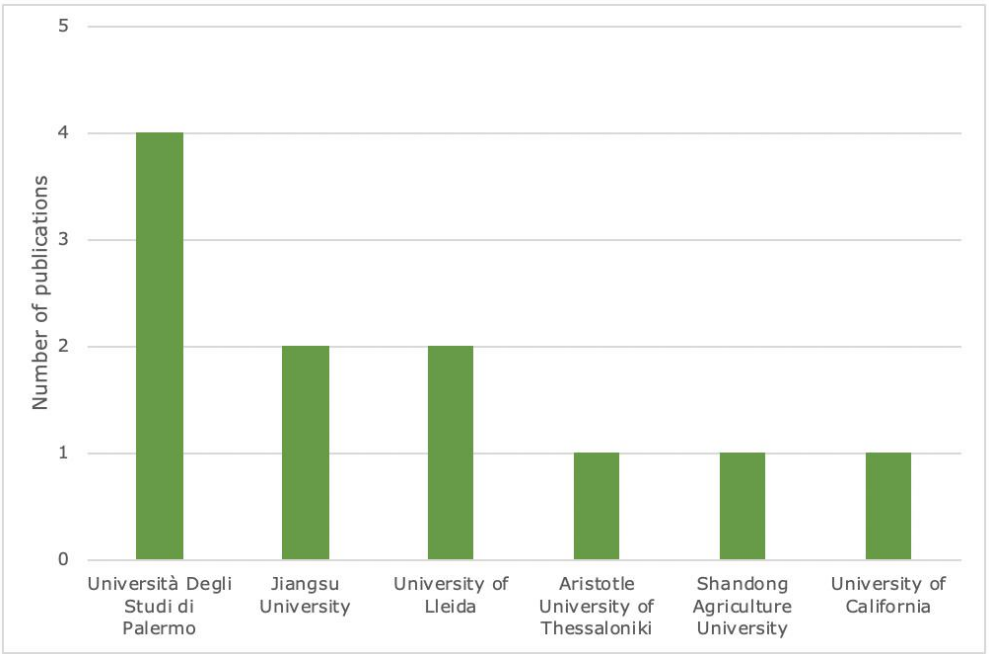

Figure 21. Top affiliations

Affiliations in European, Chinese and US Universities.

5.3. DATA TRANSFER

In this section, the technological cluster relating to data transfer in viticulture is analysed. The cluster gathers documents in which the main object concerns telecommunication systems aimed to transmit between two or more sources collected data and information. In the next paragraphs, analyses on patents and papers are respectively disclosed.

5.3.1. PATENT ANALYSIS

The patent set on data transfer in viticulture is composed by 491 patents belonging to 128 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

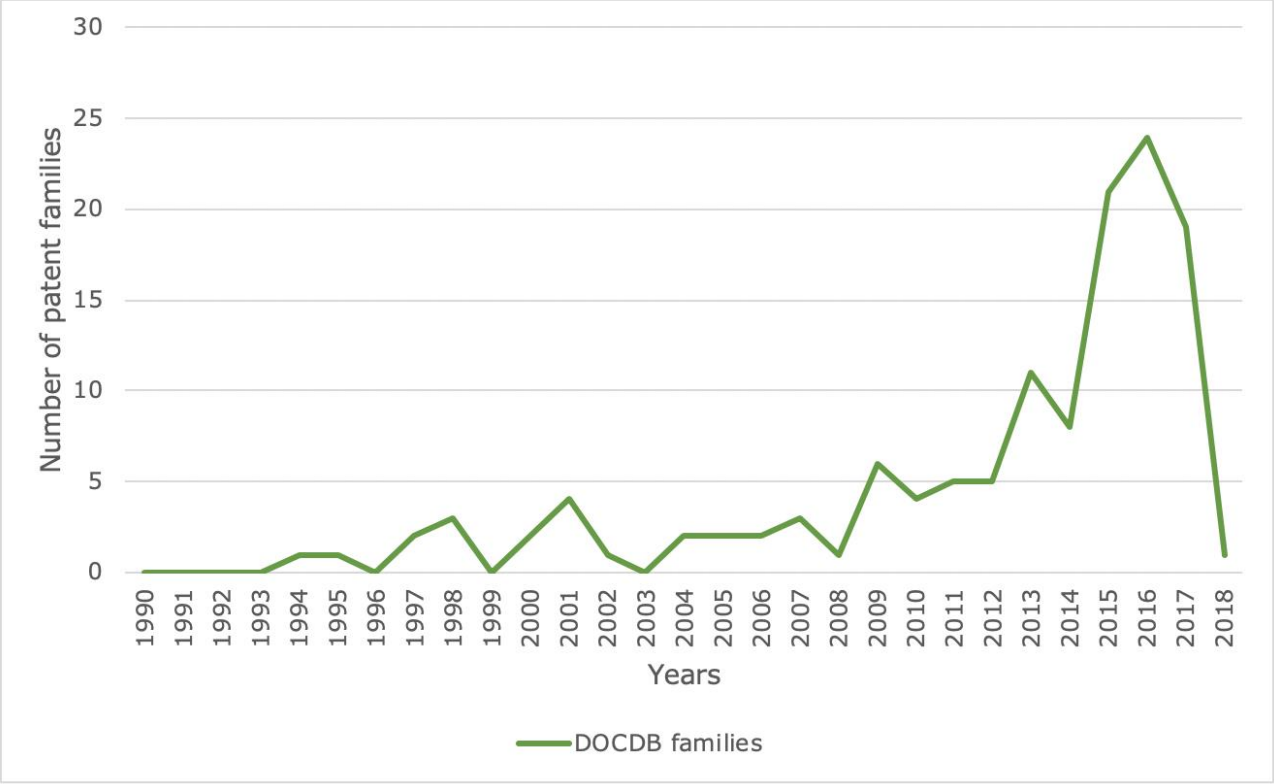

Figure 22. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows that the technological field is strongly growing. The increasing trend, in combination with the small number of filings per year, suggests that data transfer in viticulture is an **emerging technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

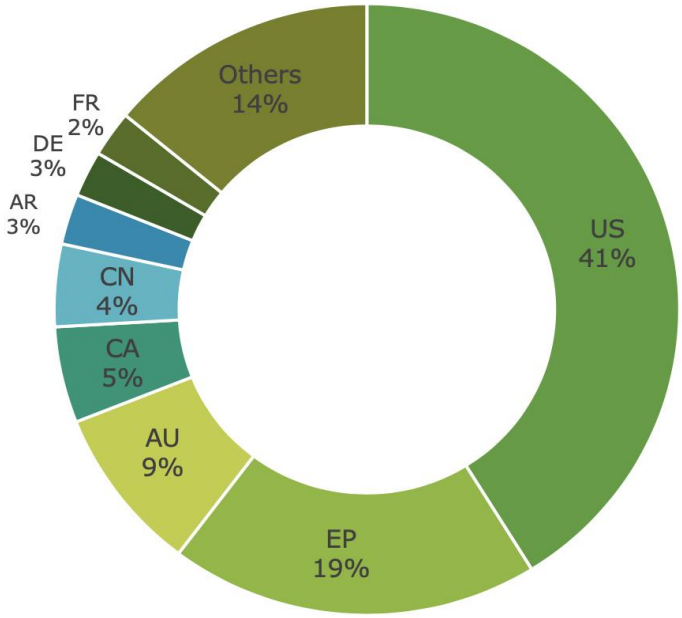

Figure 23. Percentage distribution of patents in the patent offices

USA is the main filing country (US), followed by the European jurisdiction (EP). Relevant the presence of the Australian (AU) patent office.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.

#	IPC Class	Class description	# patent families	# patents
1	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING*	40	137
2	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES*	25	68
3	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING*	24	86
4	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL.*	21	68
5	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING*	17	40

#	IPC Class	Class description	# patent families	# patents
6	G06Q	*PHYSICS || DATA PROCESSING SYSTEMS OR METHODS.*	15	35
7	G06K	*PHYSICS || RECOGNITION OF DATA; PRESENTATION OF DATA; RECORD CARRIERS; HANDLING RECORD CARRIERS*	14	26
8	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES*	14	35
9	G01S	*PHYSICS || RADIO DIRECTION-FINDING; RADIO NAVIGATION; DETERMINING DISTANCE OR VELOCITY BY USE OF RADIO WAVES; LOCATING OR PRESENCE-DETECTING BY USE OF THE REFLECTION OR RERADIATION OF RADIO WAVES; ANALOGOUS ARRANGEMENTS USING OTHER WAVES*	14	31
10	B05B	*PERFORMING OPERATIONS; TRANSPORTING || SPRAYING APPARATUS; ATOMISING APPARATUS; NOZZLES*	12	50

Table 10. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

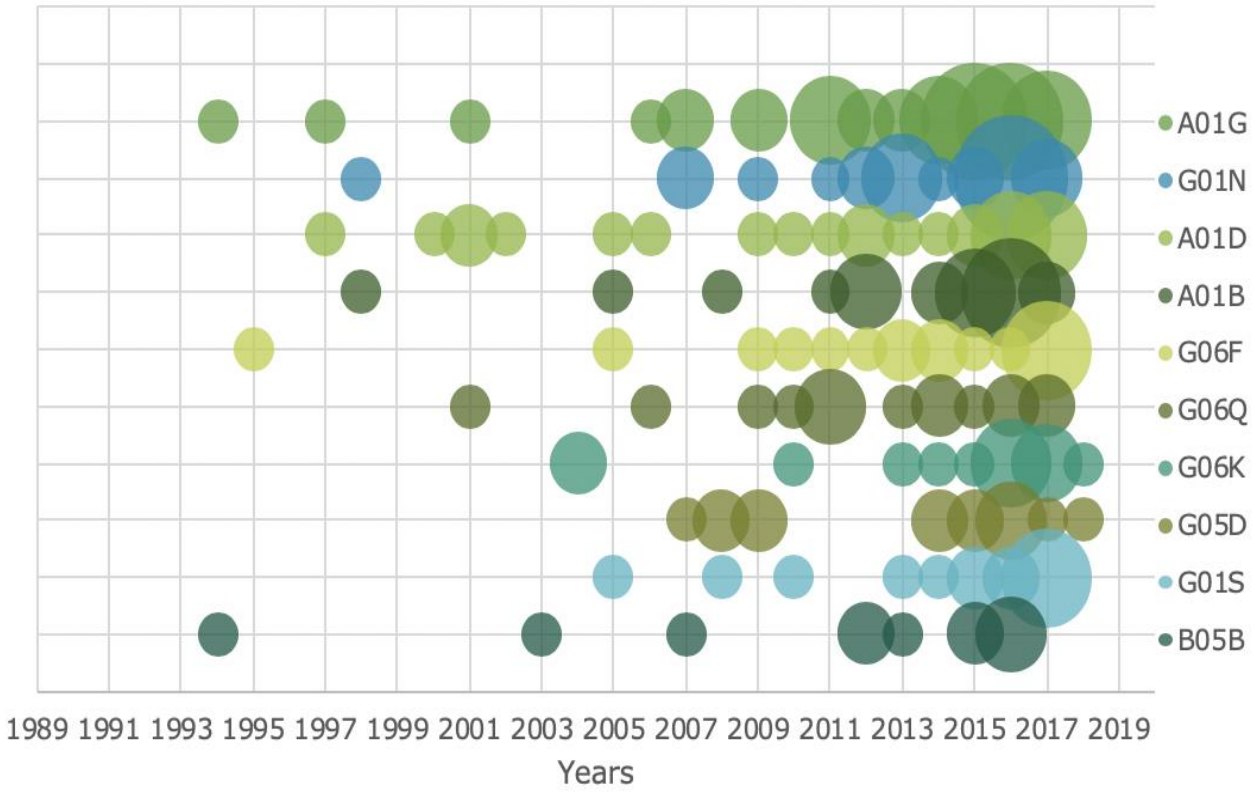

Figure 24. Evolution in time of main IPC classes

A01G is a very general class about agriculture; hence, its presence is expected for each analysed cluster. The patent activity in all the top IPC classes is intensifying in the last years. Since in the main classes almost every step of the cultivation process appears (A01D Harvesting, A01B Soil working, B05B Spraying apparatuses), data transfer technologies can be considered general purpose enabling technologies.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

Figure 25. Tag cloud 2000-2010

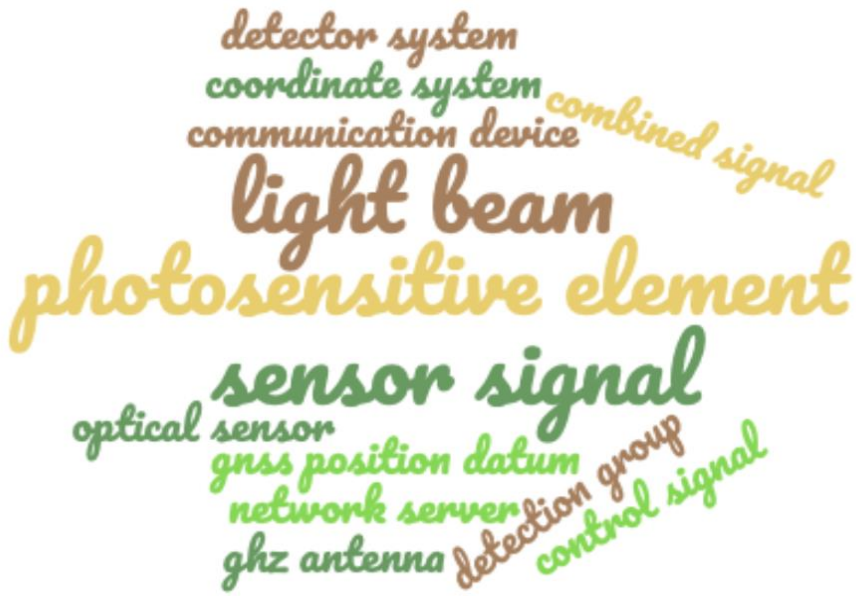

Figure 26. Tag cloud 2011-2018

In the period 2000-2010, among the others, there are several expressions referred to vehicles and controlling systems. In the most recent period, the focus is shifted on optical devices. In both the clouds tags referred to sensor systems are present.

Involved subjects

The following table shows the 12 top Assignee deriving from the analysis of the Patent-Set.

#	Assignee	# Patent families	# Patents	% Patent families
1	John Deere	12	92	9,2
2	Trinamix	4	7	3,1
3	Pellenc	4	32	3,1
4	Michigan State University	3	6	2,3
5	Agerpoint Inc	3	11	2,3
6	Crinklaw Farm Services Inc	3	5	2,3
7	Scanit Technologies	2	3	1,5
8	Ibm	2	4	1,5

#	Assignee	# Patent families	# Patents	% Patent families
9	Smartfield	2	3	1,5
10	Ge	2	2	1,5
11	University Of California	2	3	1,5
12	Ag Right Enterprises	2	7	1,5
13	Guerrieri Gonzaga	2	7	1,5
14	Timble Navigation	2	6	1,5
15	Dow Agrosciences	1	9	0,8

Table 11. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Anderson Noel Wayne	5	24
2	Pellenc Roger	4	30
3	Bruder Ingmar	4	7
4	Valouch Sebastian	4	7
5	Send Robert	4	7
6	Aivazian Bryan L	3	5
7	Kaprielian Craig L	3	9
8	Mcpeek K Thomas	3	8
9	Hermes Wilfried	3	6
10	Gialis Jean-Marc	3	19

Table 12. Top inventors

5.3.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about data transfer in viticulture is composed by 82 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

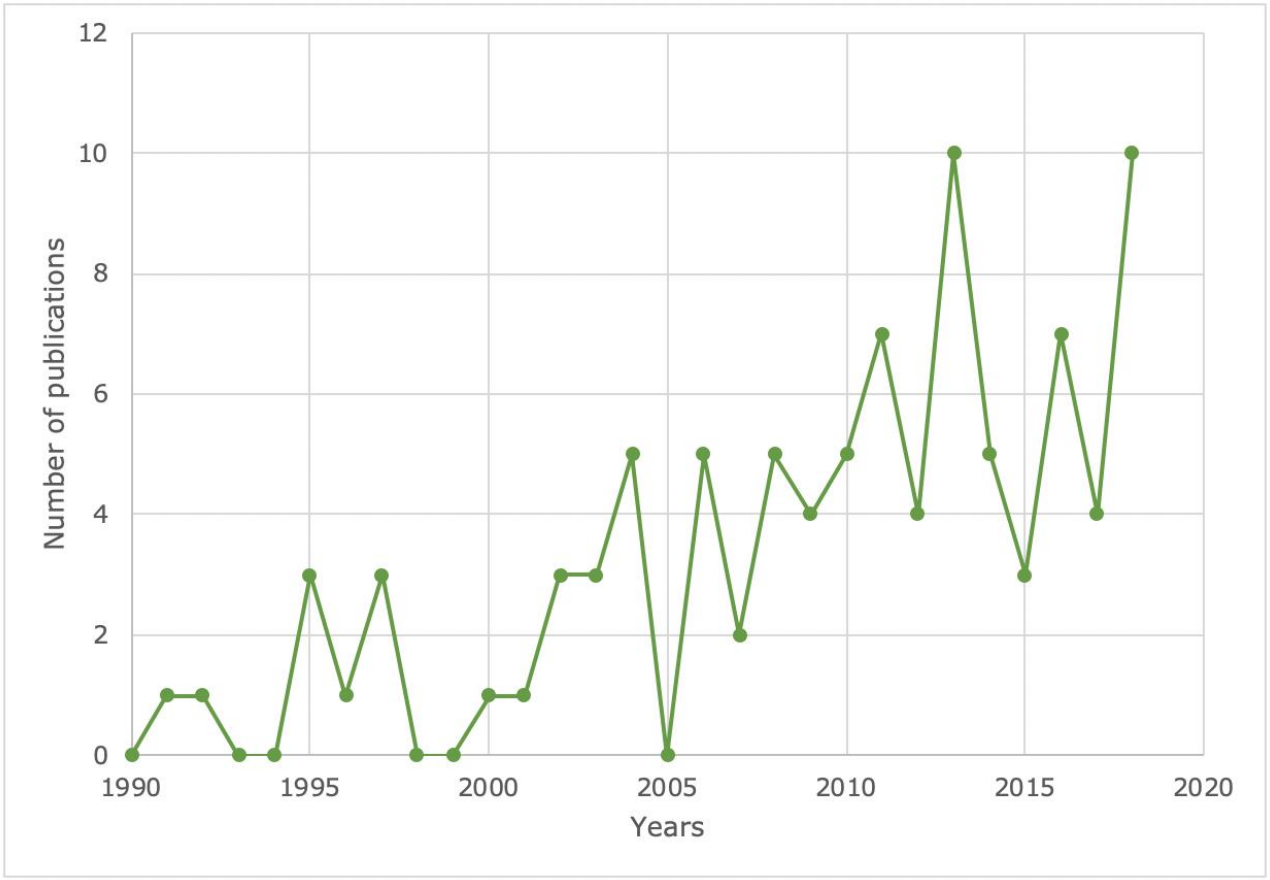

Figure 27. Distribution of the scientific literature according to publication dates

The small number of publications per year does not allow a reliable statistical interpretation of the tendency.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

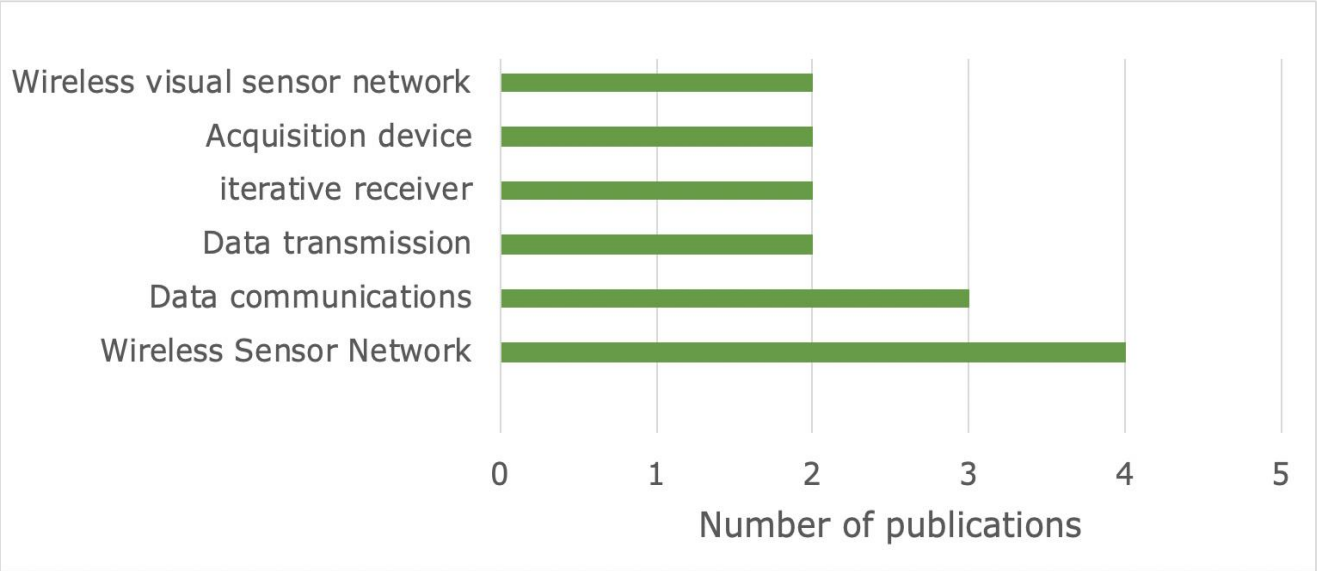

Figure 28. Papers' tags histogram

Figure 29. Papers' tag cloud

Several expressions, among the main tags, are referred to sensor systems and in particular to wireless sensor systems.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

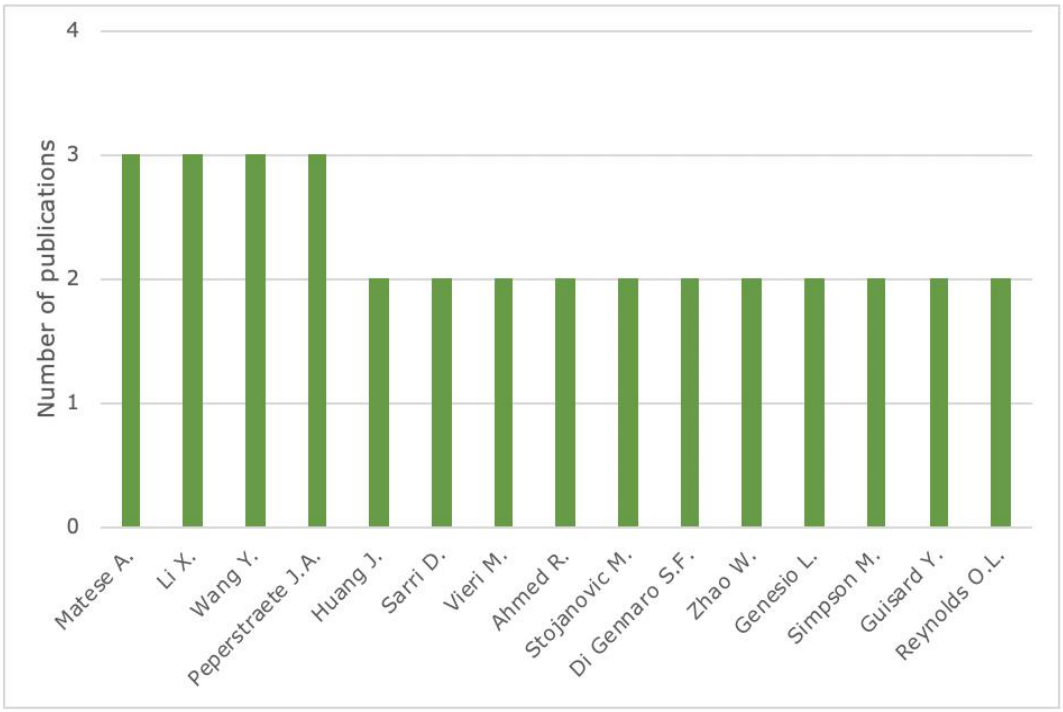

Figure 30. Top 15 authors

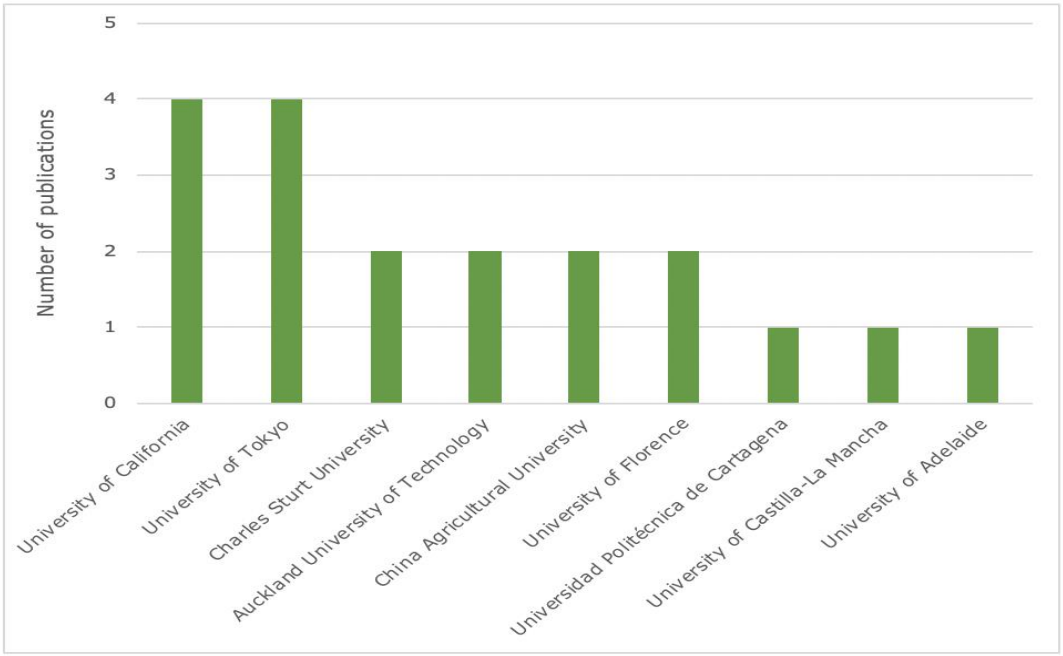

Figure 31. Top affiliations

The main authors' affiliations are in American, Japanese, Australian and New Zealand Universities.

5.4. HARVESTING AND PRUNING

In this section, the technological cluster relating to harvesting and pruning in viticulture is analysed. The cluster gathers documents in which the main object concerns systems having function of interaction with plants in order to pick grapes or to prune the vineyard. In the next paragraphs, analyses on patents and papers are respectively disclosed.

5.4.1. PATENT ANALYSIS

The patent set on harvesting and pruning in viticulture is composed by 580 patents belonging to 133 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

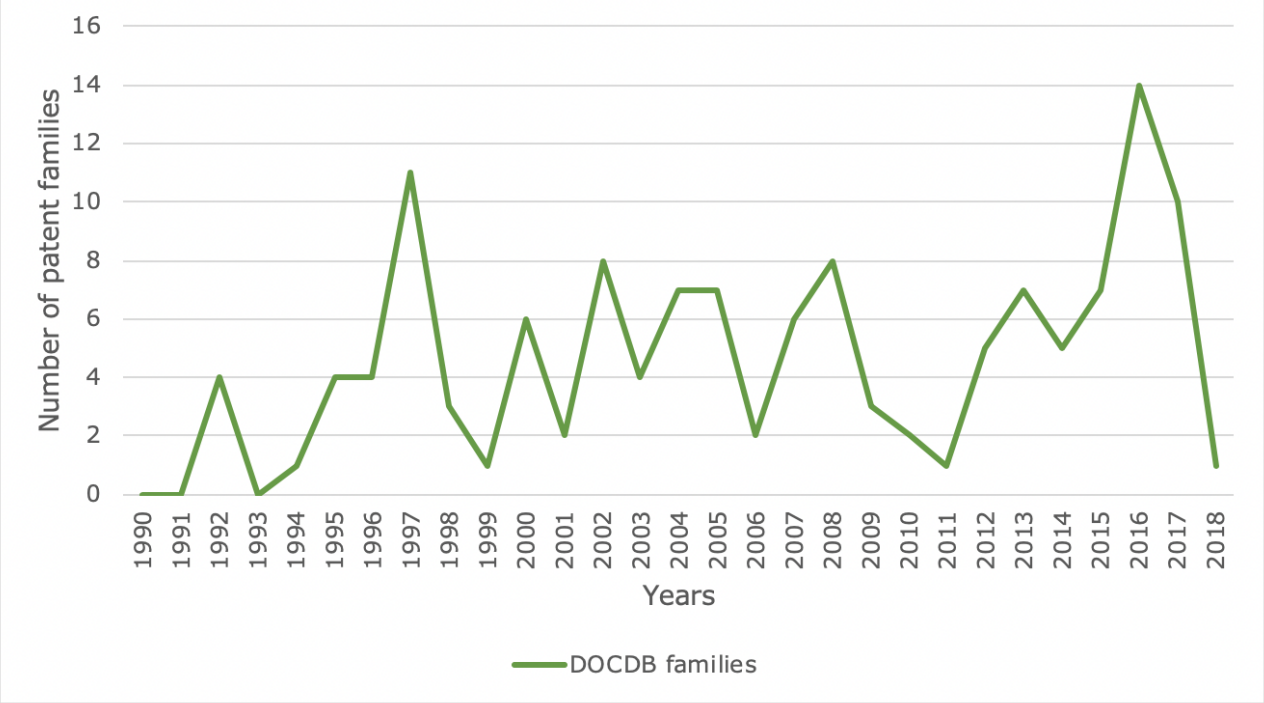

Figure 32. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The figure shows a noisy graph and a small number of filings per year: no trends can be detected because of the low statistical reliability of data in this cluster.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

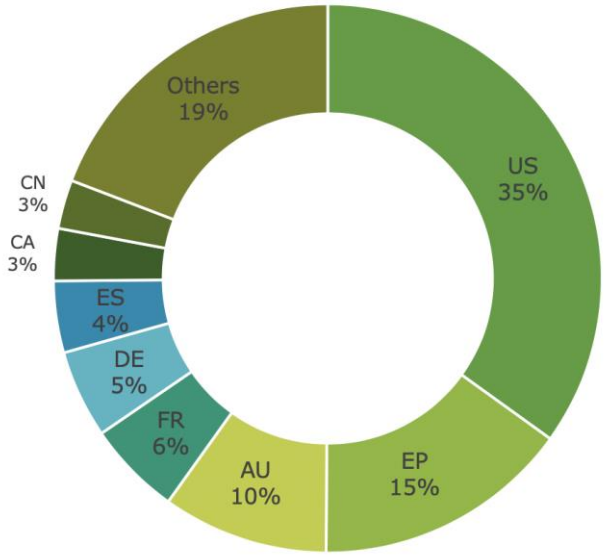

Figure 33. Percentage distribution of patents in the patent offices

USA is the main filing country (US), followed by the European jurisdiction (EP). Relevant the presence of the Australian (AU) patent office.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.

#	IPC Class	Class description	# Patent families	# Patents
1	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING.*	75	327
2	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING.*	31	83
3	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL*	24	85
4	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING*	19	41
5	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES*	13	57

#	IPC Class	Class description	# Patent families	# Patents
6	A01C	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING*	8	25
7	G06K	*PHYSICS || RECOGNITION OF DATA; PRESENTATION OF DATA; RECORD CARRIERS; HANDLING RECORD CARRIERS*	8	15
8	G01S	*PHYSICS || RADIO DIRECTION-FINDING; RADIO NAVIGATION; DETERMINING DISTANCE OR VELOCITY BY USE OF RADIO WAVES; LOCATING OR PRESENCE-DETECTING BY USE OF THE REFLECTION OR RERADIATION OF RADIO WAVES; ANALOGOUS ARRANGEMENTS USING OTHER WAVES*	8	16
9	A23N	*HUMAN NECESSITIES || MACHINES OR APPARATUS FOR TREATING HARVESTED FRUIT, VEGETABLES, OR FLOWER BULBS IN BULK, NOT OTHERWISE PROVIDED FOR; PEELING VEGETABLES OR FRUIT IN BULK; APPARATUS FOR PREPARING ANIMAL FEEDING-STUFFS*	7	14
10	G01C	*PHYSICS || MEASURING DISTANCES, LEVELS OR BEARINGS; SURVEYING; NAVIGATION; GYROSCOPIC INSTRUMENTS; PHOTOGRAMMETRY OR VIDEOGRAMMETRY.*	6	15

Table 13. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

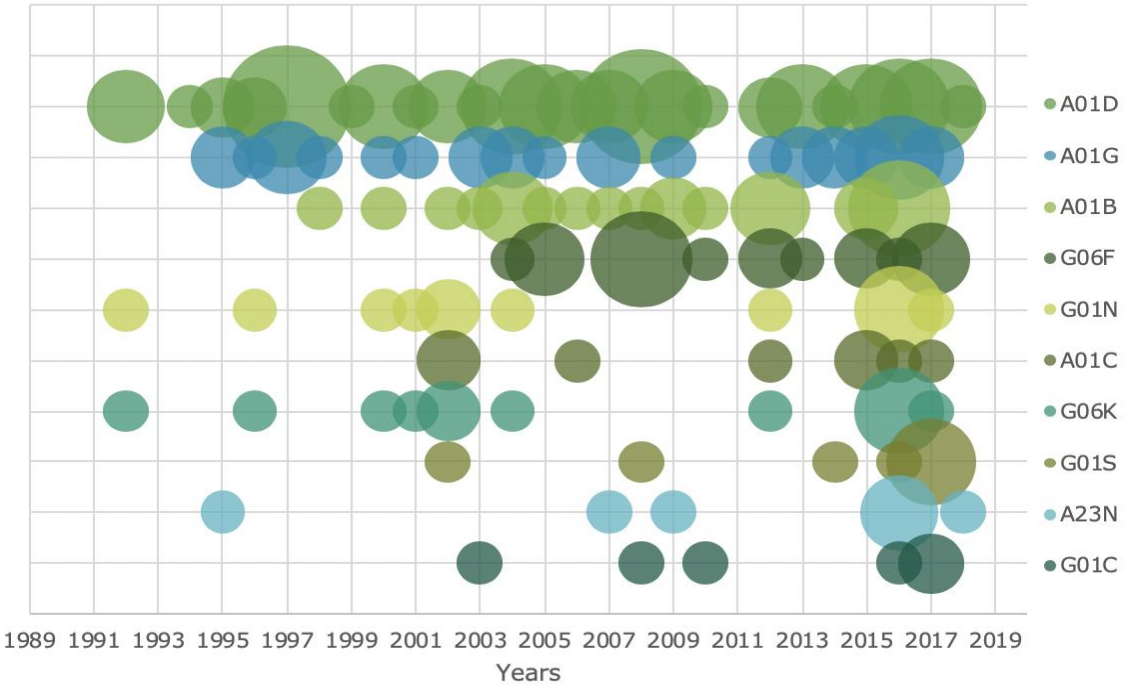

Figure 34. Evolution in time of main IPC classes

A01D and A01G are respectively related to agriculture and harvesting techniques; since this cluster is about harvesting/pruning technologies, their presence is expected.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

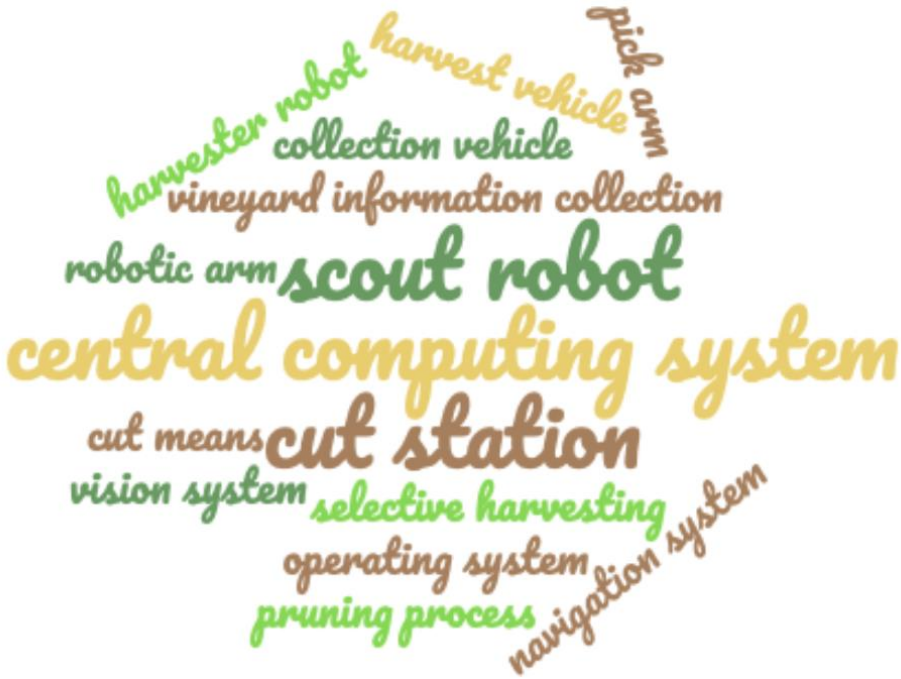

Figure 35. Tag cloud 2000-2010

Figure 36. Tag cloud 2011-2018

In both the tag clouds, several expressions are referred to robotic manipulation.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# Patent families	# Patents	% Patent families
1	Cnh	14	56	10,4
2	Pellenc	10	85	7,4
3	John Deere	6	53	4,4
4	Trinamix	4	7	3
5	Agerpoint	3	11	2,2
6	Ag Right Enterprises	3	10	2,2
7	Missotten Bart Ma	3	7	2,2
8	Fmc Corporation	2	28	2,2
9	Vision Robotics Corporation	2	7	1,5

#	Assignee	# Patent families	# Patents	% Patent families
10	Trimble Navigation	2	2	1,5
11	Knut Kummel	2	2	1,5
12	Automated Systems	2	2	1,5
13	Knut kummel	2	2	1,5
14	Michigan State University	2	5	1,5
15	Claas Selbstfahrende Erntemachinen	2	12	1,5

Table 14. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Pellenc Roger	10	80
2	Valouch Sebastian	4	7
3	Gialis Jean-Marc	4	7
4	Missotten Bart M A	4	13
5	Send Robert	4	7
6	Bruder Igmar	4	7
7	Scott Phillip R	3	9
8	Mcpeek K Thomas	3	8
9	Youman Marty D	3	7
10	Caine Kevin M	3	7

Table 15. Top inventors

5.4.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about harvesting and pruning in viticulture is composed by 106 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

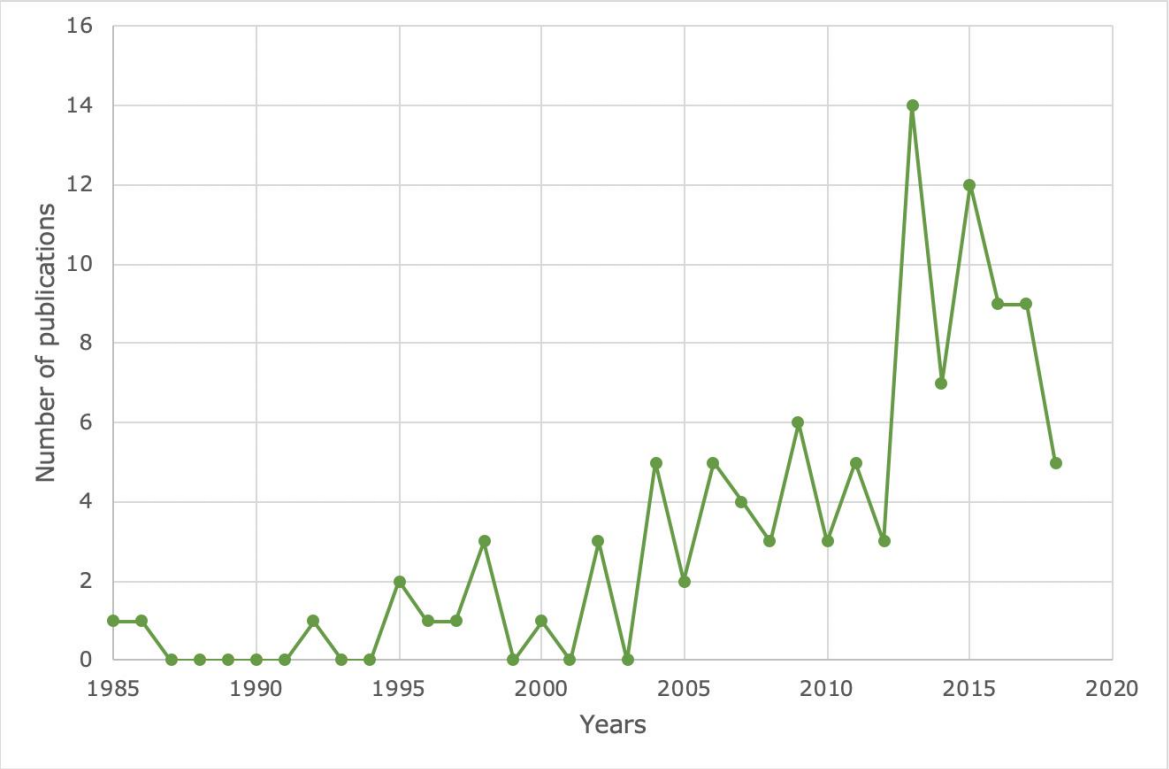

Figure 37. Distribution of the scientific literature according to publication dates

The small number of publications per year does not allow a reliable statistical interpretation of the tendency.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

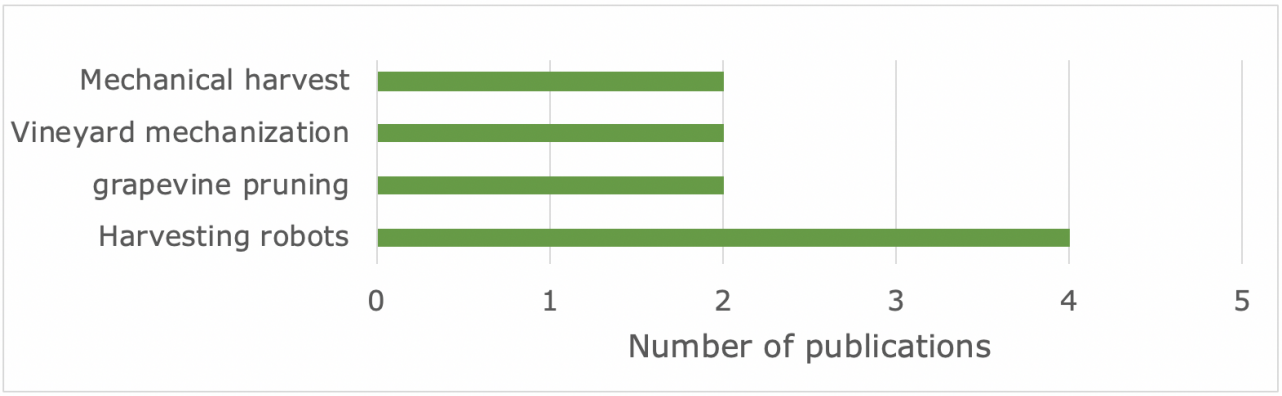

Figure 38. Papers' tags histogram

Figure 39. Papers' tag cloud

Several expressions among the main tags are referred to mechanization of harvesting and pruning activities.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

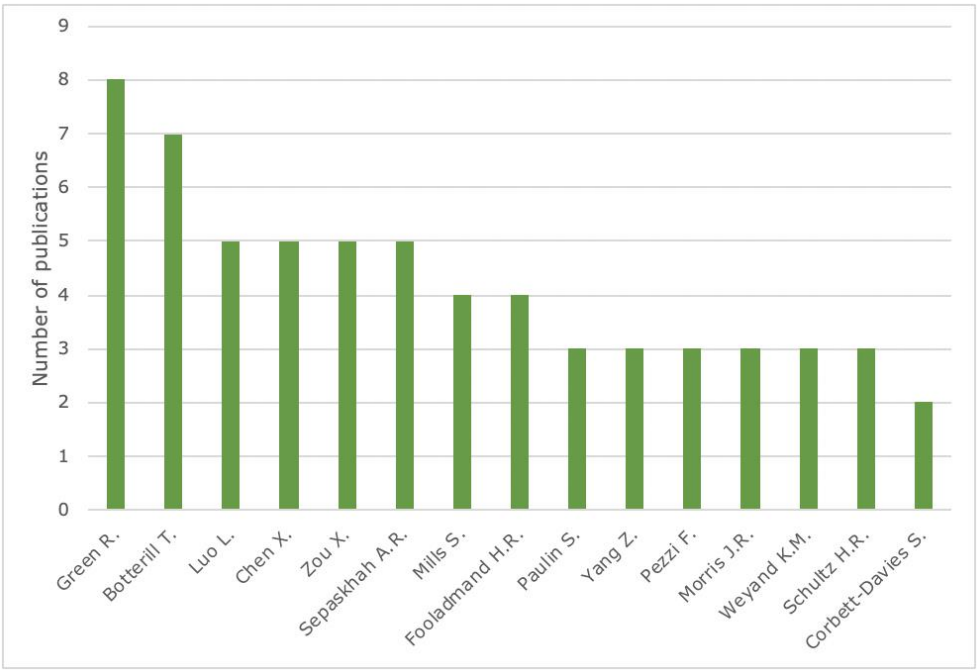

Figure 40. Top 15 authors

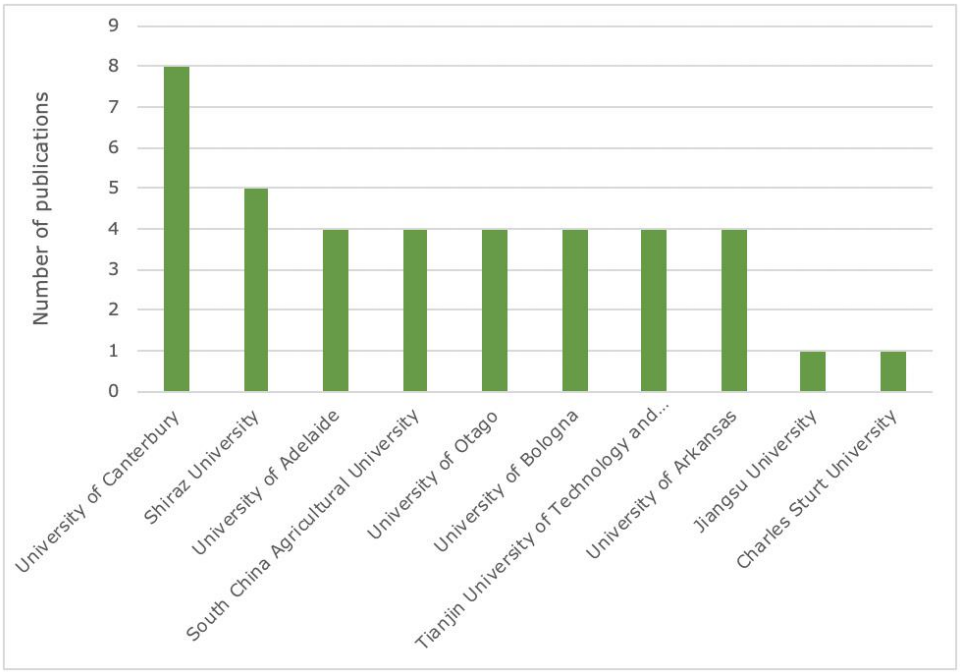

Figure 41. Top affiliations

The main authors' affiliations are in British, Iranian and Australian Universities. Other Universities are located in China, New Zealand, Italy and USA.

5.5. VINEYARD CARE

In this section, the technological cluster relating to vineyard care is analysed. The cluster gathers documents in which the main object concerns systems having functions of planting, cultivating, irrigating or protecting the vineyard. In the next paragraphs, analyses on patents and papers are respectively disclosed.

5.5.1. PATENT ANALYSIS

The patent set on vineyard care is composed by 1239 patents belonging to 332 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

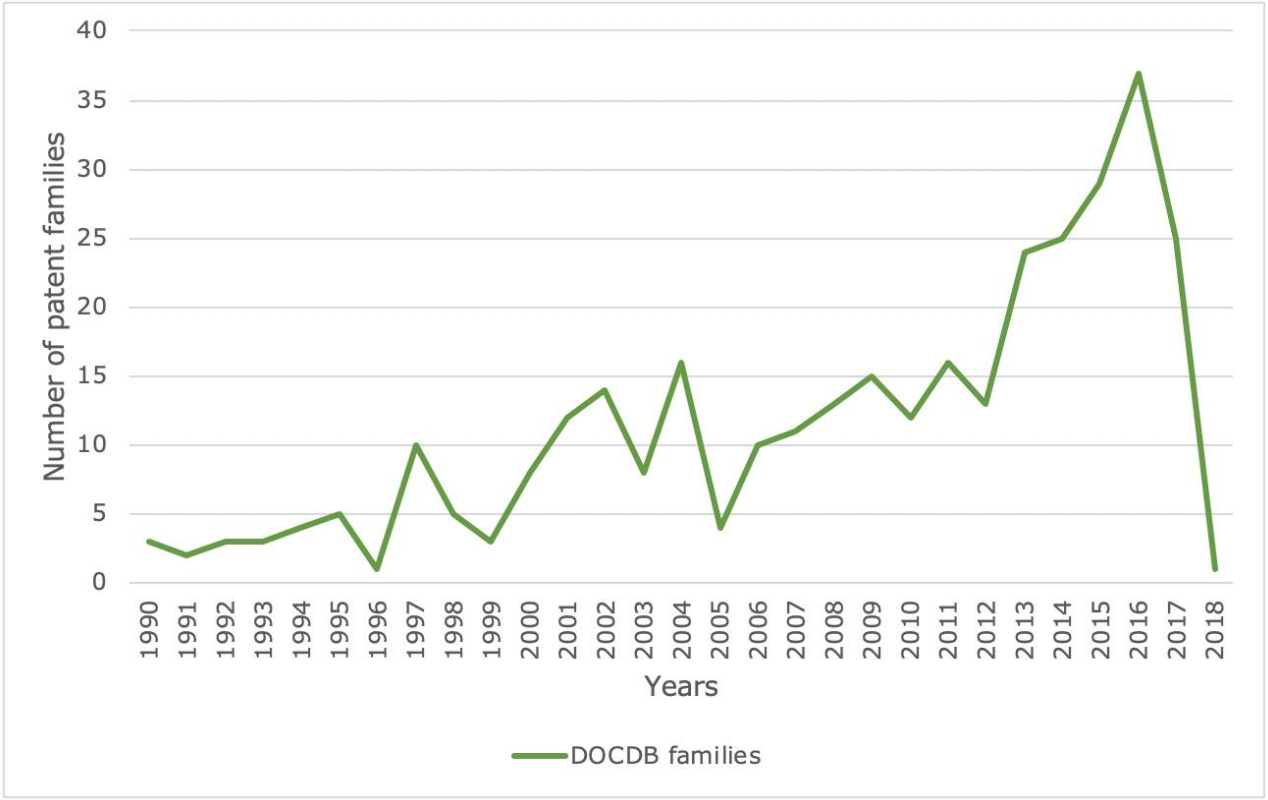

Figure 42. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The growing trend, in combination with the small number of filings per year, suggests that vineyard care in viticulture is an **emerging technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

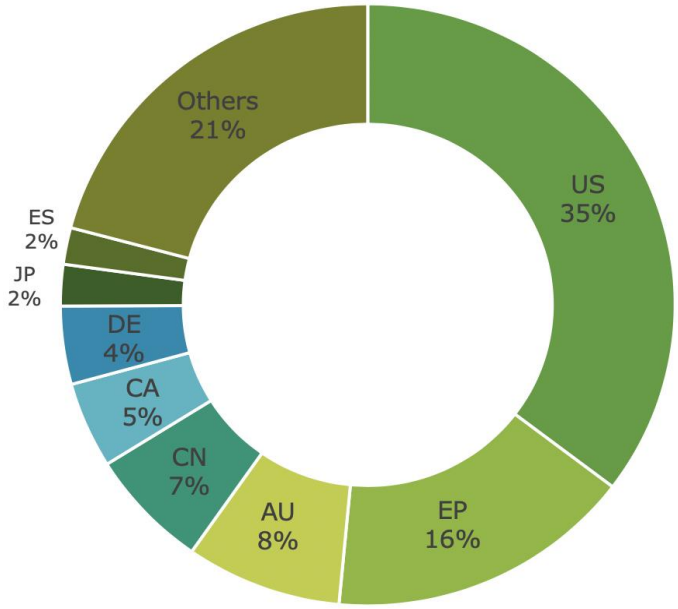

Figure 43. Percentage distribution of patents in the patent offices

USA is the main filing country (US), followed by the European jurisdiction (EP). Relevant the presence of the Australian (AU) patent office.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.

#	IPC Class	Class description	# Patent families	# Patents
1	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING*	174	516
2	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL*	50	138
3	A01M	*HUMAN NECESSITIES || CATCHING, TRAPPING OR SCARING OF ANIMALS, APPARATUS FOR THE DESTRUCTION OF NOXIOUS ANIMALS OR NOXIOUS PLANTS*	42	190
4	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES*	39	105

#	IPC Class	Class description	# Patent families	# Patents
5	A01C	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING.*	32	81
6	B05B	*PERFORMING OPERATIONS; TRANSPORTING || SPRAYING APPARATUS; ATOMISING APPARATUS; NOZZLES*	32	127
7	A01D	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING*	29	124
8	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING*	27	83
9	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES.*	27	66
10	G06K	*PHYSICS || RECOGNITION OF DATA; PRESENTATION OF DATA; RECORD CARRIERS; HANDLING RECORD CARRIERS.*	21	54

Table 16. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

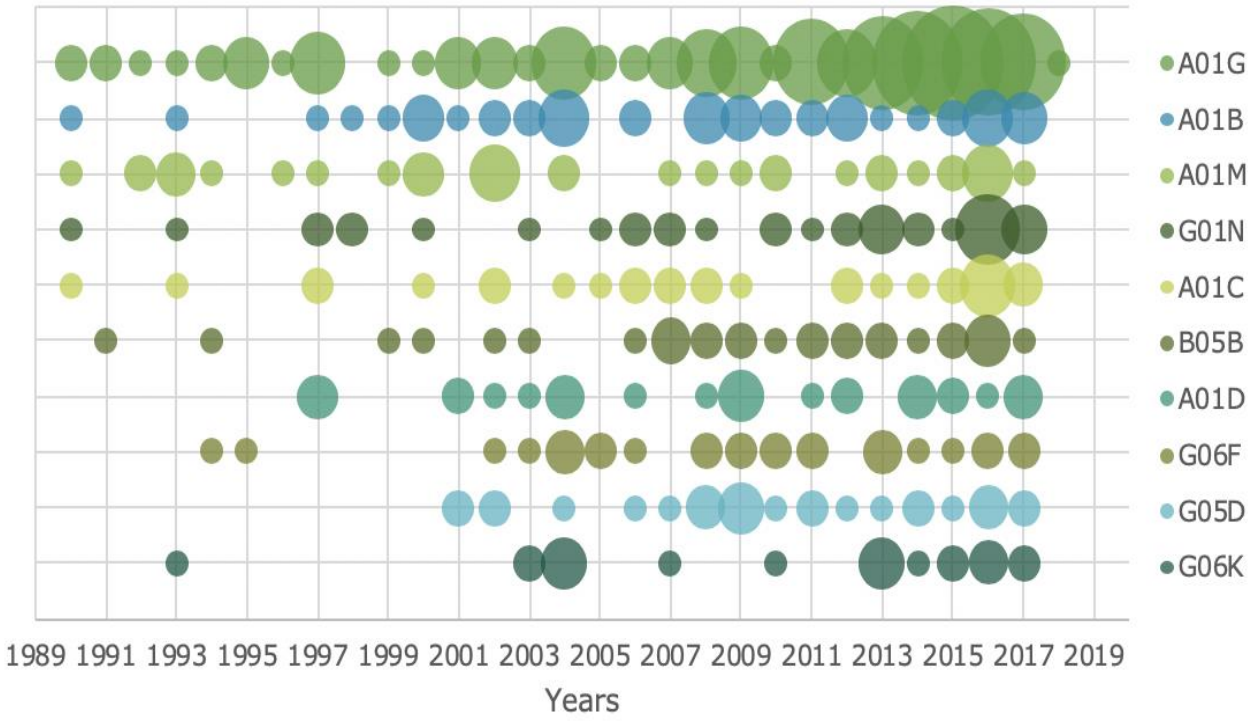

Figure 44. Evolution in time of main IPC classes

A01G is a very general class about agriculture; hence, its presence is expected for each analysed cluster. Most of the classes are, more or less, constant over time; the class with the highest rate of growth, except A01G, is G01N that is related to sensing systems.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

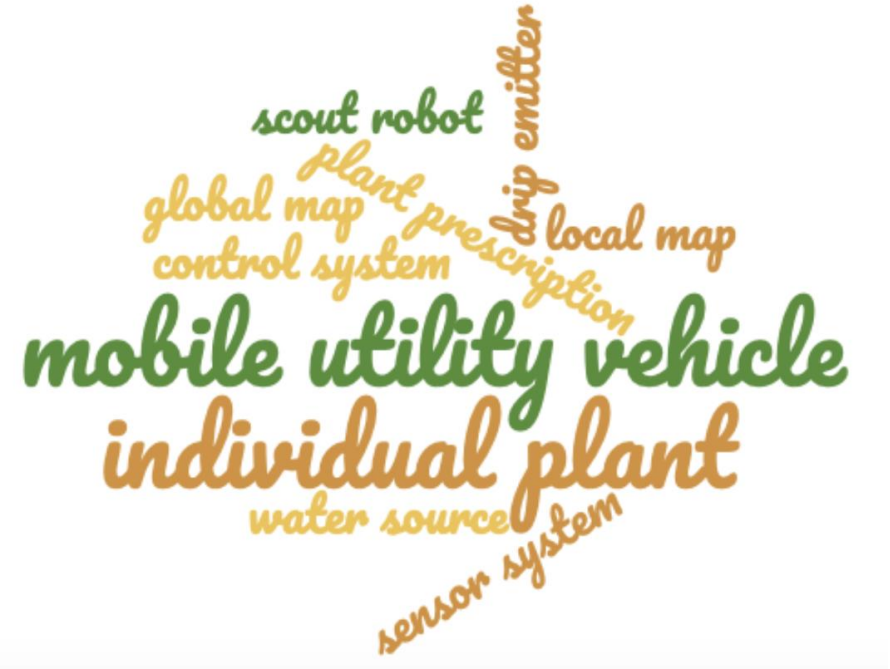

Figure 45. Tag cloud 2000-2010

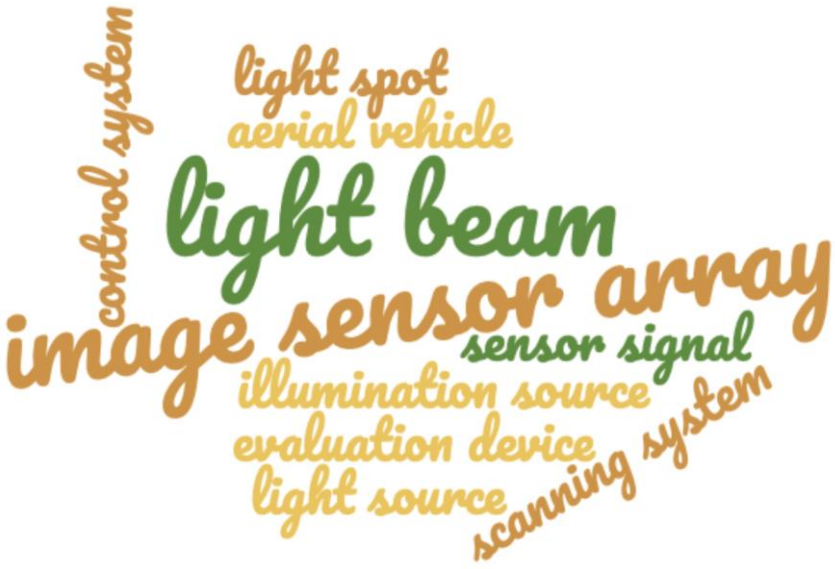

Figure 46. Tag cloud 2011-2018

In the first tag cloud, expressions are referred to several and various technologies/applications. On the contrary, most of the keywords of the second cloud are referred to optical systems. The presence of tags referred to aerial vehicles in the second figure is also remarkable.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# Patent families	# Patents	% Patent families
1	John Deere	20	113	5,7
2	Cnh	8	35	2,3
3	Trinamix	4	7	1,1
4	Monsanto Company	4	19	1,1
5	Pellenc	4	33	1,1
6	Trimble Navigation	3	8	0,8
7	Aguila Corporation	3	8	0,8
8	Elwa	3	8	0,8
9	Fmc Corporation	3	7	0,8
10	Zim Plant Technology	3	22	0,8
11	The United States Of America As Represented By The Secretary Of Agriculture	3	5	0,8
12	Crinklaw Farm Services Inc.	3	5	0,8
13	Guerrieri Gonzaga Aliana	3	9	0,8
14	Phytoculture Control Company	2	13	0,6
15	Agerpoint	2	8	0,6

Table 17. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Anderson Noel Wayne	9	37
2	Pellenc Roger	4	29
3	Bruder Ingmar	4	7
4	Send Robert	4	7
5	Valouch Sebastian	4	7
6	Guerrieri Gonzaga	3	9
7	Colburn John	3	3
8	Hermes Wilfried	3	6
9	Schapansky Chase	3	5
10	Crinklaw David Curtis	3	5

Table 18. Top inventors

5.5.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about vineyard care is composed by 450 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

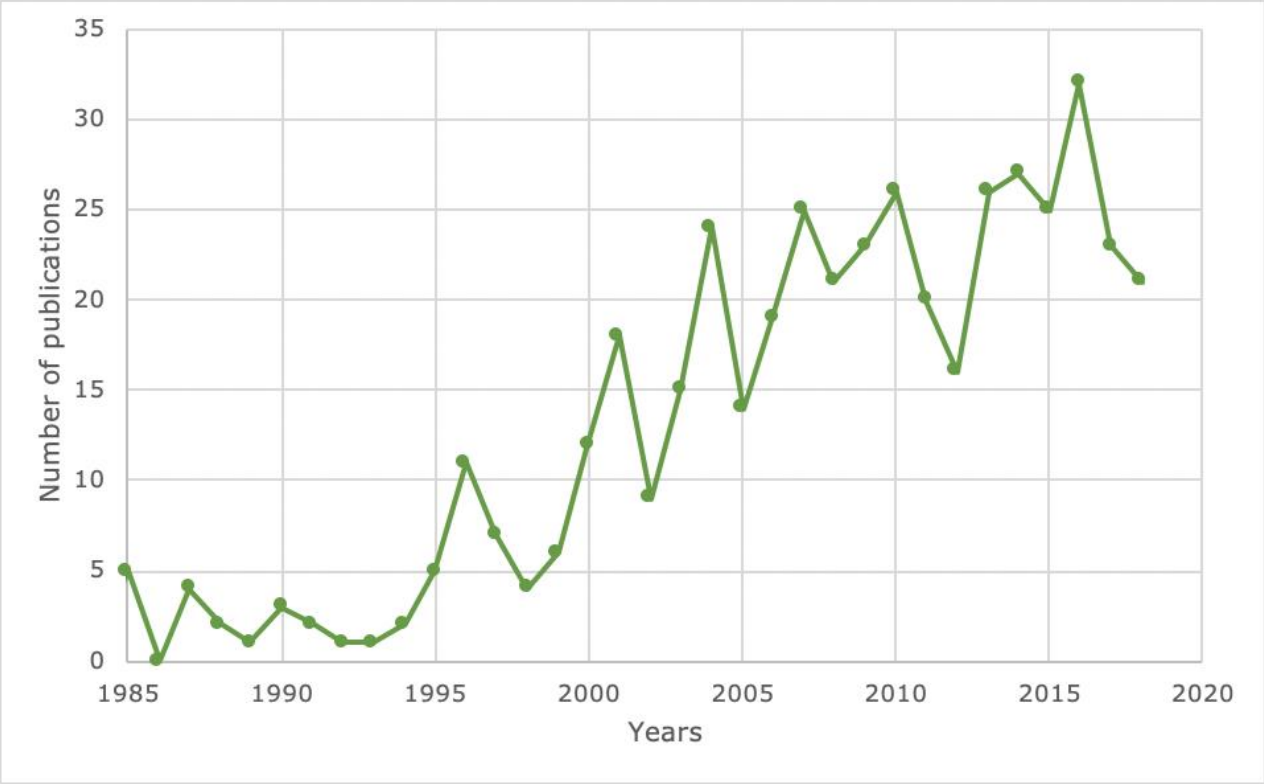

Figure 47. Distribution of the scientific literature according to publication dates

In accordance to the patent analysis' trend, the graph shows a growing technological field.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

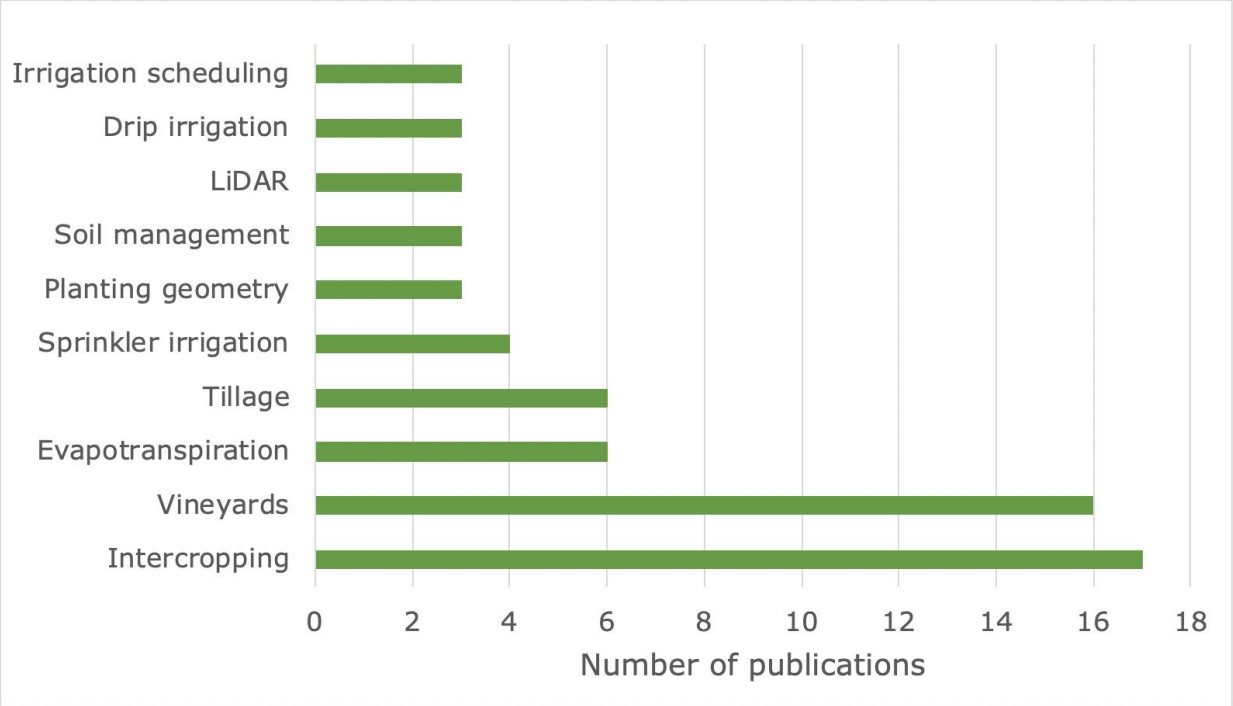

Figure 48. Papers' tags histogram

Figure 49. Papers' tag cloud

Many terms refer to irrigation and planting techniques.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

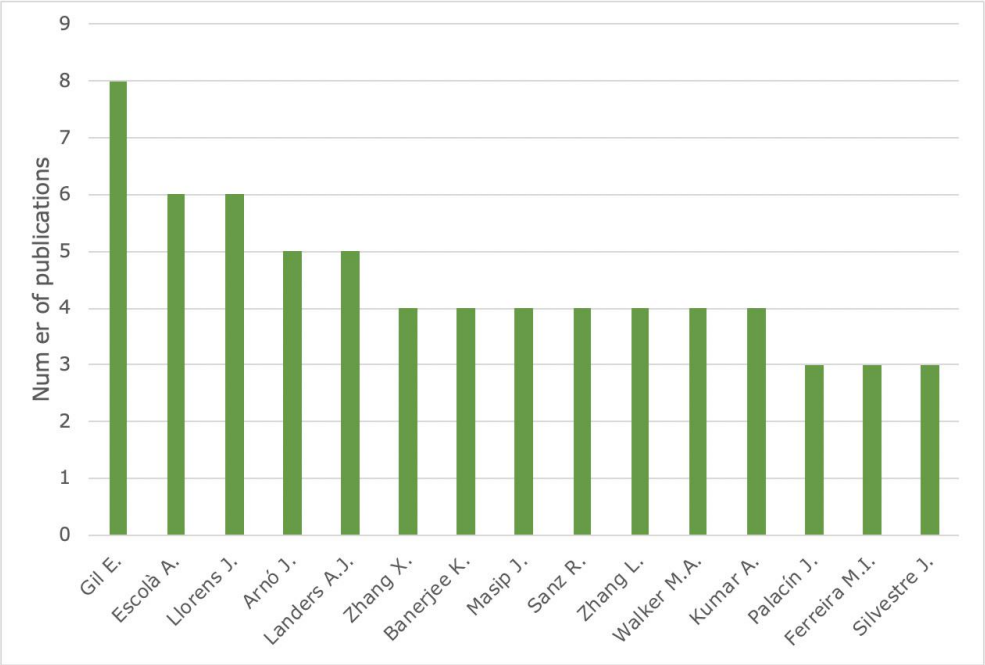

Figure 50. Top 15 authors

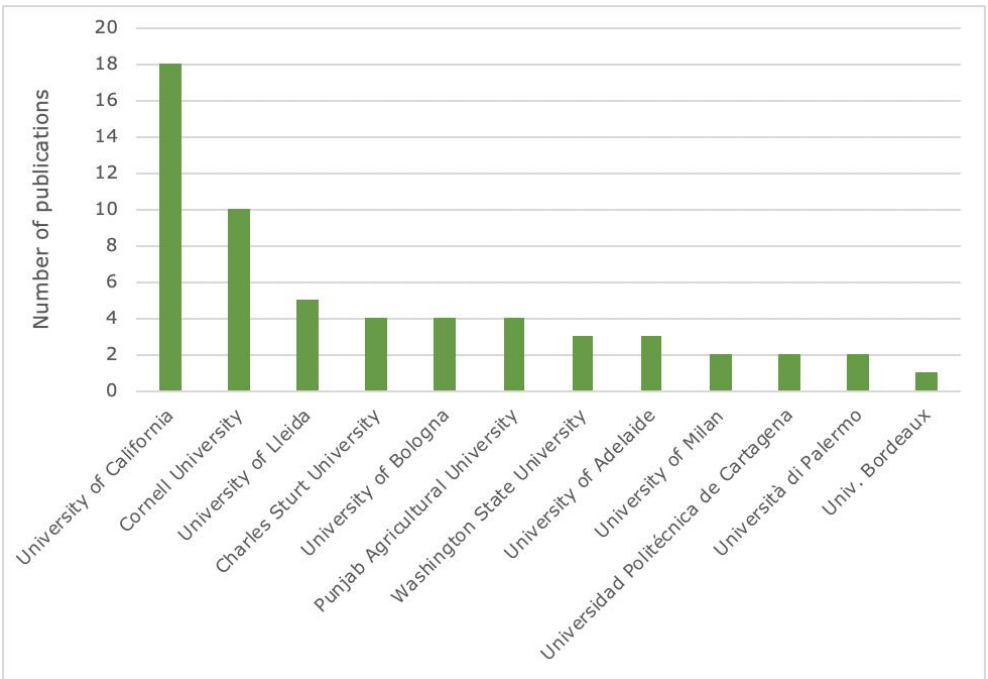

Figure 51. Top affiliations

The main authors' affiliations are in American, Belgian and Australian Universities. Other Universities are located in Italy, India, Spain and France.

6. IN-DEPTH ANALYSIS - ARABLE CROPS

In this chapter, an analysis of precision agriculture technologies applied on arable crops is disclosed. In the following sections, every identified technological cluster will be introduced and examined.

6.1. DATA PROCESSING

In this section, the technological cluster relating to data processing in arable crops is analysed. The cluster gathers documents in which the main object concerns algorithms and proceedings for data elaboration, computing systems etc. aimed to process several kinds of data deriving from variables detected on the fields. In the next paragraphs, analyses on patents and papers are respectively disclosed.

6.1.1. PATENT ANALYSIS

The patent set on data processing is composed by 3396 patents belonging to 961 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

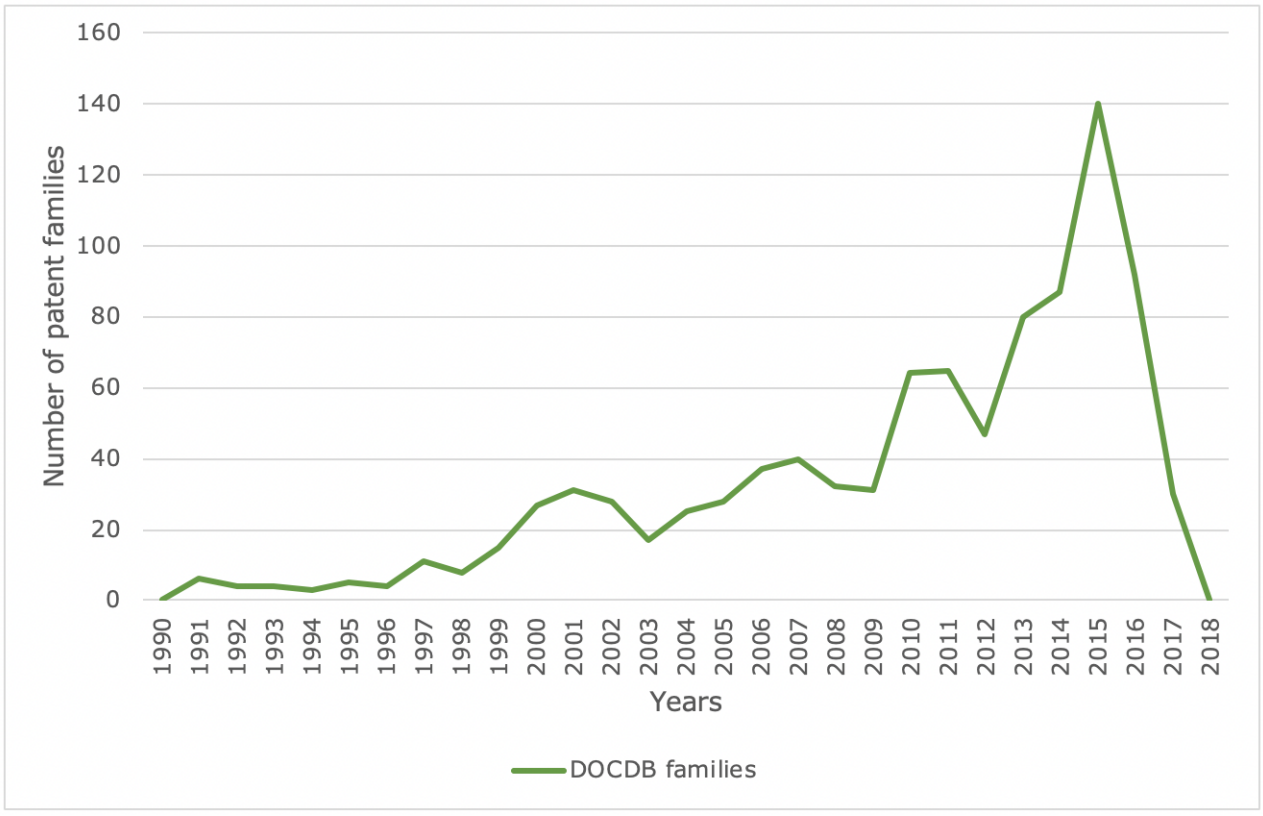

Figure 52. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The increasing trend, in combination with the significant number of filings per year, suggests that data processing in arable crops is a **growing technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

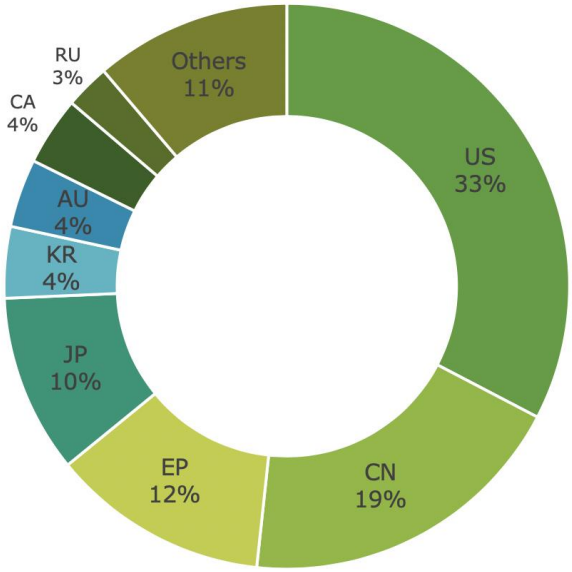

Figure 53. Percentage distribution of patents in the patent offices

USA is the main filing country (US), followed by China (CN) and the European jurisdiction (EP).

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.

#	IPC Class	Class description	# patent families	# patents
1	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING.*	390	958
2	G06Q	*PHYSICS || DATA PROCESSING SYSTEMS OR METHODS*	327	826
3	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING.*	316	913
4	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL*	153	492

#	IPC Class	Class description	# patent families	# patents
5	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING.*	151	567
6	G06K	*PHYSICS || RECOGNITION OF DATA; PRESENTATION OF DATA; RECORD CARRIERS; HANDLING RECORD CARRIERS.*	124	319
7	G06T	*PHYSICS || IMAGE DATA PROCESSING OR GENERATION, IN GENERAL*	115	262
8	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES.*	101	292
9	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES*	96	273
10	G05B	*PHYSICS || CONTROL OR REGULATING SYSTEMS IN GENERAL; FUNCTIONAL ELEMENTS OF SUCH SYSTEMS; MONITORING OR TESTING ARRANGEMENTS FOR SUCH SYSTEMS OR ELEMENTS.*	88	189

Table 19. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

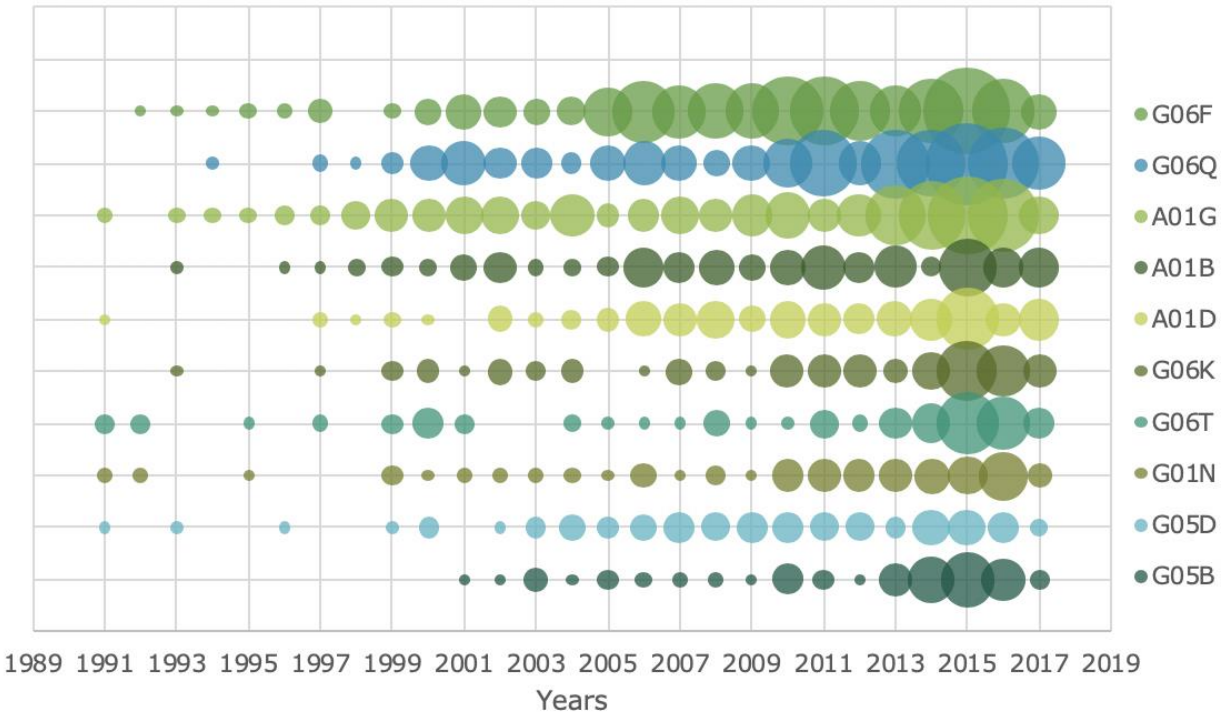

Figure 54. Evolution in time of main IPC classes

Every technological class is active and growing since last '90s; among the other classes, the increasing activity in class G06T (Image data processing) is remarkable.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

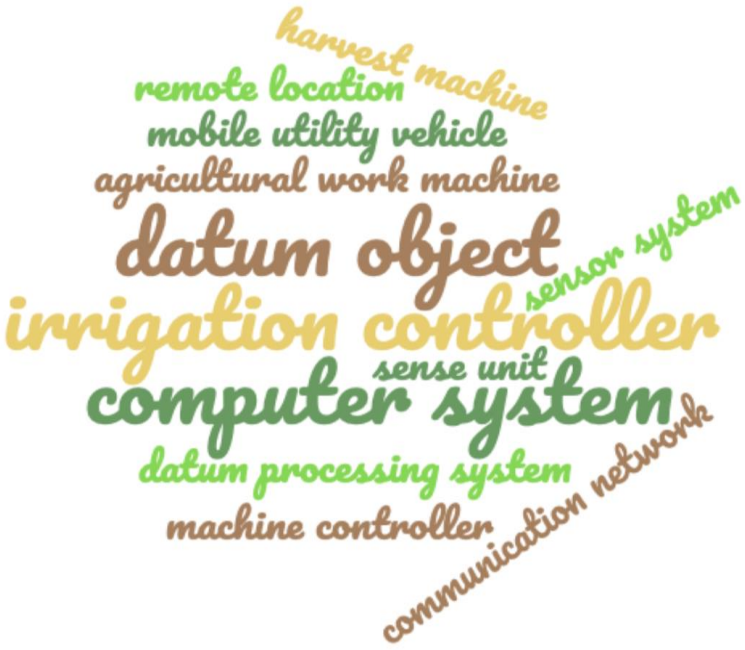

Figure 55. Tag cloud 2000-2010

Figure 56. Tag cloud 2011-2018

In both the tag clouds, the terminology is focused on machines and their control.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# Patent families	# Patents	% Patent families
1	John Deere	78	435	8
2	The Climate Corporation	42	143	4,3
3	Cnh	32	120	3,3
4	Claas Selbstfahrende Erntesmaschinen	27	181	2,8
5	Trimble Navigation	20	48	2
6	Pioneer Hi Bred International	20	117	2
7	Iteris	18	37	1,8
8	Kubota Corporation	16	47	1,6
9	Agco	15	26	1,5
10	Precision Planting	10	52	1
11	Case Corporation	9	21	0,9
12	Fujitsu	8	26	0,8
13	Ag Leader Technology	7	19	0,7
14	Bejiing Research Center for Information Technology in Agriculture	6	9	0,6
15	Monsanto Company	5	24	0,5

Table 20. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Anderson Noel Wayne	17	83
2	Mewes John J	15	29
3	Salentiny Dustin M	14	26
4	Romney Matt	7	11
5	Lindores Robert J	7	17
6	Takahara Kazuhiro	7	25
7	Xu Ying	6	22
8	Koch Justin	6	27
9	Endrizzi Clark	6	8
10	Sauder Doug	6	30

Table 21. Top inventors

6.1.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about data processing is composed by 1703 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

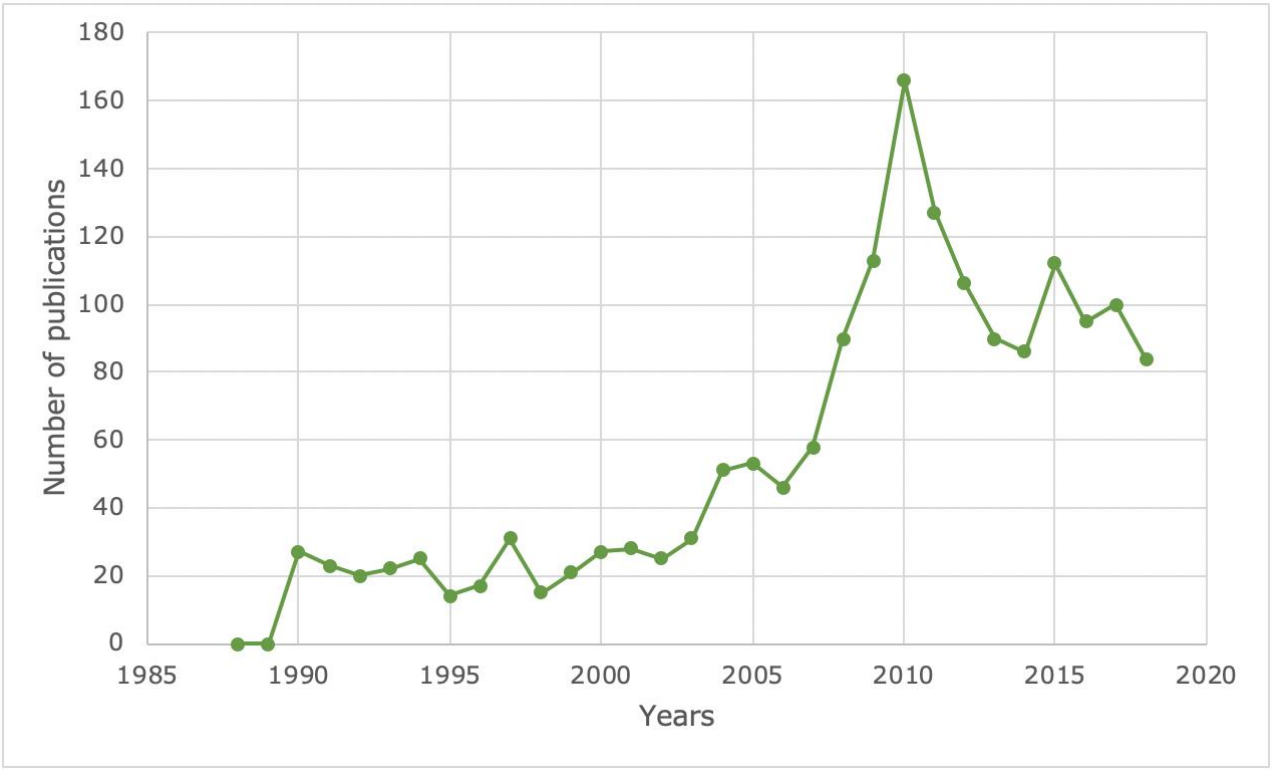

Figure 57. Distribution of the scientific literature according to publication dates

The publications' distribution in time shows a growing tendency until 2010; after a spike, the diagram decreases and oscillates around 100 publications per year.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

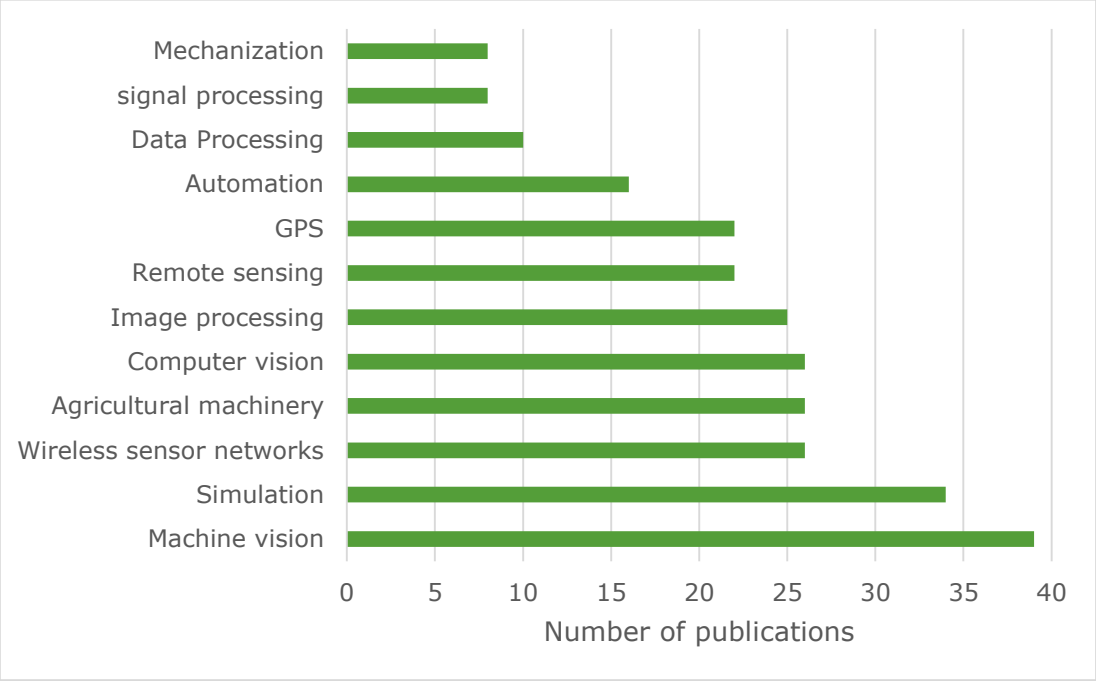

Figure 58. Papers' tags histogram

Figure 59. Papers' tag cloud

Several expressions among the main tags are referred to mechanization and optical instruments.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

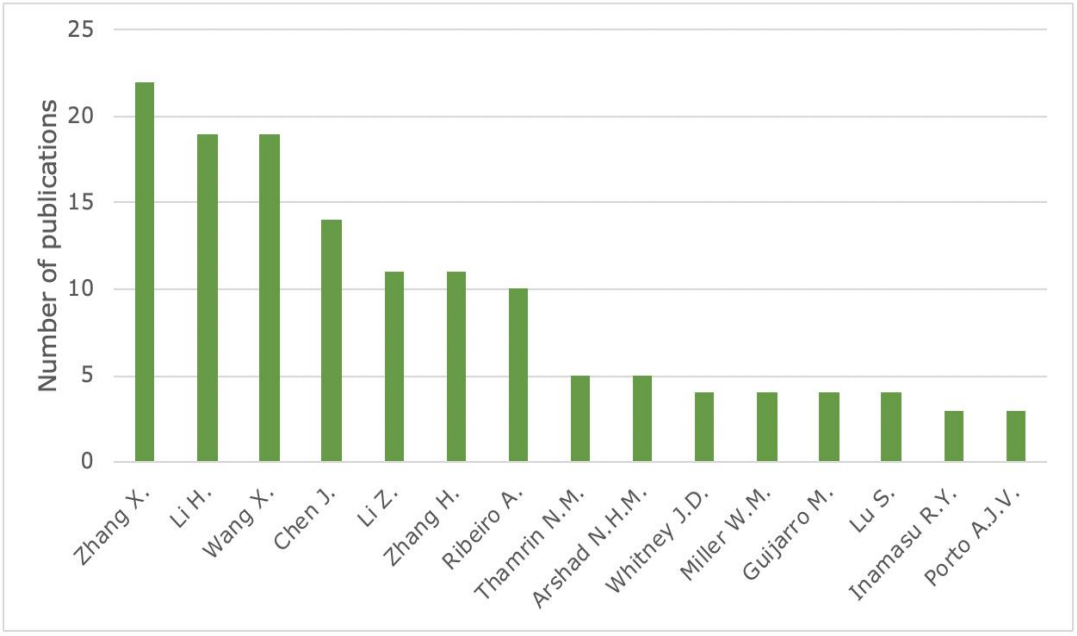

Figure 60. Top 15 authors

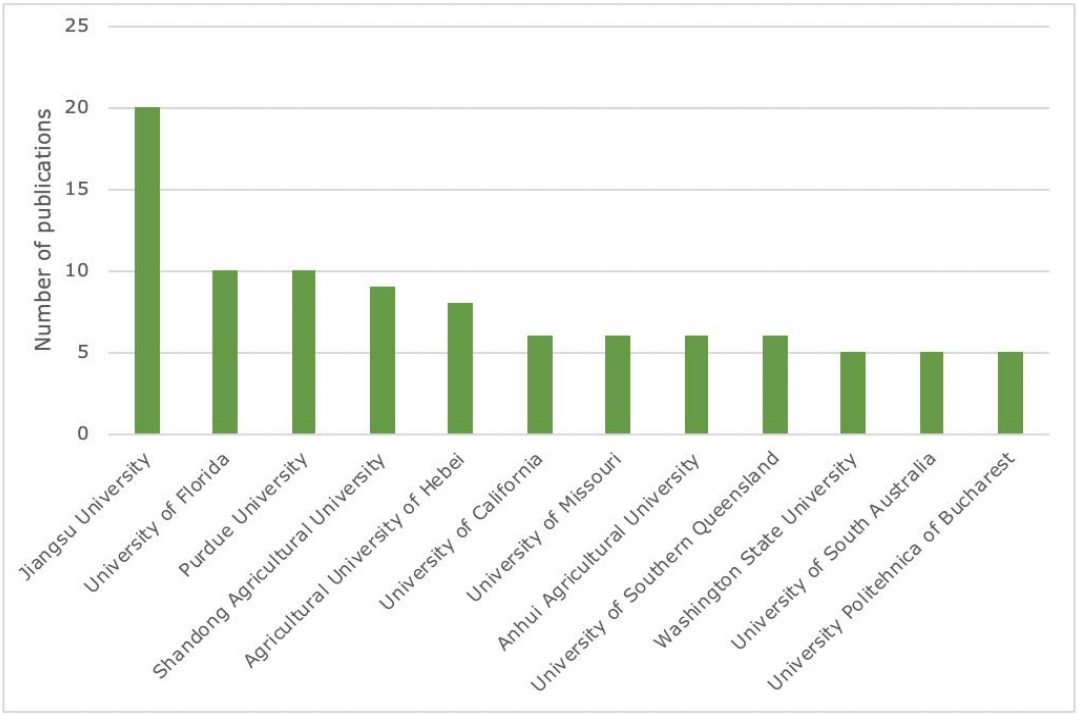

Figure 61. Top affiliations

The most Universities are located in China and USA. Other Universities are located in Australia and Romania.

6.2. MEASUREMENT AND DATA COLLECTION

In this section, the technological cluster relating to measurement and data collection in arable crops is analysed. The cluster gathers documents in which the main object concerns systems for detecting variables and parameters related to vineyards such as distance, temperature, pressure etc. In the next paragraphs, analyses on patents and papers are respectively disclosed.

6.2.1. PATENT ANALYSIS

The patent set on measurement and data collection is composed by 5539 patents belonging to 1581 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

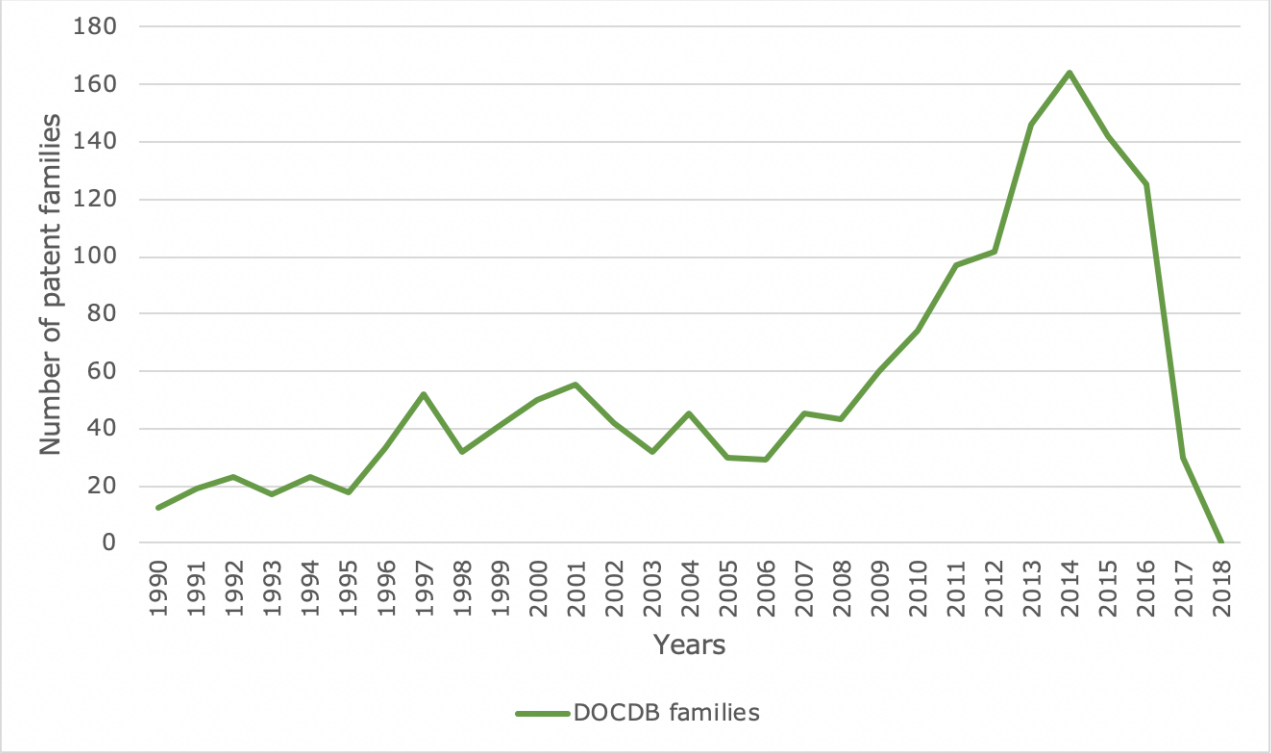

Figure 62. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The increasing trend, in combination with the significant number of filings per year, suggests that measurement and data collection in arable crops is a **growing technological** field, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

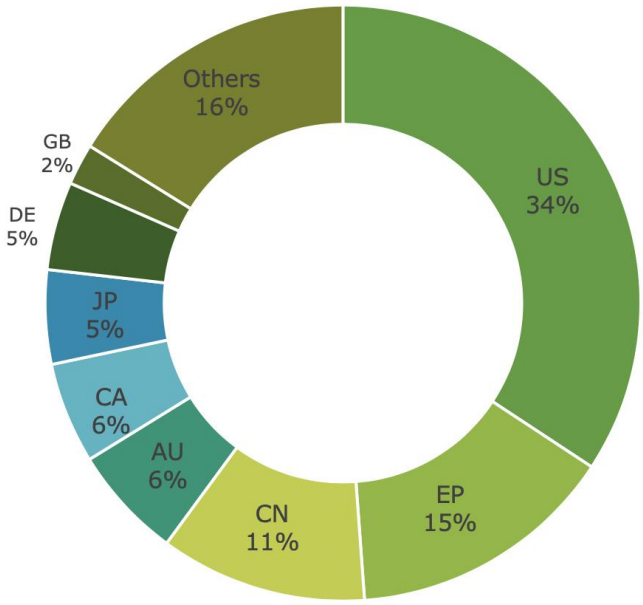

Figure 63. Percentage distribution of patents in the patent offices

USA is the main filing country (US), followed by European (EP), Chinese (CN) and Australian jurisdictions.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.

#	IPC Class	Class description	# Patent families	# Patents
1	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING.*	589	1573
2	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES.*	501	1722
3	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES.*	284	887
4	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING.*	266	1045
5	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL.*	213	759

#	IPC Class	Class description	# Patent families	# Patents
6	G05B	*PHYSICS || CONTROL OR REGULATING SYSTEMS IN GENERAL; FUNCTIONAL ELEMENTS OF SUCH SYSTEMS; MONITORING OR TESTING ARRANGEMENTS FOR SUCH SYSTEMS OR ELEMENTS.*	153	404
7	A01C	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING.*	143	492
8	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING.*	126	399
9	G01S	*PHYSICS || RADIO DIRECTION-FINDING; RADIO NAVIGATION; DETERMINING DISTANCE OR VELOCITY BY USE OF RADIO WAVES; LOCATING OR PRESENCE-DETECTING BY USE OF THE REFLECTION OR RERADIATION OF RADIO WAVES; ANALOGOUS ARRANGEMENTS USING OTHER WAVES*	122	410
10	G01F	*PHYSICS || MEASURING VOLUME, VOLUME FLOW, MASS FLOW, OR LIQUID LEVEL; METERING BY VOLUME.*	115	341

Table 22. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

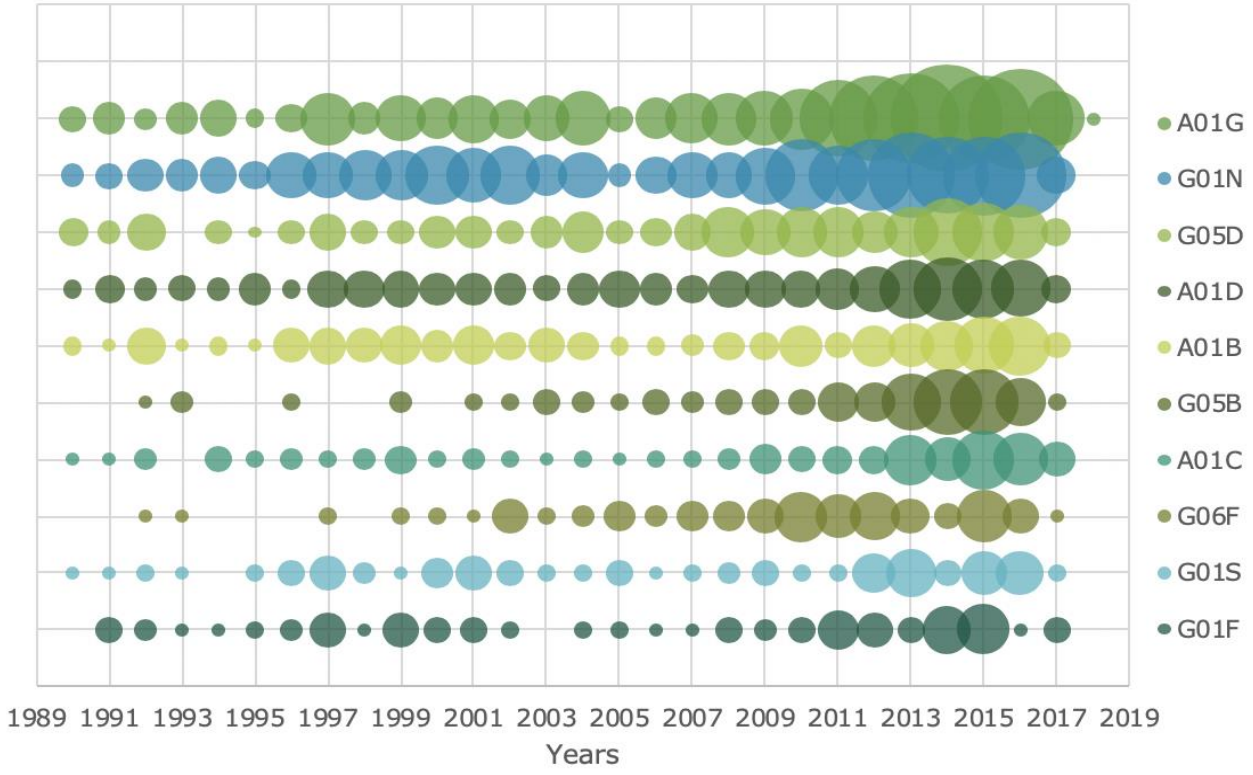

Figure 64. Evolution in time of main IPC classes

A01G is a very general class about agriculture; hence, its presence is expected for each analysed cluster. Class G05B, related to controlling, monitoring and regulating systems, shows the highest rate of growth.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

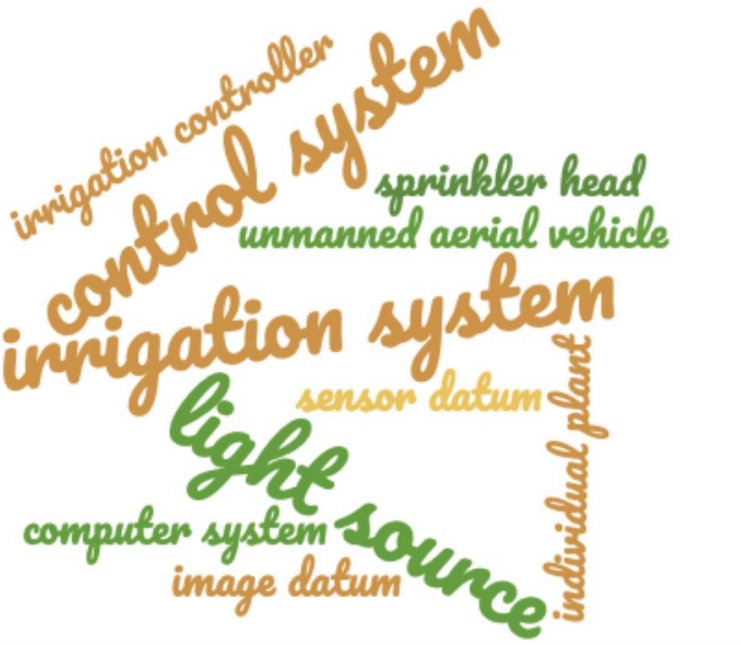

Figure 65. Tag cloud 2000-2010

Figure 66. Tag cloud 2011-2018

The two tag clouds show many expressions about irrigation and control systems; other references to optical systems and vehicles, comprising aerial vehicles, are present.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	#Patent families	# Patents	%Patent families
1	John Deere	81	457	4,7
2	Cnh	46	216	2,7
3	Claas Selbstfahrende Erntesmaschinen	28	146	1,6
4	Jiangsu University	26	39	1,5
5	Trimble Navigation	23	89	1,3
6	Yanmar Agricult Equip Company	19	28	1,1
7	New Holland North America	19	70	1,1
8	Iseki & Co	18	34	1
9	Precision Planting	18	95	1
10	China Agricultural University	18	29	1
11	Pioneer Hi Bred International	17	86	1
12	Case Corporation	16	48	0,9
13	Kubota Corporation	14	41	0,8
14	The United States of America As Represented by The Secretary Of Agriculture	13	15	0,8
15	University Of California	11	22	0,6

Table 23. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Diekhans Norbert	17	83
2	Li Yaoming	15	29
3	Anderson Noel Wayne	14	26
4	Koch Justin	7	11
5	Behnke Willi	7	17
6	Lange Arthur F	7	25
7	Strubbe Gilbert J I	6	22
8	Romney Matt	6	27
9	Missotten Bart M A	6	8
10	Foster Christopher A	6	30

Table 24. Top inventors

6.2.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about measurement and data collection is composed by 513 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

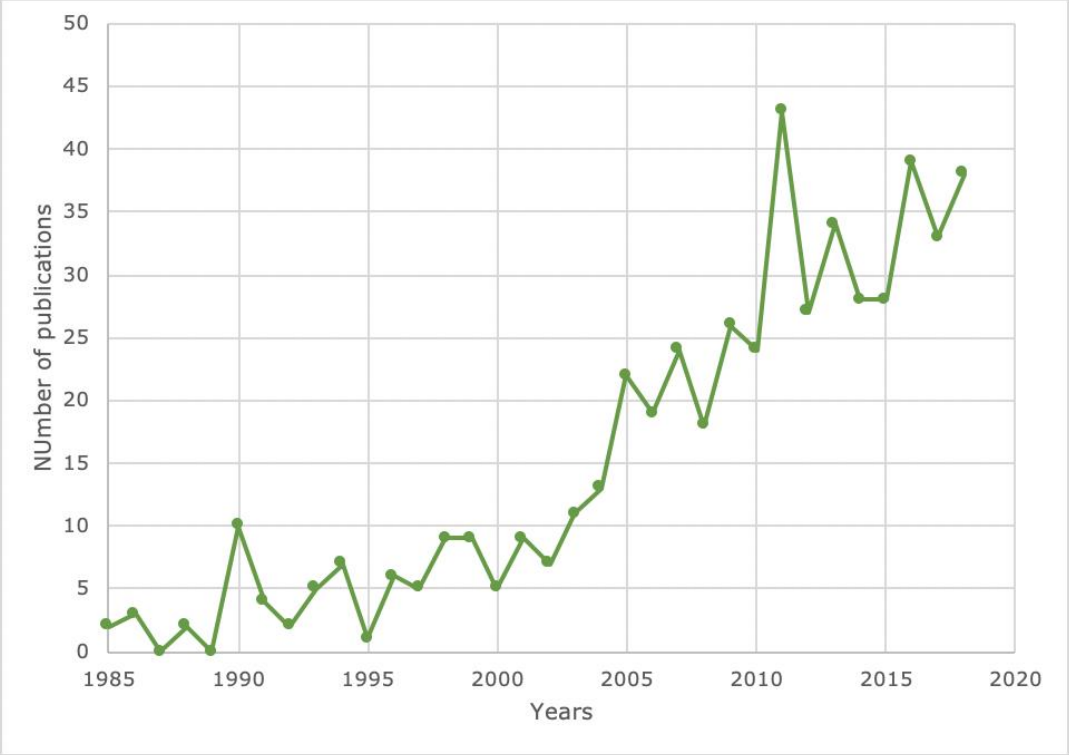

Figure 67. Distribution of the scientific literature according to publication dates

In accordance to the patent analysis' trend, the graph shows a growing technological field. It is interesting to highlight the presence of the highest spike in 2010.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

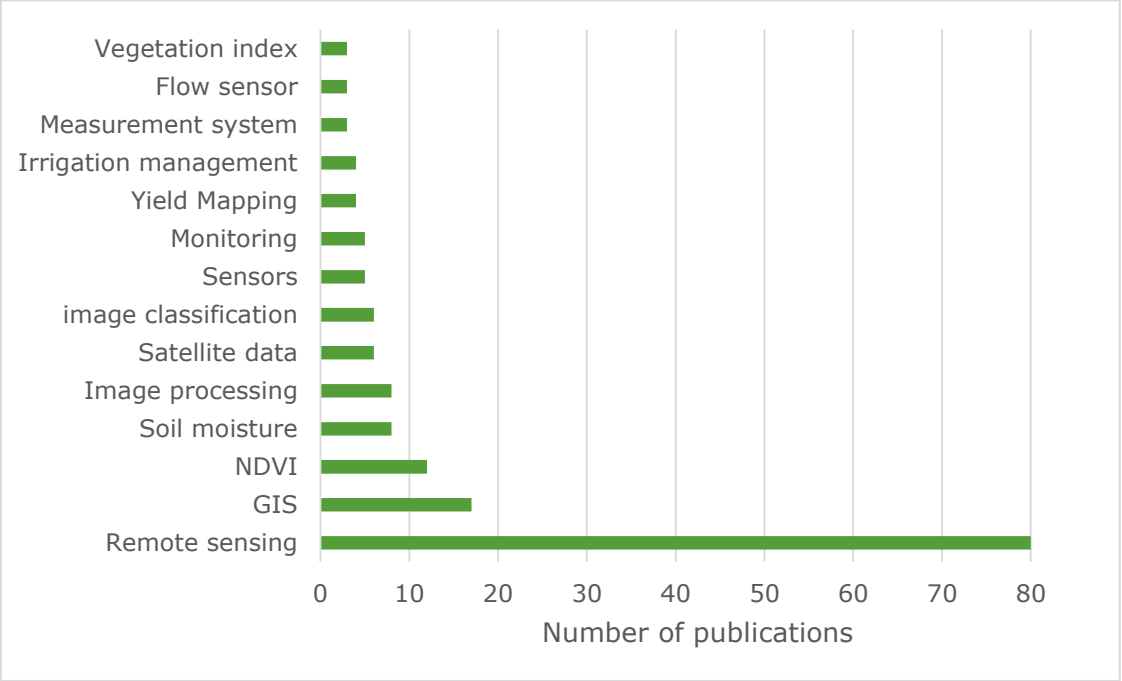

Figure 68. Papers' tags histogram

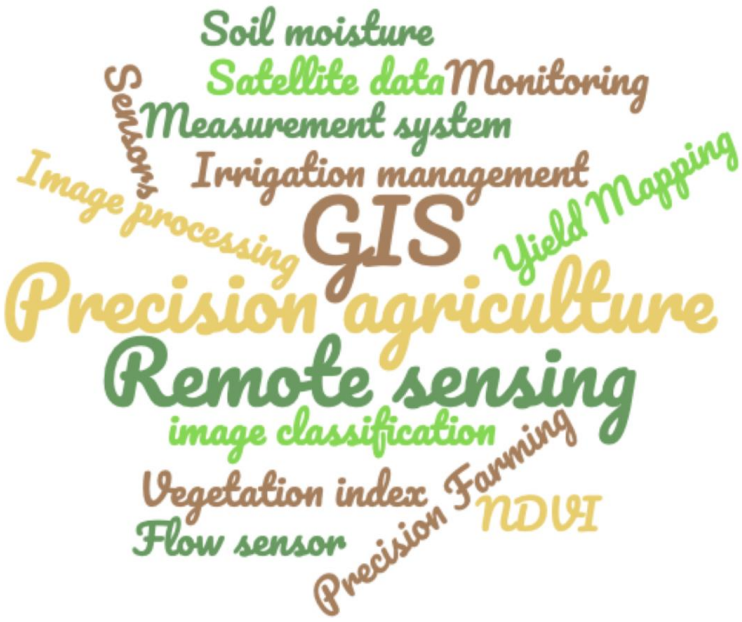

Figure 69. Papers' tag cloud

Once again, it is important to highlight the importance of image analysis. Moreover, many expressions are referred to geographical characterization (GIS, NDVI, satellite data).

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

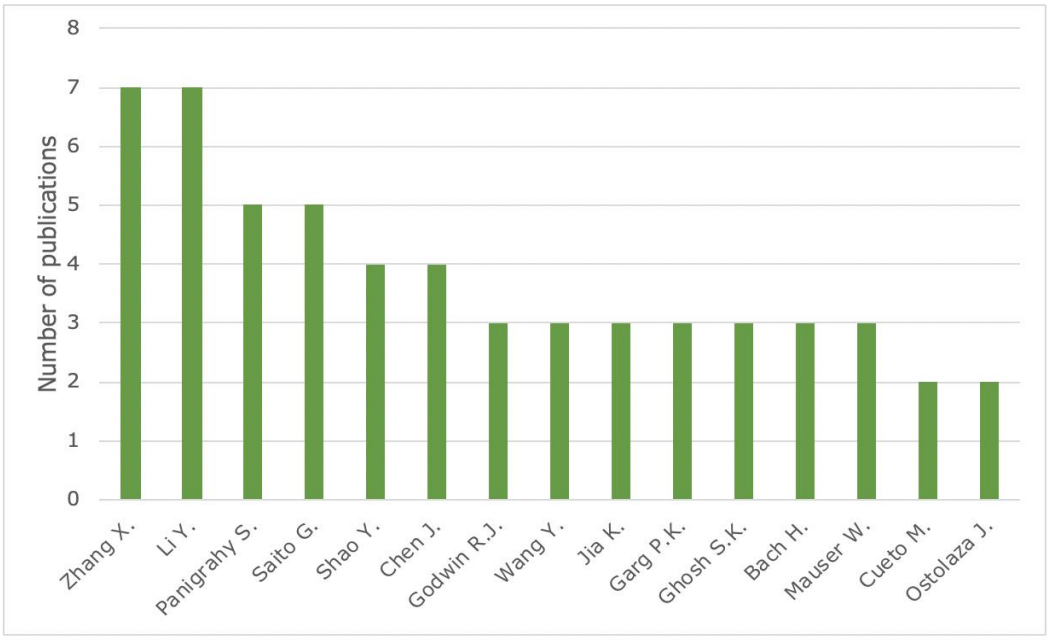

Figure 70. Top 15 authors

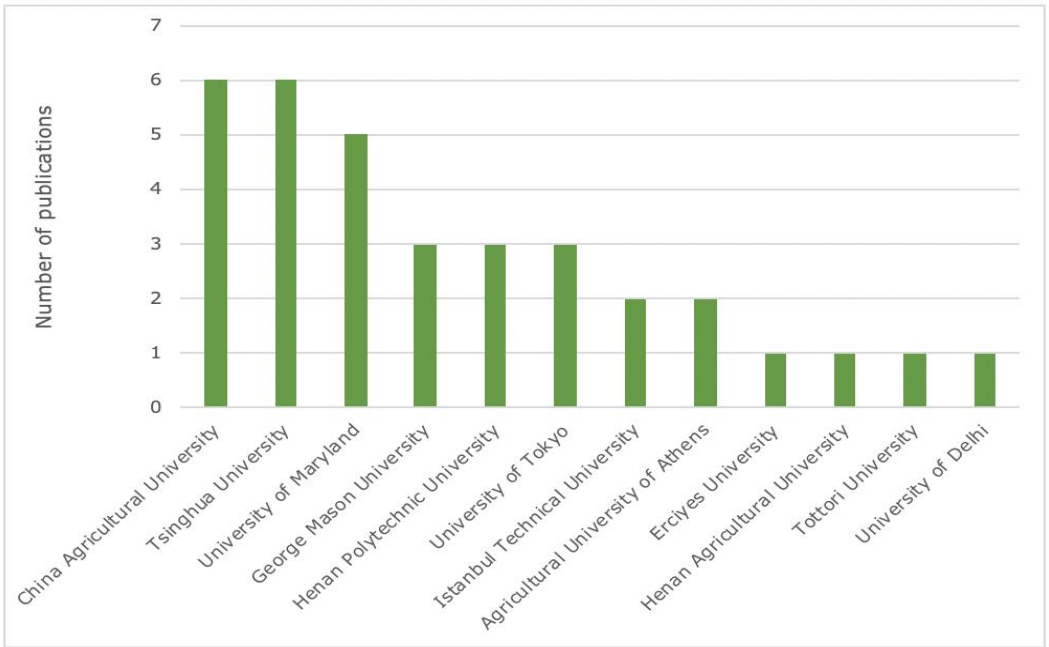

Figure 71. Top affiliations

The top five Universities are located in China and USA.

6.3. DATA TRANSFER

In this section, the technological cluster relating to data transfer is analysed. The cluster gathers documents in which the main object concerns telecommunication systems aimed to transmit data and information collected between two or more sources. In the next paragraphs, analyses on patents and papers are respectively disclosed.

6.3.1. PATENT ANALYSIS

The patent set on data transfer is composed by 2046 patents belonging to 530 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

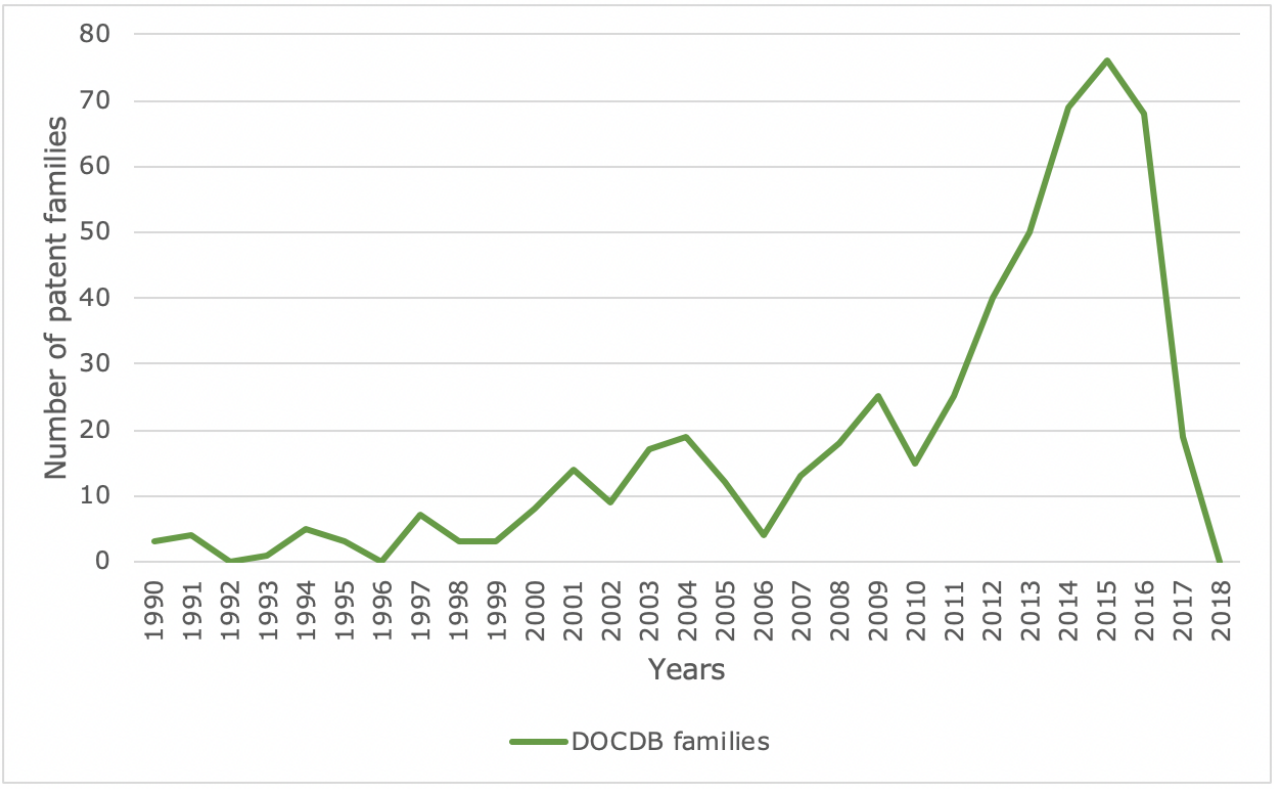

Figure 72. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The increasing trend, in combination with the significant number of filings per year, suggests that data transfer in arable crops is a **growing technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

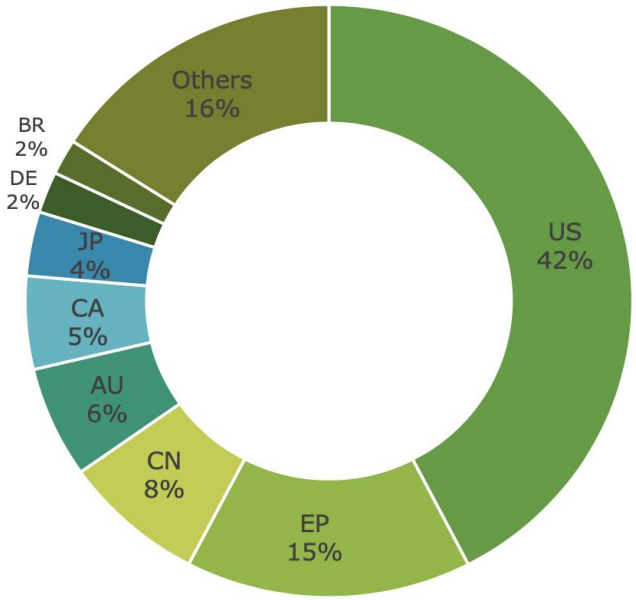

Figure 73. Percentage distribution of patents in the patent offices

USA is the main filing country (US), followed by European (EP), Chinese (CN) and Australian jurisdictions.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.
In the following table, some rows are highlighted in light green; besides being expected and, hence, scarcely relevant, IPC classes contained in said rows have been omitted from the subsequent bubble chart, because of their scale is an order of magnitude greater than the others. Their presence in the bubble chart would flatten the signal of the subsequent relevant classes.

#	IPC Class	Class description	# Patent families	# Patents
1	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING.*	316	1061
2	H04N	*ELECTRICITY || PICTORIAL COMMUNICATION.*	68	277
3	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING.*	65	190
4	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES*	62	165

#	IPC Class	Class description	# Patent families	# Patents
5	G05B	*PHYSICS || CONTROL OR REGULATING SYSTEMS IN GENERAL; FUNCTIONAL ELEMENTS OF SUCH SYSTEMS; MONITORING OR TESTING ARRANGEMENTS FOR SUCH SYSTEMS OR ELEMENTS.*	57	128
6	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES.*	54	173
7	G08B	*PHYSICS || SIGNALLING OR CALLING SYSTEMS; ORDER TELEGRAPHS; ALARM SYSTEMS*	53	123
8	H04L	*ELECTRICITY || TRANSMISSION OF DIGITAL INFORMATION, E.G. TELEGRAPHIC COMMUNICATION.*	50	121
9	G06K	*PHYSICS || RECOGNITION OF DATA; PRESENTATION OF DATA; RECORD CARRIERS; HANDLING RECORD CARRIERS.*	46	142
10	G06Q	*PHYSICS || DATA PROCESSING SYSTEMS OR METHODS.*	44	134
11	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL.*	41	133

Table 25. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

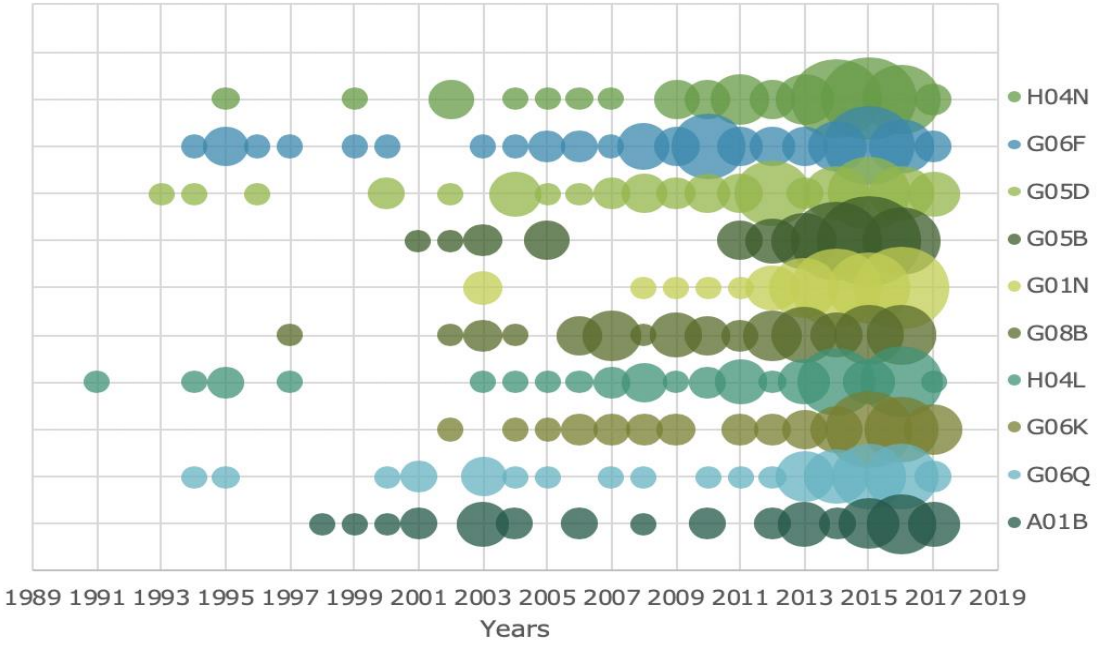

Figure 74. Evolution in time of main IPC classes

Class G05B and G01N, referred respectively to controlling, monitoring and regulating systems and investigating or analysing materials, show the highest rates of growth.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

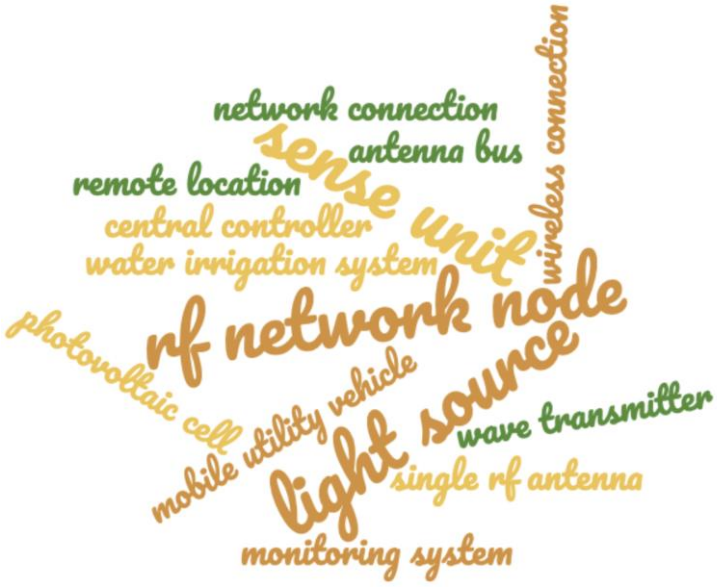

Figure 75. Tag cloud 2000-2010

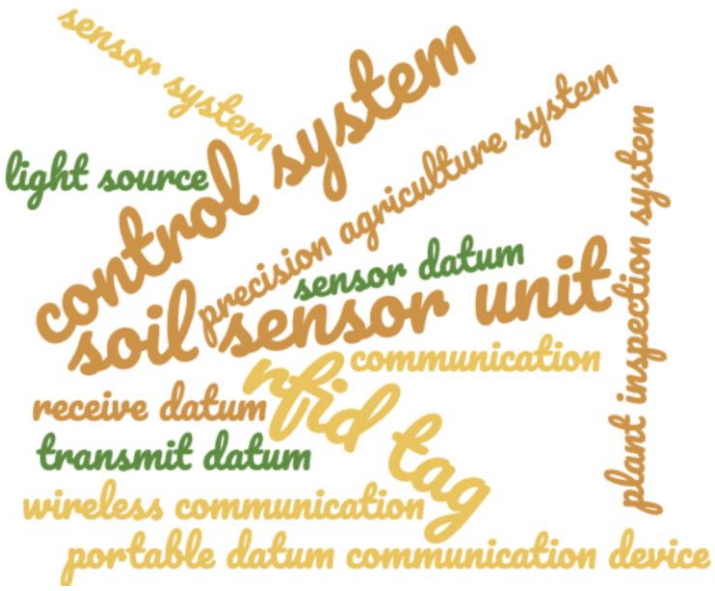

Figure 76. Tag cloud 2011-2018

In accordance with IPC classes' bubble chart, the tag clouds show expressions, among the others, related to control systems and sensors.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	#Patent families	# Patents	%Patent families
1	John Deere	25	110	4,5
2	Cnh	12	50	2,2
3	Skydrop	9	48	1,6
4	Tego	9	35	1,6
5	Philips Electronics	6	27	1,1
6	The Climate Corporation	6	27	1,1
7	Trimble Navigation	6	12	1,1
8	Agco	6	11	1,1
9	Aqua Conservation System	6	8	1,1
10	Lindsay Corporation	5	21	0,9
11	The United States of America As Represented By The Secretary Of Agriculture	4	5	0,7
12	Appareo Systems	4	17	0,7
13	Rain Bird Corporation	4	20	0,7
14	Ibm	4	9	0,7
15	Precision Planting	4	17	0,7

Table 26. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Romney Matt	9	37
2	Endrizzi Clark	9	48
3	Mats Leonid	9	35
4	Puleston David	8	28
5	Butler Timothy P	7	29
6	Addink Sylvan	7	8
7	Anderson Noel Wane	6	22
8	Hamlin Robert W	6	20
9	Moore Larry	5	18
10	Beckhardt Steve	5	18

Table 27. Top inventors

6.3.2. SCIENTIFIC LITERATURE ANALYSIS

Temporal distribution

The set of papers about data transfer is composed by 365 documents. In the following section, the statistical analysis of said documents is disclosed.

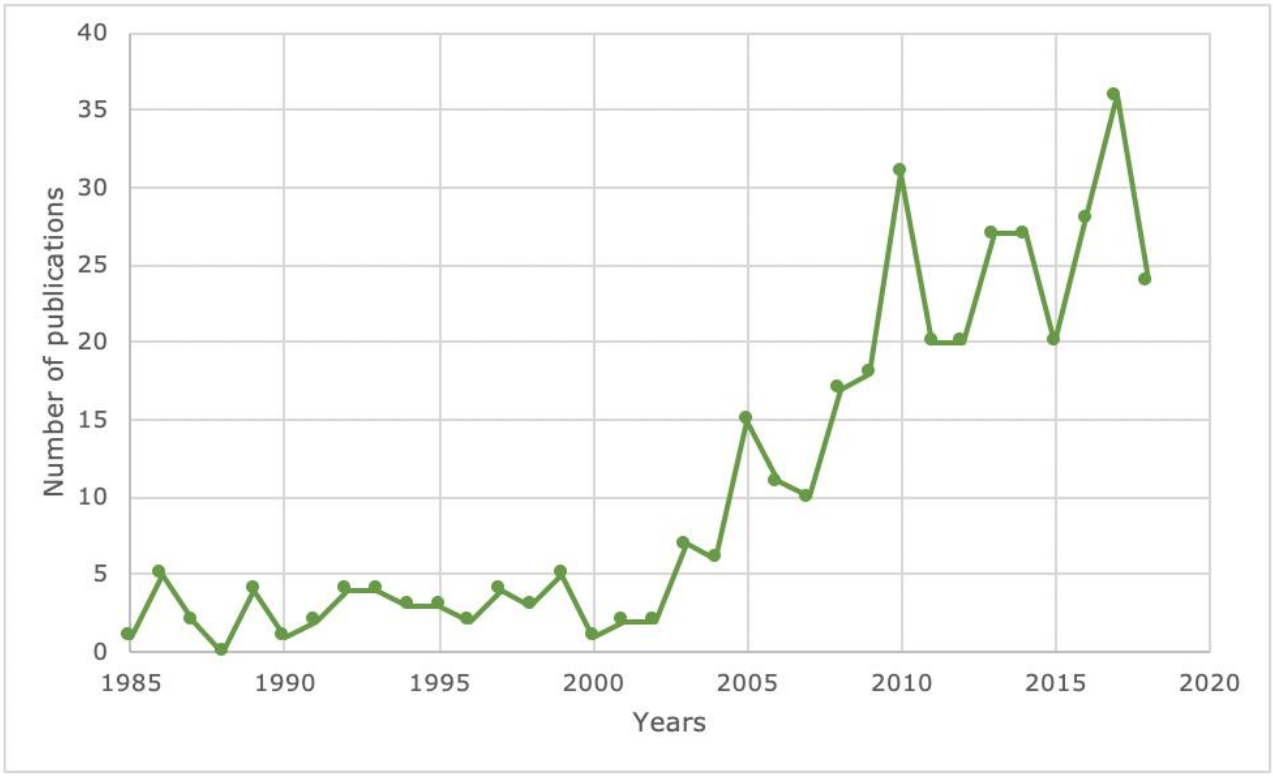

Figure 77. Distribution of the scientific literature according to publication dates

In accordance to the patent analysis' trend, the graph shows a growing technological field.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

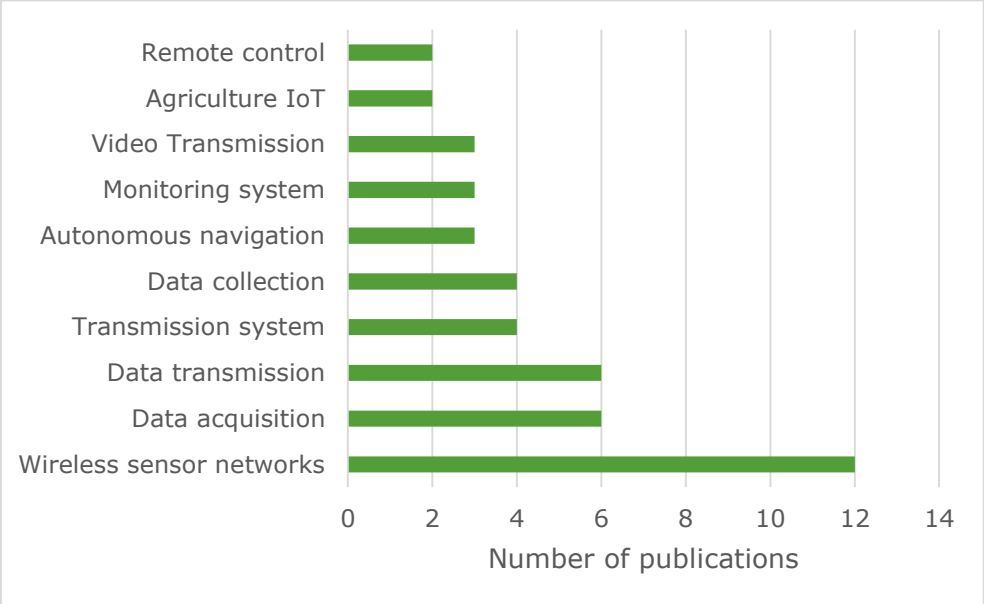

Figure 78. Papers' tags histogram

Figure 79. Papers' tag cloud

The main significant expressions are referred to sensor systems (wireless sensor networks, data acquisition, data collection) and control systems (autonomous navigation, monitoring systems, remote control).

Involved subjects

The next two figures show the main authors and main authors' affiliation for the analysed documents.

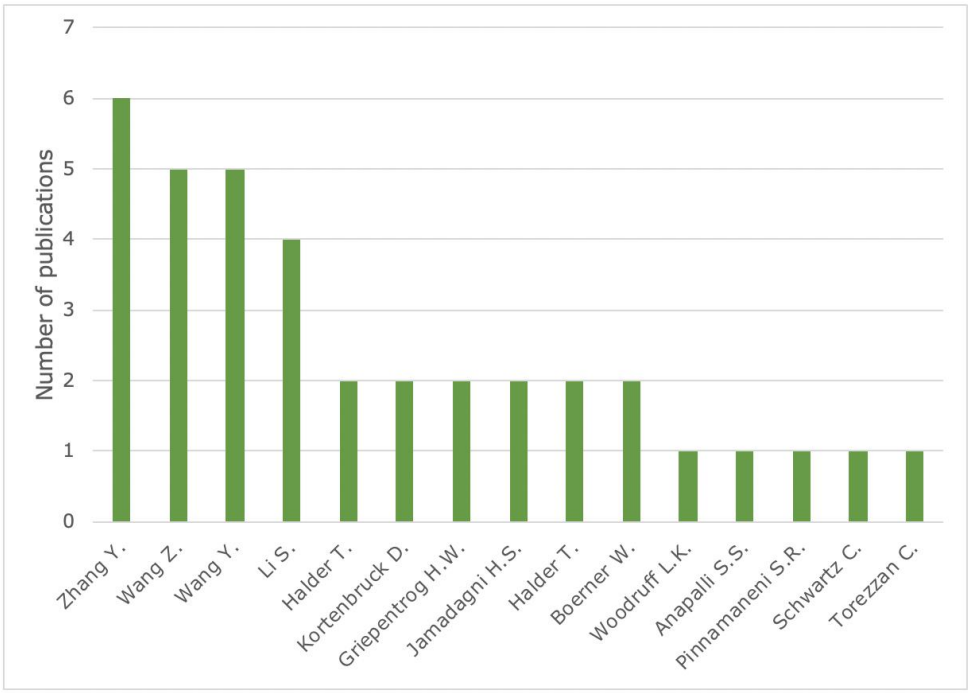

Figure 80. Top 15 authors

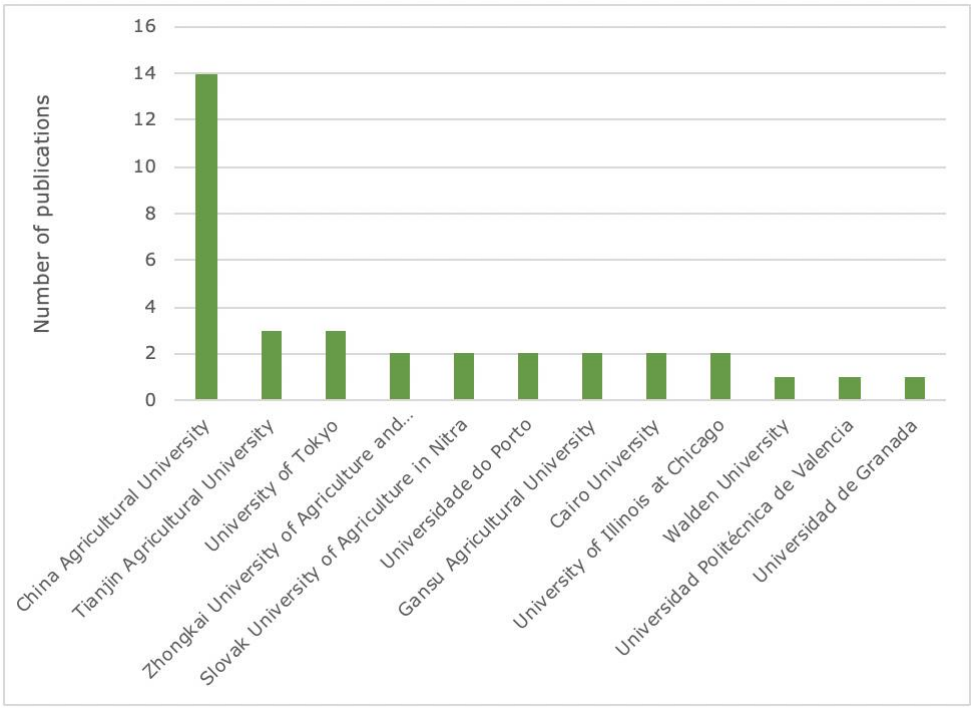

Figure 81. Top affiliations

Most affiliations are in Chinese Universities.

6.4. HARVESTING AND MANIPULATION

In this section, the technological cluster relating to harvesting and manipulation is analysed. The cluster gathers documents in which the main object concerns to systems for harvesting and manipulation of the crop, such as automatic systems and robots. In the next paragraphs, analyses on patents and papers are respectively disclosed.

6.4.1. PATENT ANALYSIS

The patent set on harvesting and manipulation is composed by 7439 patents belonging to 2250 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

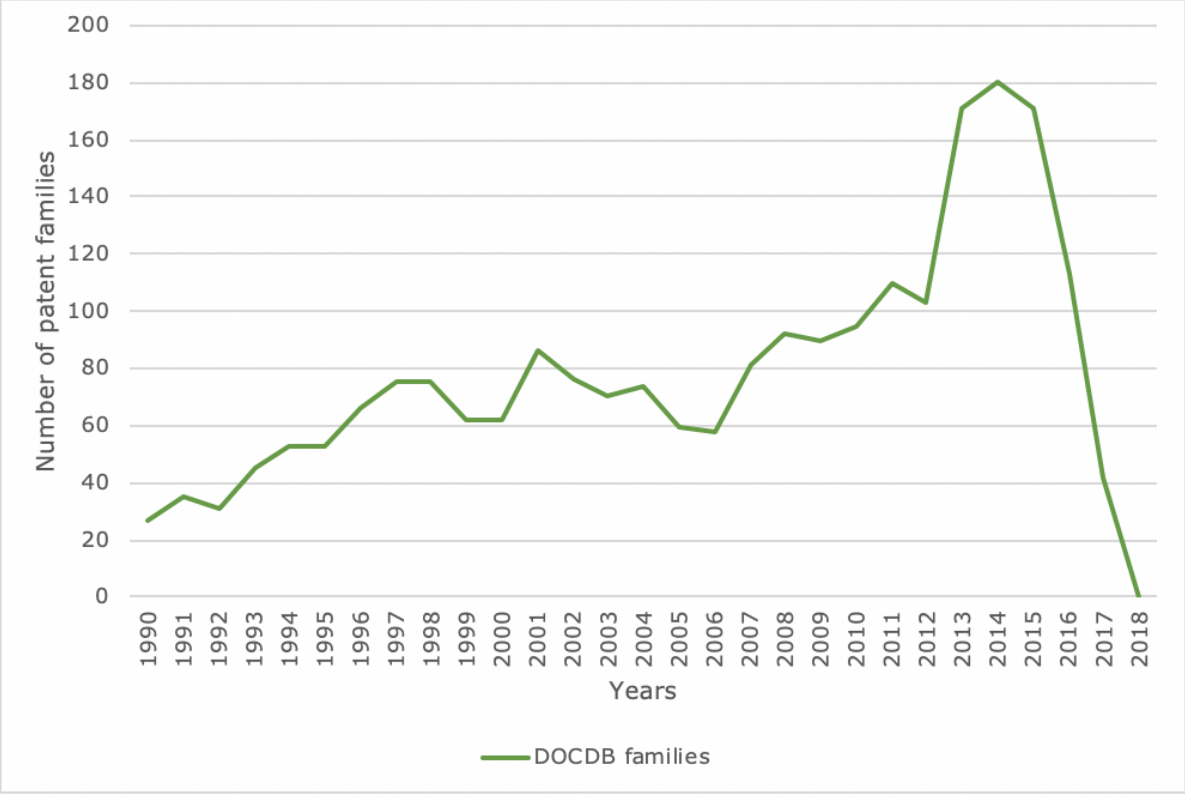

Figure 82. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The increasing trend, in combination with the significant number of filings per year, suggests that harvesting and manipulation in arable crops is a **growing technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

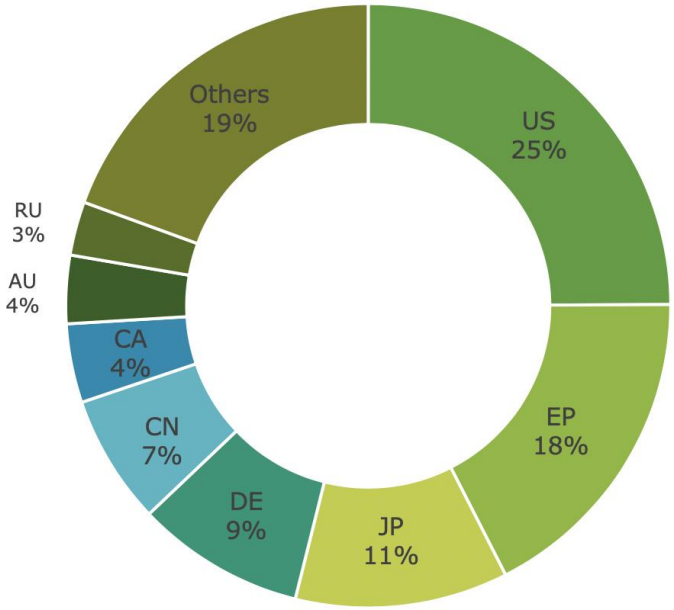

Figure 83. Percentage distribution of patents in the patent offices

The main three filing countries are American, European and Japanese. Also Germany and China hold high percentages.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.
In the following table, some rows highlighted in light green have been omitted from the subsequent bubble chart. The classes in said rows are expected and scarcely relevant since they are related to collection, handling and storage of crops: functions that every traditional harvesting system owns. In addition, their scale is an order of magnitude greater than the other classes; hence, their presence in the bubble chart would flatten the signal of the subsequent relevant classes.

#	IPC Class	Class description	# Patent families	# Patents
1	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING.*	2095	7022
2	A01F	*HUMAN NECESSITIES || THRESHING; BALING OF STRAW, HAY OR THE LIKE; STATIONARY APPARATUS OR HAND TOOLS FOR FORMING OR BINDING STRAW, HAY OR THE LIKE INTO BUNDLES; CUTTING OF STRAW, HAY OR THE LIKE; STORING AGRICULTURAL OR HORTICULTURAL PRODUCE*	752	2288
3	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL.*	244	700
4	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING.*	211	557
5	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING.*	104	220
6	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES.*	93	295
7	B25J	*PERFORMING OPERATIONS; TRANSPORTING || MANIPULATORS; CHAMBERS PROVIDED WITH MANIPULATION DEVICES.*	74	199
8	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES.*	68	229
9	G05B	*PHYSICS || CONTROL OR REGULATING SYSTEMS IN GENERAL; FUNCTIONAL ELEMENTS OF SUCH SYSTEMS; MONITORING OR TESTING ARRANGEMENTS FOR SUCH SYSTEMS OR ELEMENTS.*	55	154
10	G01F	*PHYSICS || MEASURING VOLUME, VOLUME FLOW, MASS FLOW, OR LIQUID LEVEL; METERING BY VOLUME*	52	138
11	B65G	*PERFORMING OPERATIONS; TRANSPORTING || TRANSPORT OR STORAGE DEVICES, E.G. CONVEYORS FOR LOADING OR TIPPING, SHOP CONVEYOR SYSTEMS OR PNEUMATIC TUBE CONVEYORS*	46	141
12	A01C	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING.*	45	113

Table 28. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

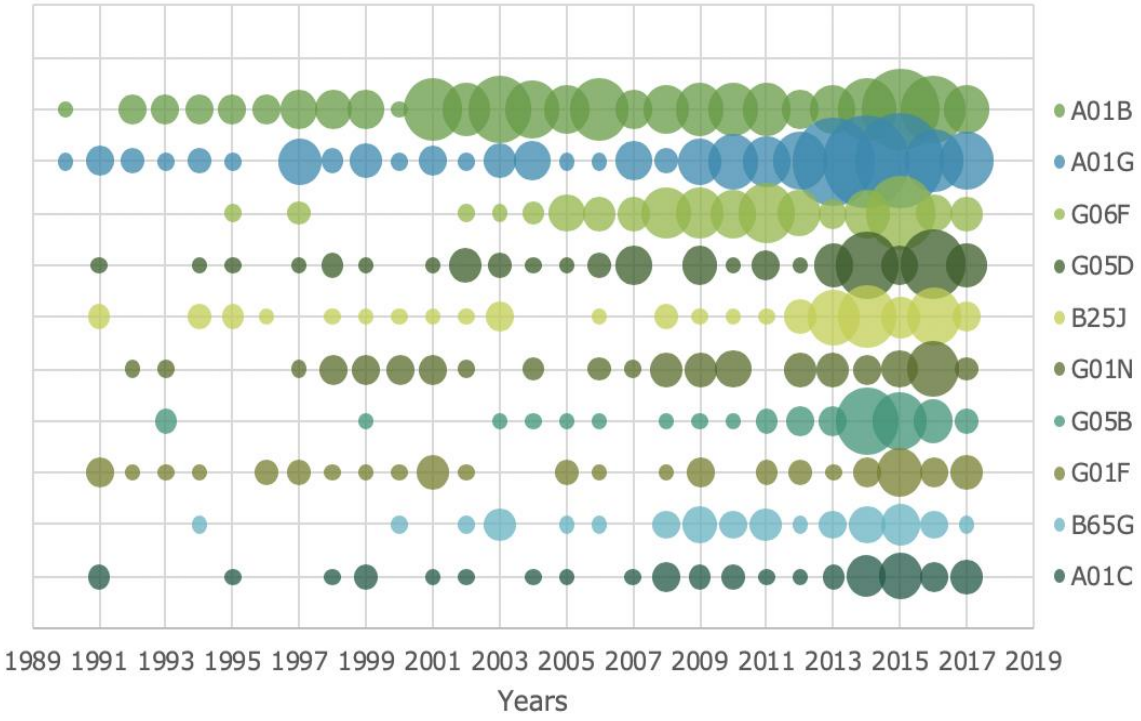

Figure 84. Evolution in time of main IPC classes

A01G is a very general class about agriculture; hence, its presence is expected for each analysed cluster. Among the main classes, G06F, related to data processing, is active since early 2000s and with a spike in 2015. Furthermore, the most growing classes are related to control of systems (G05D and G05B) and manipulators (B25J).

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

Figure 85. Tag cloud 2000-2010

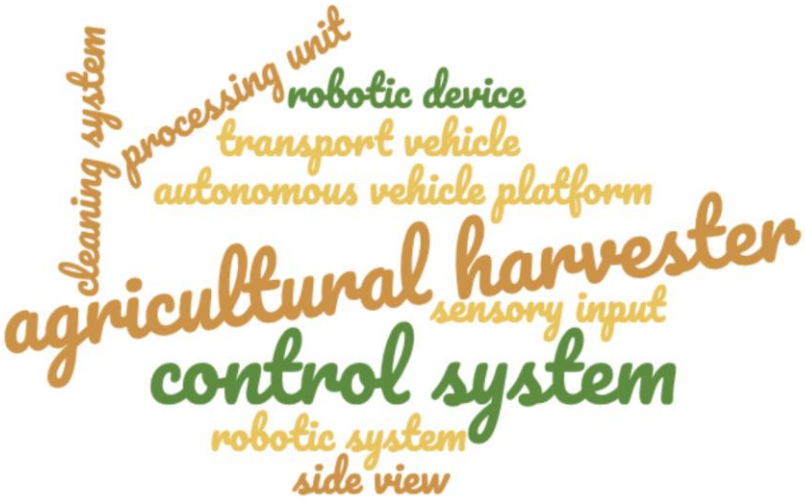

Figure 86. Tag cloud 2011-2018

In the years, the terminological focus has been switching from vehicles/machines to automation and robotics.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# Patent families	# Patents	% Patent families
1	John Deere	247	1592	9,3
2	Iseki & Co	235	310	8,9
3	Cnh	201	886	7,6
4	Yanmar Company	165	286	6,2
5	Kubota Corporation	134	245	5,1
6	Claas Selbstfahrende	129	779	4,9
7	Mitsubishi Agricultural	74	97	2,8
8	Agco	56	275	2,1
9	Case Corporation	40	70	1,5
10	Seirei Ind Corporation	37	54	1,4
11	Jiangsu University	32	49	1,2
12	Sperry Corporation	27	83	1
13	Husqvarna	21	84	0,8
14	Fmca Corporation	11	45	0,4
15	Quingdao Agricultural University	8	11	0,1

Table 29. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Missotten Bart M A	42	163
2	Matsuzawa Hiroki	36	38
3	Takahara Kazuhiro	34	86
4	Yoshimura Fumio	32	41
5	Diekhans Norbert	27	148
6	Li Yaoming	26	39
7	Hirayama Hidetaka	25	36
8	Behnke Willi	23	128
9	Nakagawa Wataru	22	34
10	Yamagata Koji	21	33

Table 30. Top inventors

6.4.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about harvesting and manipulation is composed by 113 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

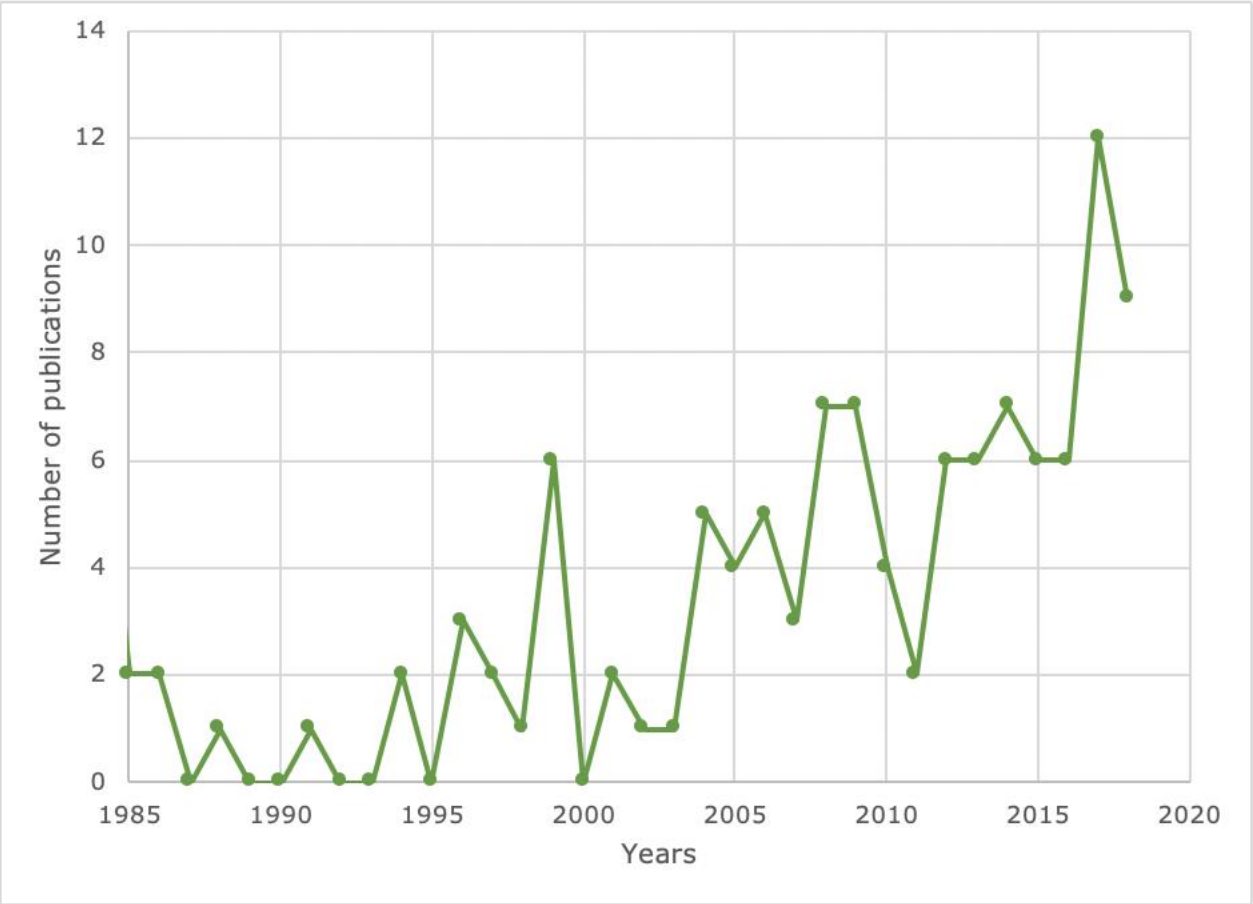

Figure 87. Distribution of the scientific literature according to publication dates

The small number of publications per year does not allow a reliable statistical interpretation of the tendency.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

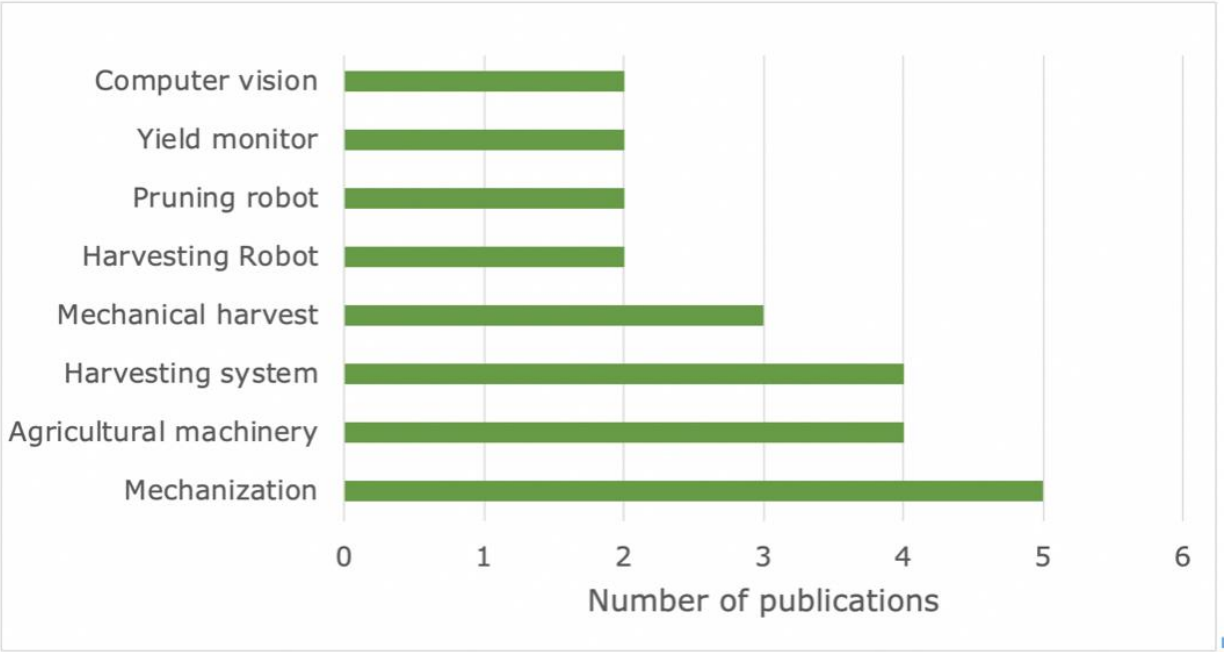

Figure 88. Papers' tags histogram

Figure 89. Papers' tag cloud

Many tags are about mechanization and robotics.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

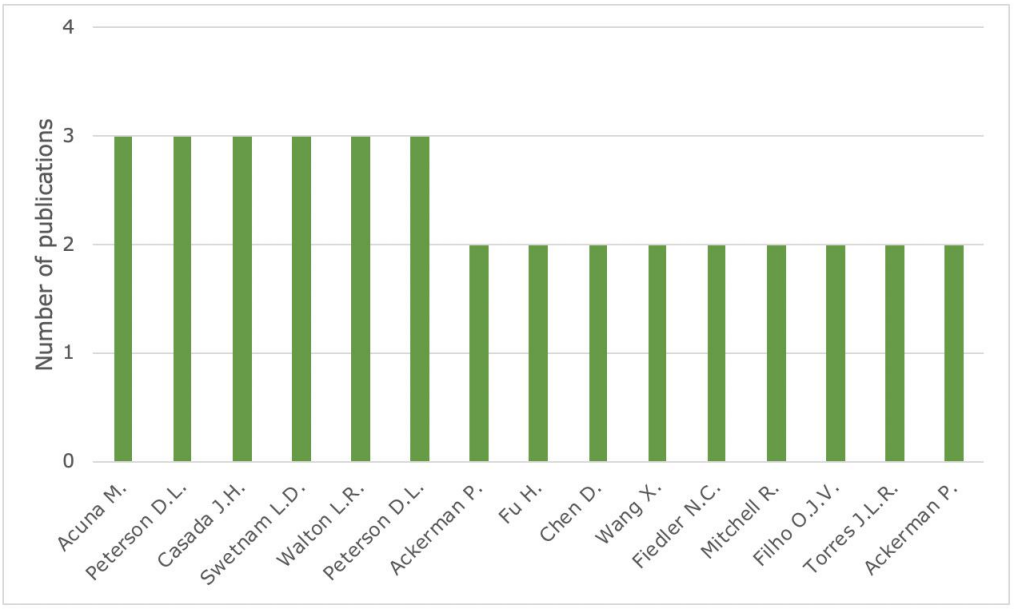

Figure 90. Top 15 authors

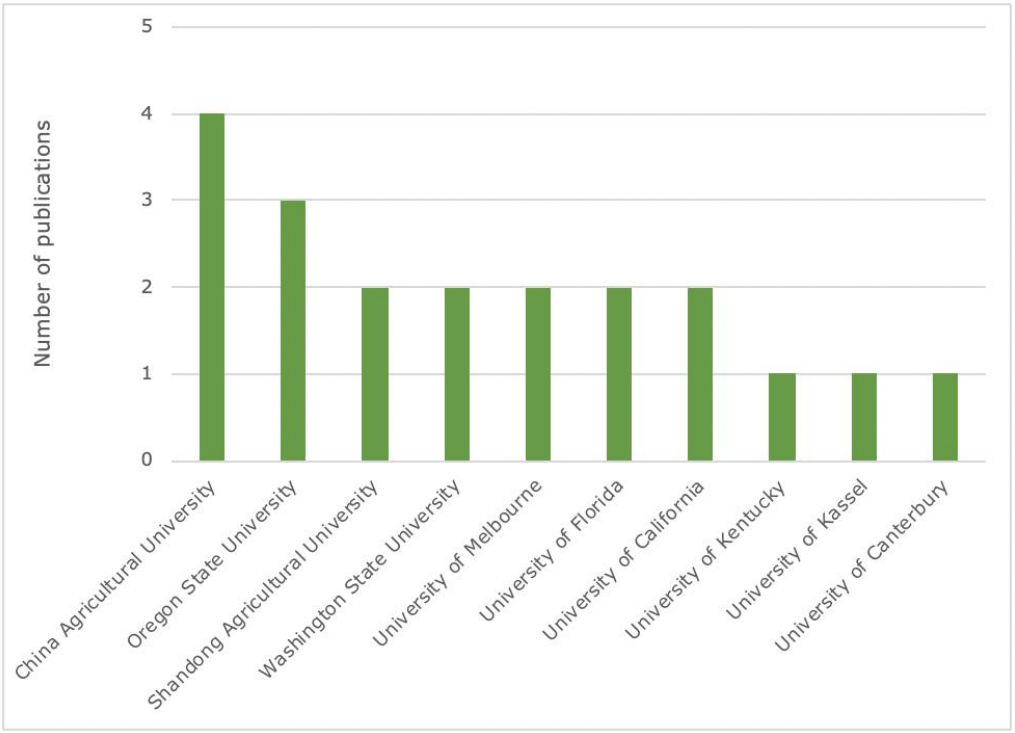

Figure 91. Top affiliations

Most affiliations are in Chinese, American and Australian Universities.

6.5. PLANTING AND SOIL WORKING

In this section, the technological cluster relating to planting and soil working is analysed. The cluster gathers documents in which the main object concerns to systems having functions of supporting each agricultural operation prior to the seeding and seeding itself. In the next paragraphs, analyses on patents and papers are respectively disclosed.

6.5.1. PATENT ANALYSIS

The patent set on harvesting and manipulation is composed by 4537 patents belonging to 1963 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

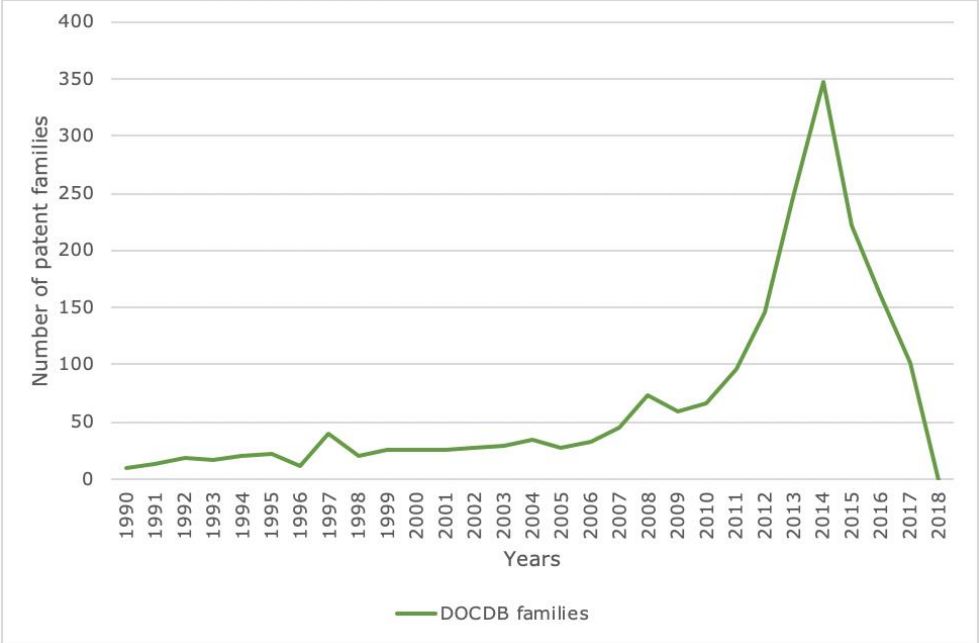

Figure 92. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The strongly increasing trend, in combination with the significant number of filings per year, suggests that planting and soil working in arable crops is a **growing technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

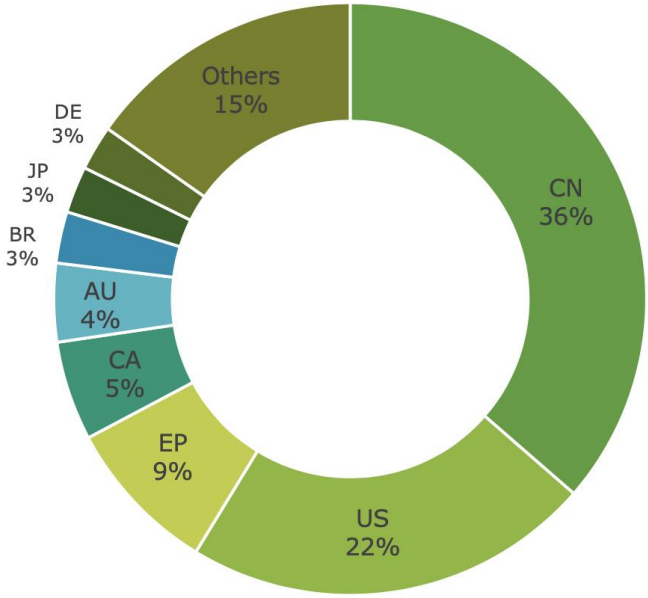

Figure 93. Percentage distribution of patents in the patent offices

Patents are firstly concentrated in China and consequently in US and EP jurisdictions.

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.
In the following table, some rows highlighted in light green have been omitted from the subsequent bubble chart. The classes in said rows are expected and scarcely relevant. In addition, their scale is an order of magnitude greater than the other classes; hence, their presence in the bubble chart would flatten the signal of the subsequent relevant classes.

#	IPC Class	Class description	# Patent families	# Patents
1	A01C	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING.*	1308	3513
2	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING.*	1119	1793
3	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL.*	301	784

#	IPC Class	Class description	# Patent families	# Patents
4	A01M	*HUMAN NECESSITIES || CATCHING, TRAPPING OR SCARING OF ANIMALS; APPARATUS FOR THE DESTRUCTION OF NOXIOUS ANIMALS OR NOXIOUS PLANTS*	42	96
5	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING.*	35	105
6	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING.*	31	53
7	A01H	*HUMAN NECESSITIES || NEW PLANTS OR PROCESSES FOR OBTAINING THEM; PLANT REPRODUCTION BY TISSUE CULTURE TECHNIQUES.*	29	81
8	B65G	*PERFORMING OPERATIONS; TRANSPORTING || TRANSPORT OR STORAGE DEVICES, E.G. CONVEYORS FOR LOADING OR TIPPING, SHOP CONVEYOR SYSTEMS OR PNEUMATIC TUBE CONVEYORS.*	19	48
9	G05B	*PHYSICS || CONTROL OR REGULATING SYSTEMS IN GENERAL; FUNCTIONAL ELEMENTS OF SUCH SYSTEMS; MONITORING OR TESTING ARRANGEMENTS FOR SUCH SYSTEMS OR ELEMENTS.*	19	34
10	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES.*	17	45
11	B05B	*PERFORMING OPERATIONS; TRANSPORTING || SPRAYING APPARATUS; ATOMISING APPARATUS; NOZZLES.*	15	51
12	G06Q	*PHYSICS || DATA PROCESSING SYSTEMS OR METHODS.*	14	42
13	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES.*	13	28

Table 31. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

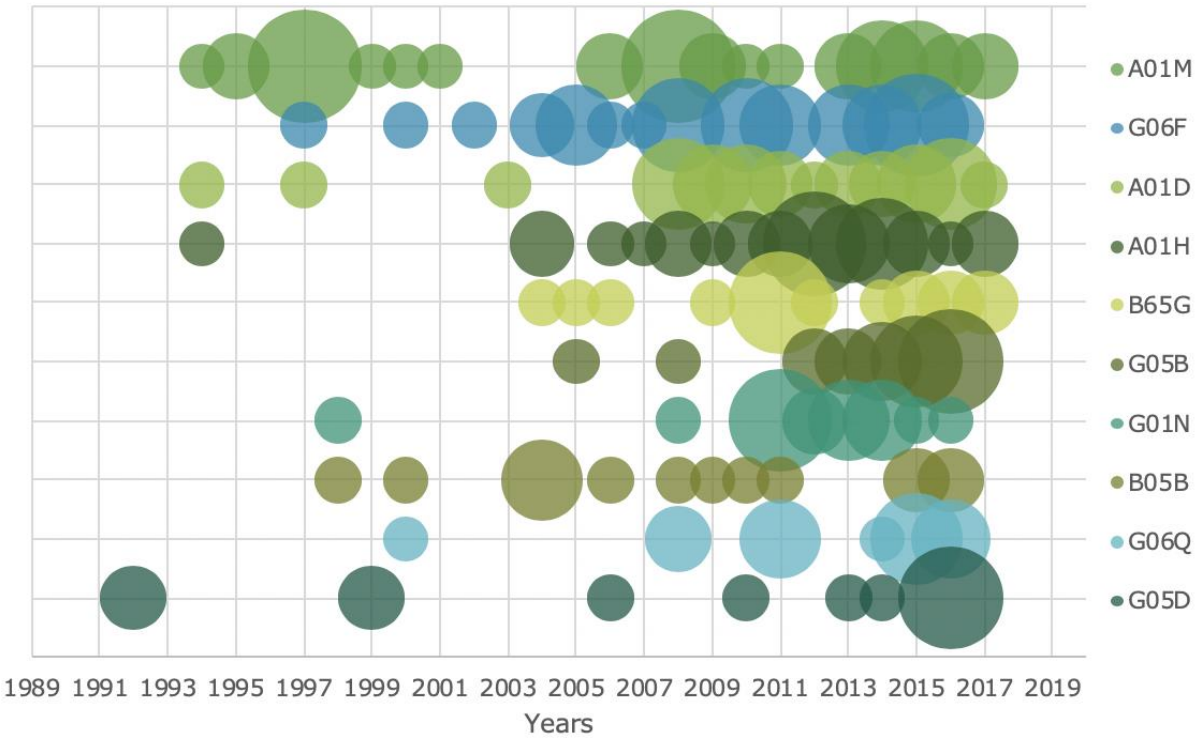

Figure 94. Evolution in time of main IPC classes

The most growing classes are related to control systems (G05B and G05D).

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

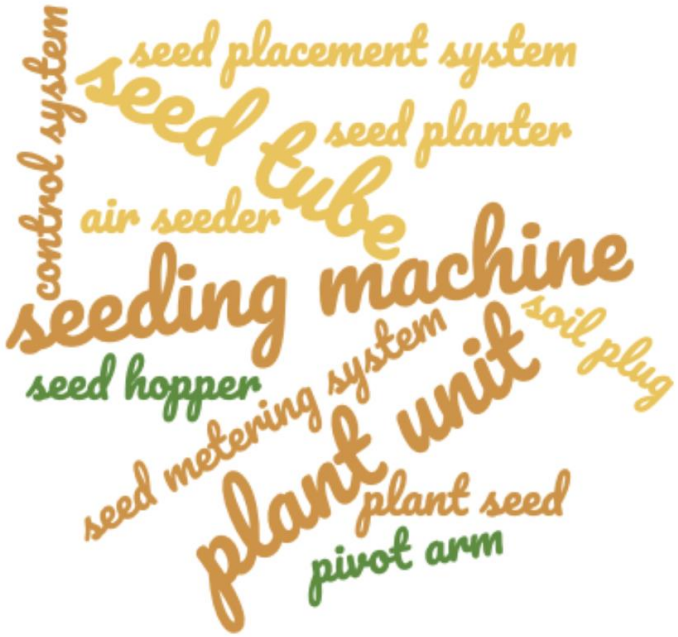

Figure 95. Tag cloud 2000-2010

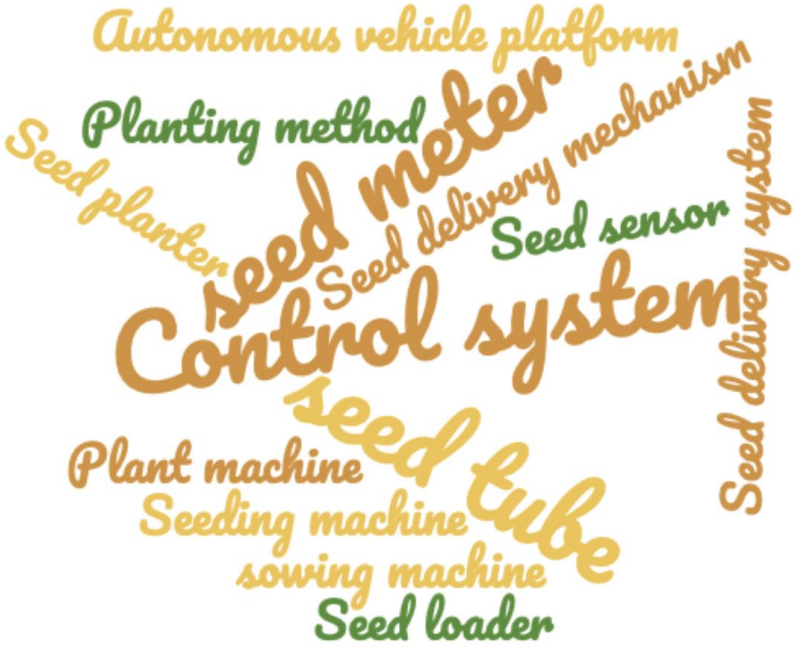

Figure 96. Tag cloud 2011-2018

In both the clouds several expressions referred to seeding systems are present. In the second figure references to automation and control appear.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# Patent families	# Patents	% Patent families
1	John Deere	59	442	2,8
2	China Agricultural University	28	43	1,3
3	Cnh	27	154	1,3
4	Precision Planting	22	114	1
5	Huazhong Agricultural University	20	25	0,9
6	Case Corporation	17	46	0,8
7	Gansu Agricultural University	16	21	0,8
8	Iseki & Co	16	28	0,8
9	Chinese Academy of Science	15	27	0,8
10	Kinze Manufacturing	13	107	0,6
11	Yanmar Company	12	19	0,6
12	Dir Ehnd Kompani	11	21	0,5
13	Amazonen Werke H Dreyer & Company	8	19	0,4
14	Vaederstad Verken	8	37	0,4
15	Flexi Coil	6	16	0,3

Table 32. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patent families	# Patents
1	Huang Haidong	15	19
2	Liao Qingxi	14	18
3	Garner Elija B	13	40
4	Tian Boping	11	14
5	Shu Caixia	11	14
6	Duan Hongbing	10	12
7	Zhang Dongxing	9	15
8	Shi Song	9	14
9	Cui Tao	9	15
10	Wendthe Keith W	8	34

Table 33. Top Inventors

6.5.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about planting and soil working is composed by 1186 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

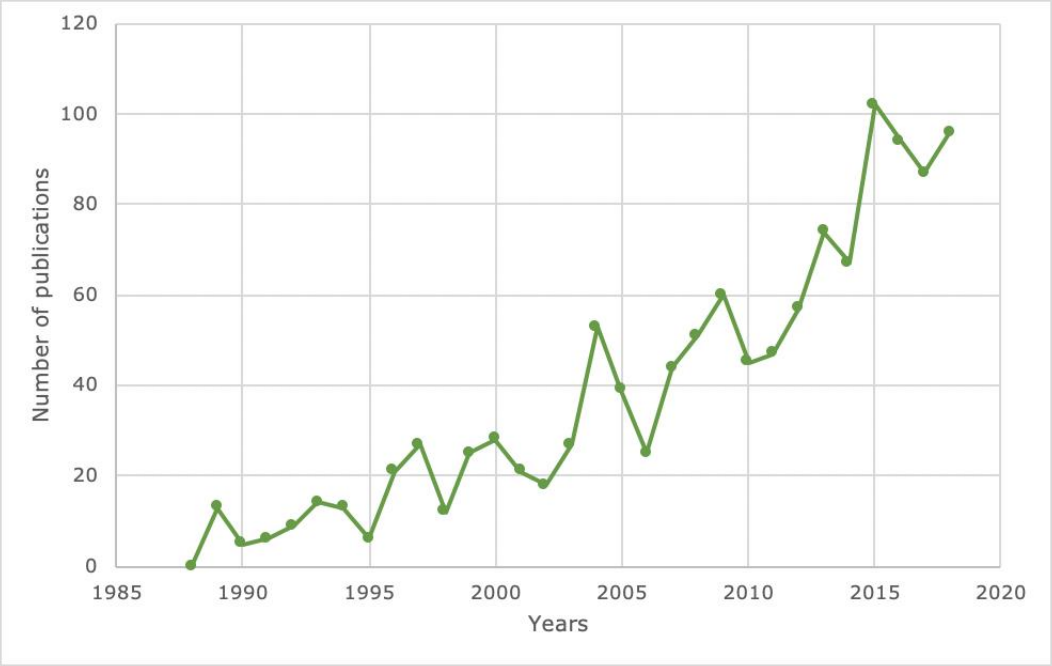

Figure 97. Distribution of the scientific literature according to publication dates

In accordance to the patent analysis' trend, the graph shows a growing technological field.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

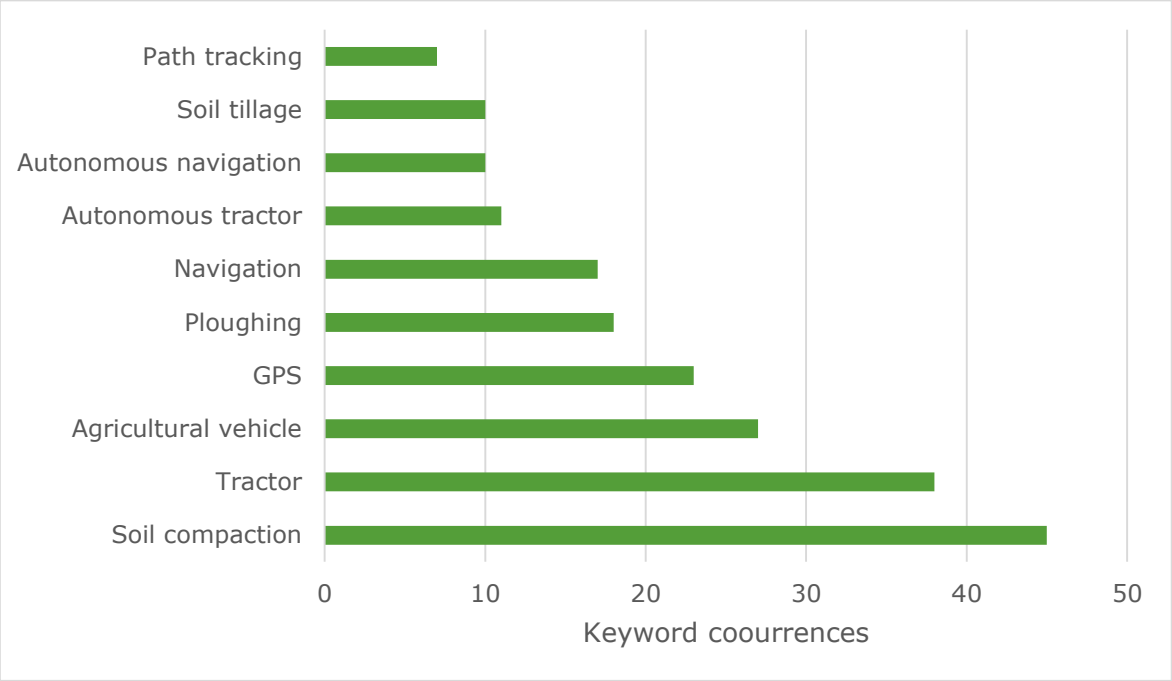

Figure 98. Papers' tags histogram

Figure 99. Papers' tag cloud

Most of the tags are referred to automation and navigation.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

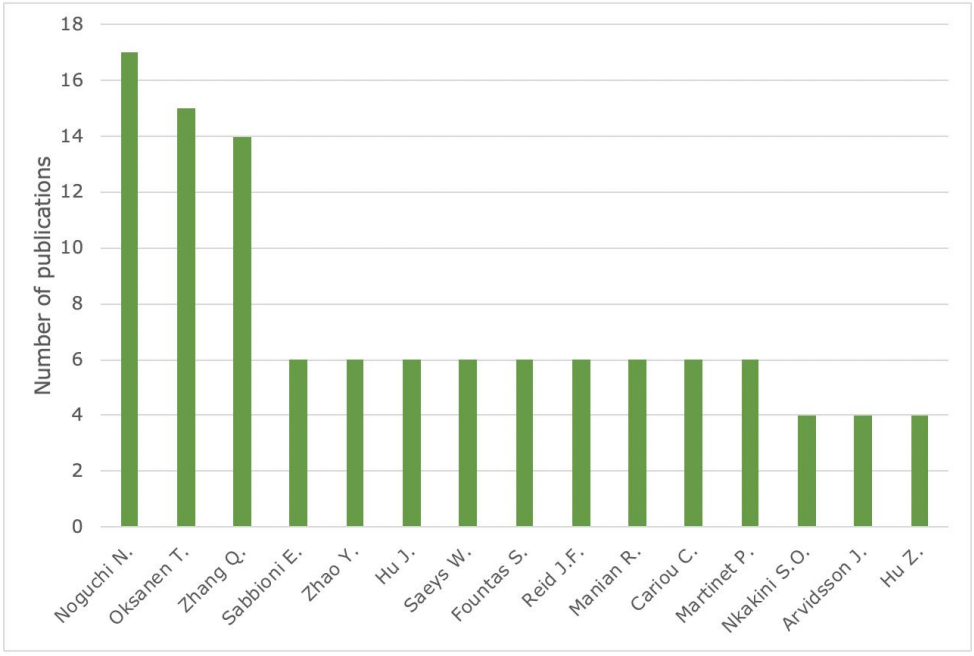

Figure 100. Top 15 authors

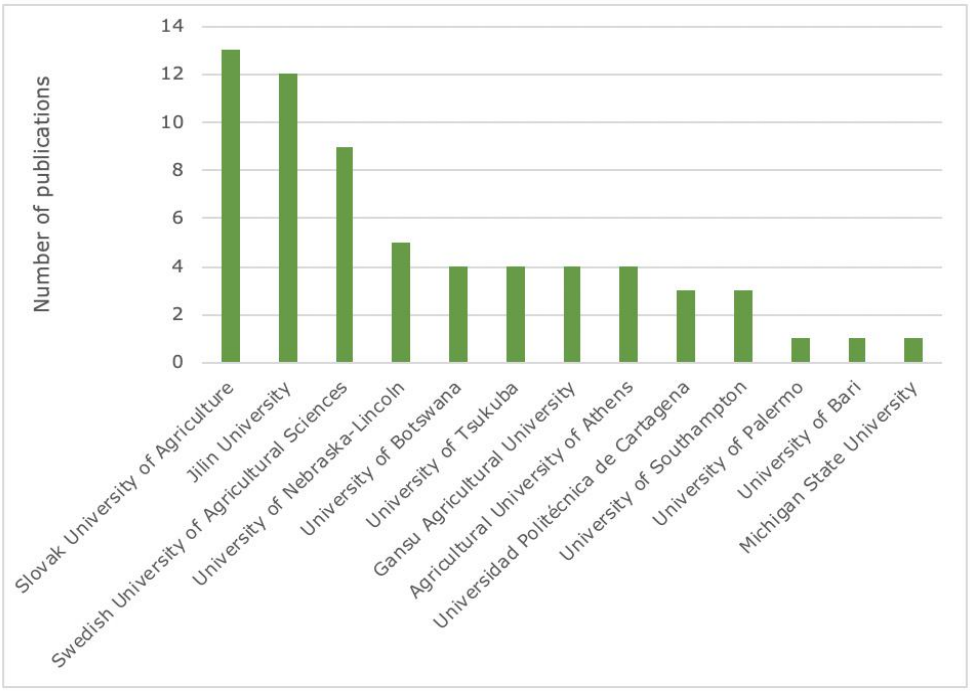

Figure 101. Top affiliations

The affiliations are spread in all the continents, with a prevalence of European Universities.

6.6. AGRICULTURAL VEHICLES

In this section, the technological cluster relating to agricultural vehicle is analysed. The cluster gathers documents in which the main object concerns to vehicles and related accessories or subsystems aimed to support every step of agricultural process. In the next paragraphs, analyses on patents and papers are respectively disclosed.

6.6.1. PATENT ANALYSIS

The patent set on agricultural vehicle is composed by 2750 patents belonging to 640 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

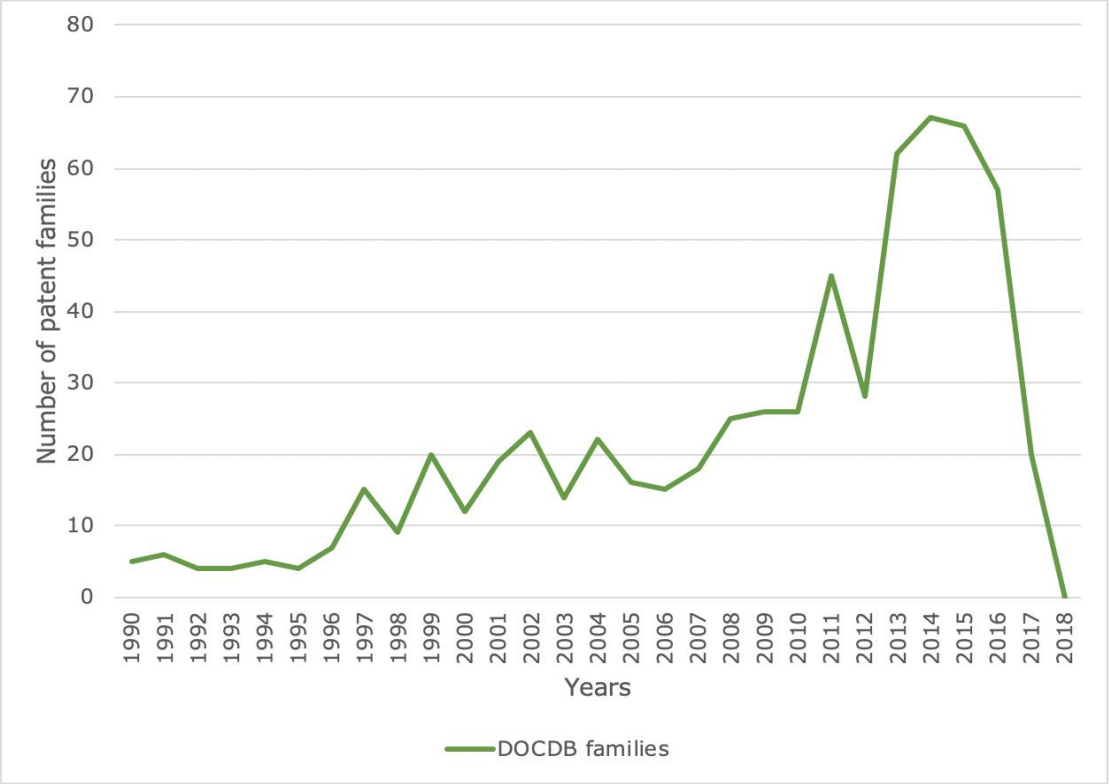

Figure 102. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The increasing trend, in combination with the little number of filings per year, suggests that agricultural vehicles for arable crops is an **emerging technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

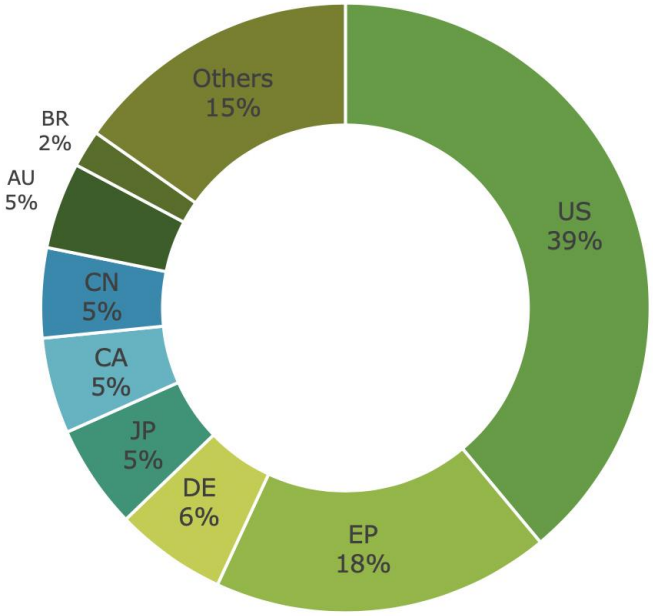

Figure 103. Percentage distribution of patents in the patent offices

The American jurisdiction gathers by far the majority of patents. Consequently, the graph shows European, German and Japanese Patent Offices.

PC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.

#	IPC Class	Class description	# Patent families	# Patents
1	B62D	*PERFORMING OPERATIONS; TRANSPORTING || MOTOR VEHICLES; TRAILERS.*	186	700
2	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING.*	173	585
3	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL.*	169	547
4	A01D	*HUMAN NECESSITIES || HARVESTING; MOWING.*	145	584

#	IPC Class	Class description	# Patent families	# Patents
5	B60K	*PERFORMING OPERATIONS; TRANSPORTING || ARRANGEMENT OR MOUNTING OF PROPULSION UNITS OR OF TRANSMISSIONS IN VEHICLES; ARRANGEMENT OR MOUNTING OF PLURAL DIVERSE PRIME-MOVERS IN VEHICLES; AUXILIARY DRIVES FOR VEHICLES; INSTRUMENTATION OR DASHBOARDS FOR VEHICLES; ARRANGEMENTS IN CONNECTION WITH COOLING, AIR INTAKE, GAS EXHAUST OR FUEL SUPPLY OF PROPULSION UNITS IN VEHICLES.*	99	441
6	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES.*	92	386
7	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING.*	69	164
8	B64C	*PERFORMING OPERATIONS; TRANSPORTING || AEROPLANES; HELICOPTERS*	67	156
9	A01C	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING.*	65	179
10	B60R	*PERFORMING OPERATIONS; TRANSPORTING || VEHICLES, VEHICLE FITTINGS, OR VEHICLE PARTS, NOT OTHERWISE PROVIDED FOR.*	60	237

Table 34. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

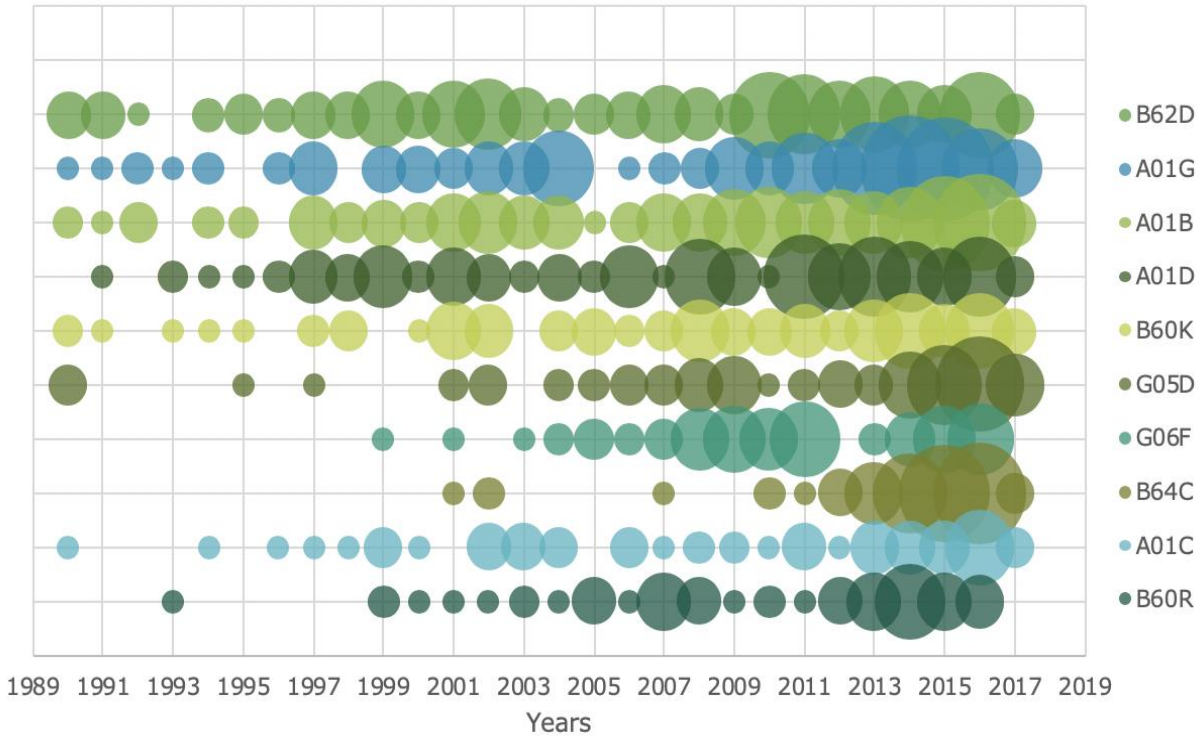

Figure 104. Evolution in time of main IPC classes

The most growing technological classes regard aerial vehicles (B64C) and control systems (G05D). Application classes regards each cultivation step (A01G, A01B, A01D, A01C); among them A01G and A01B display the highest growing rate.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set have been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

Figure 105. Tag cloud 2000-2010

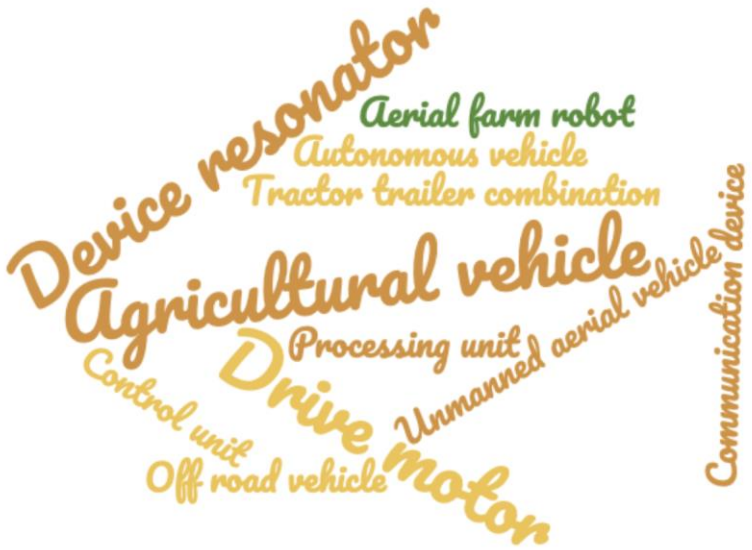

Figure 106. Tag cloud 2011-2018

In the first cloud, the terminology highlights the importance of data processing and control systems. In addition, in the last years the presence of aerial vehicles is remarkable.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# Patent families	# Patents	% Patent families
1	John Deere	69	390	9,7
2	Cnh	57	214	8,1
3	Iseki & Co	21	28	3
4	Claas Selbstfahrende Erntemaschinen	20	103	2,8
5	Kubota Corporation	18	64	2,5
6	Yanmar Company	17	56	2,4
7	Agco	15	56	2,1
8	Witricity Corporation	9	43	1,3
9	Caterpillar	7	115	1
10	Kline & Walker	6	22	0,8
11	Autonomous Solutions	6	17	0,8
12	Husco International	5	15	0,7
13	Trimble Navigation	5	16	0,7
14	Elwa	5	22	0,7
15	Case Corporation	5	8	0,7

Table 35. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# patent families	# Patents
1	Breed David S	13	47
2	Anderson Noel Wayne	10	40
3	Hall Katherine L	9	39
4	Kurs Morris P	9	37
5	Hyde Roderick A	8	27
6	Karalis Aristeidis	8	35
7	Campanella Andrew J	7	32
8	Duvall Wilbur E	6	10
9	Slawson James	6	23
10	Wood Jr Lowell L	6	17

Table 36. Top Inventors

6.6.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about agricultural vehicle is composed by 1095 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

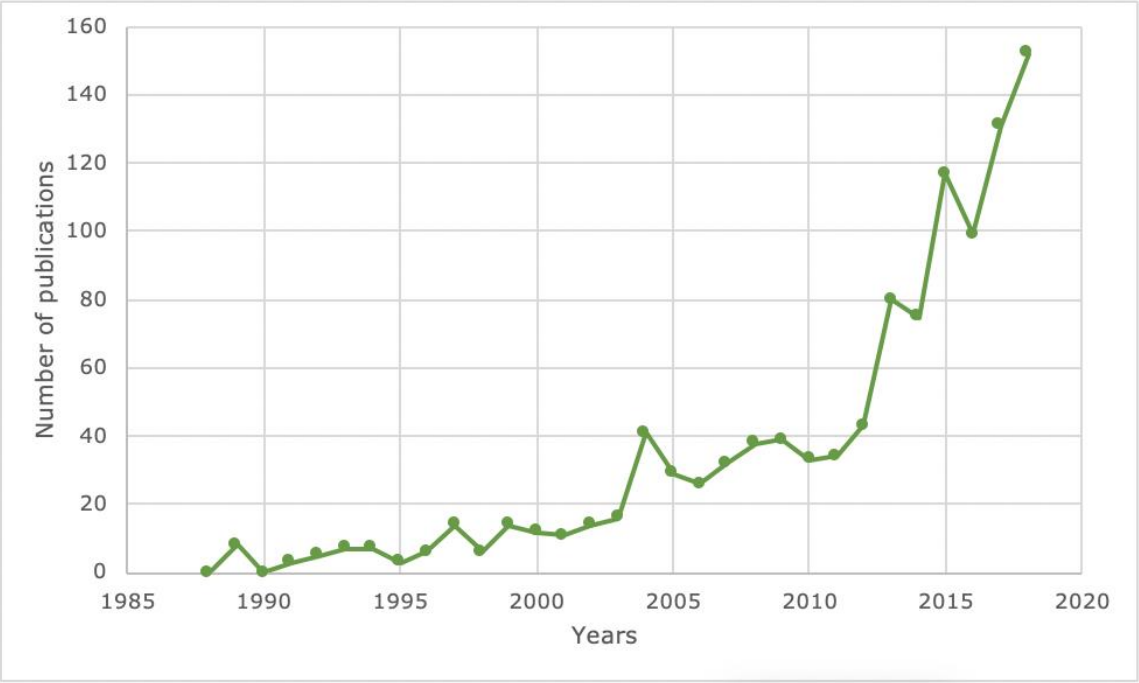

Figure 107. Distribution of the scientific literature according to publication dates

In accordance to the patent analysis' trend, the graph shows a growing technological field.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

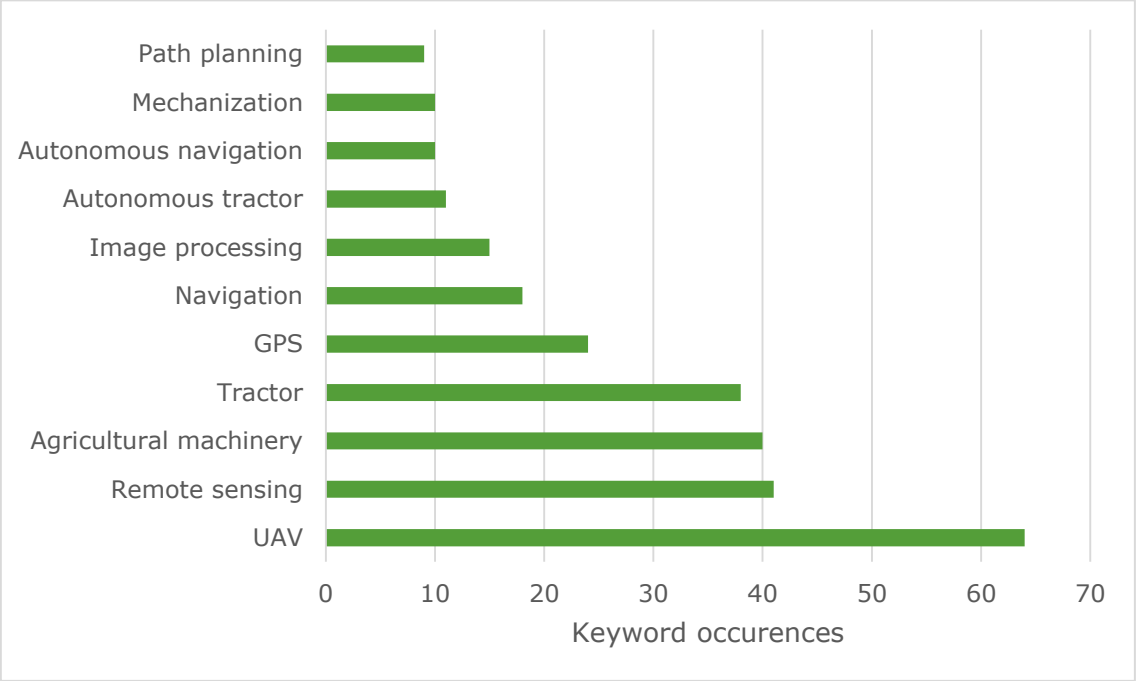

Figure 108. Papers' tags histogram

Figure 109. Papers' tag cloud

In accordance with patents' signals, the primary tag regards unmanned aerial vehicles (UAV); more than 60 publications deal with this topic.

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

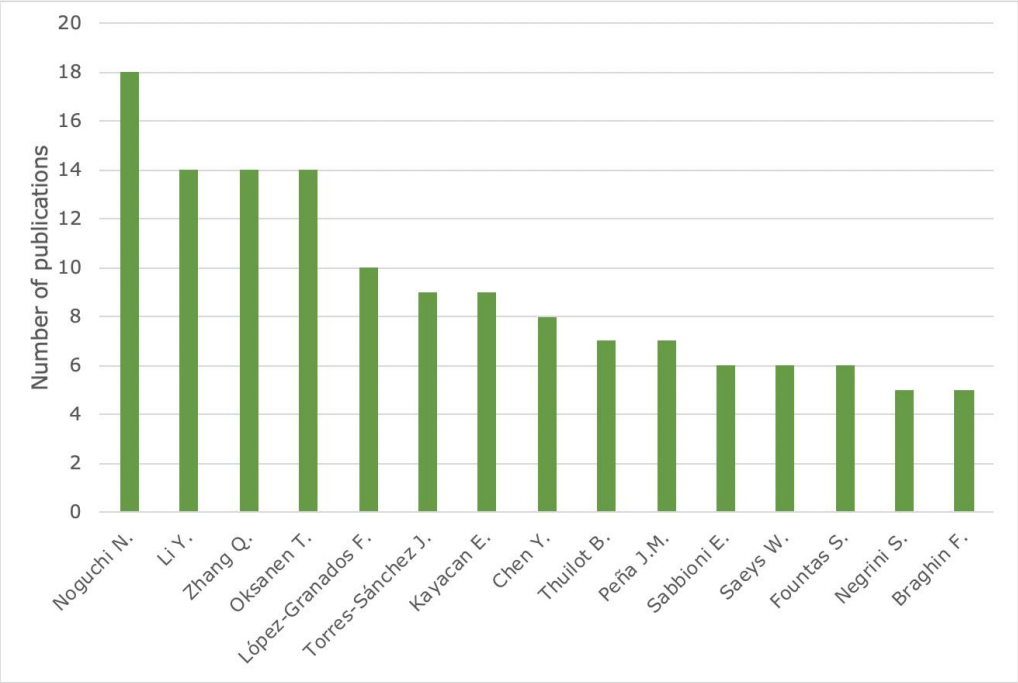

Figure 110. Top 15 authors

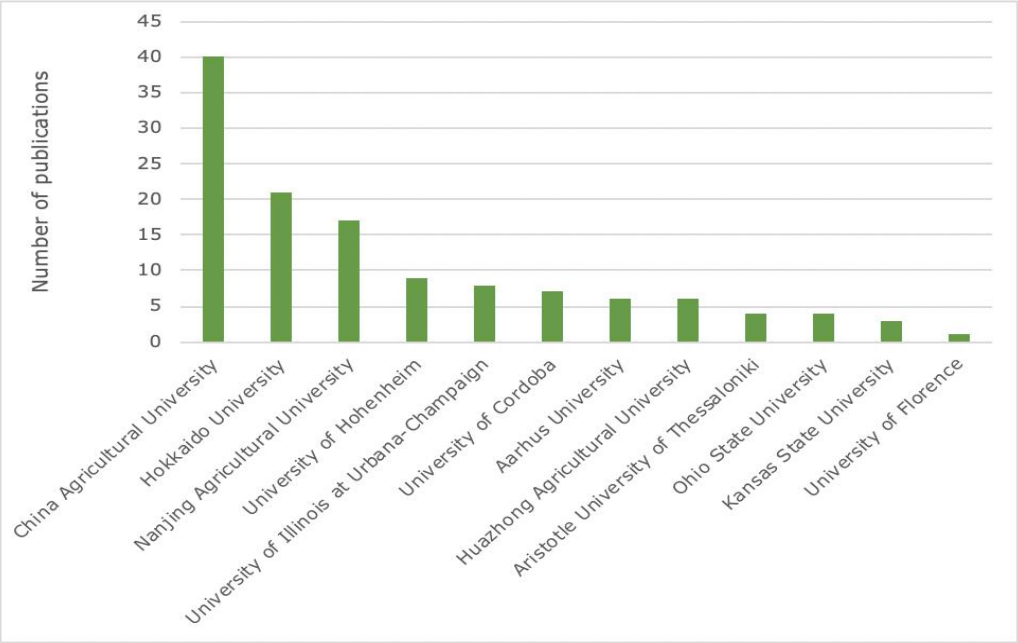

Figure 111. Top affiliations

China is by far the primary source of publications; also, a Japanese University published more than 20 papers. Most of the remaining Universities are European.

6.7. IRRIGATION AND FERTIGATION

In this section, the technological cluster relating to irrigation and fertigation is analysed. The cluster gathers documents in which the main object concerns set refers to systems for spraying of irrigating or fertilizing substances on a field. In the next paragraphs, analyses on patents and papers are respectively disclosed.

6.7.1. PATENT ANALYSIS

The patent set on irrigation and fertigation is composed by 1413 patents belonging to 504 patent families. In the following section, the statistical analysis of said patent set is disclosed.

Temporal distribution

The following graph shows the temporal distribution of the patent families, according to the earliest date of filing within the family.

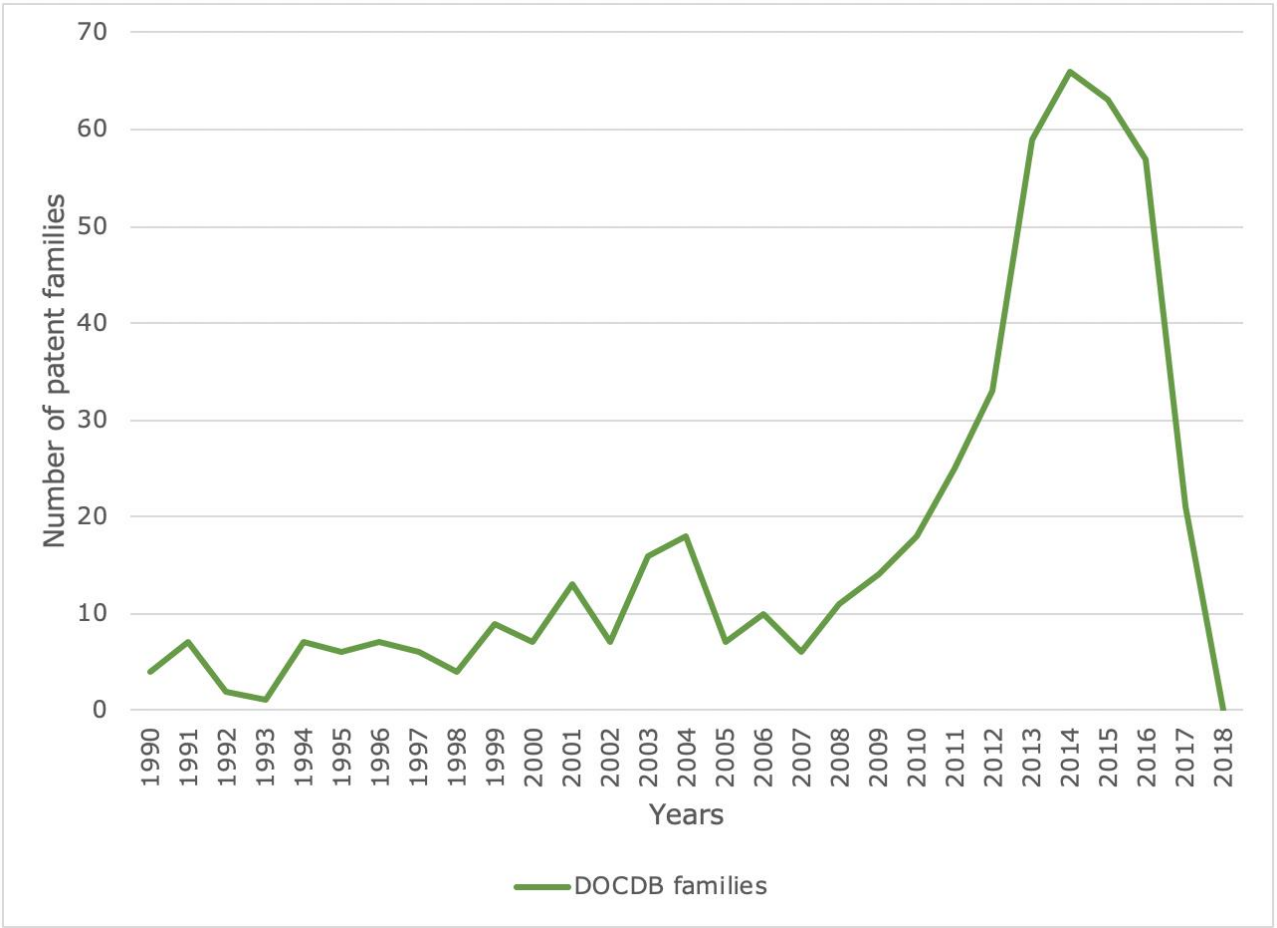

Figure 112. Distribution of the patent families according to filing dates

Note: Due to the patents' 18-month secrecy period, the number of filings in the years 2016 - 2018 could be underestimated and, hence, unreliable.

The graph shows a growing technological field. The increasing trend, in combination with the little number of filings per year, suggests that irrigation and fertigation in arable crops is an **emerging technological field**, according to technology lifecycle theory.

Distribution across patent offices

The next graph introduces the distribution of patents in the different countries' offices.

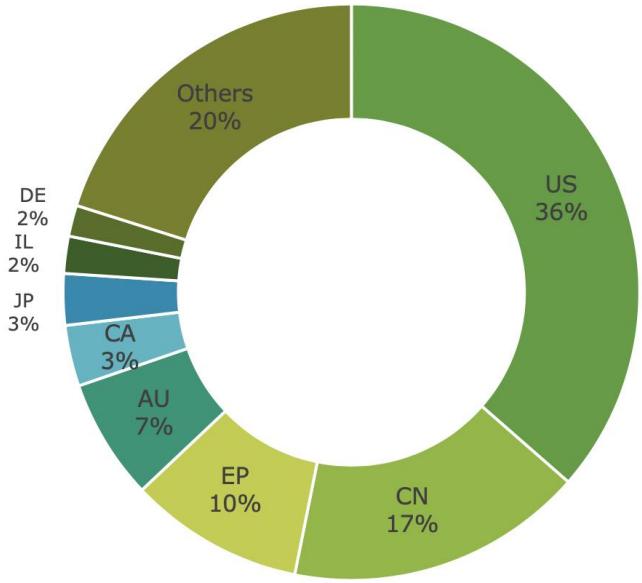

Figure 113. Percentage distribution of patents in the patent offices

USA is the main filing country (US), followed by China (CN), the European jurisdiction (EP) and Australia (AU).

IPC classes

The subsequent table shows the main IPC (International Patent Classification) classes to which the patents belong. In the table, for each IPC class, a description, number of patent families and number of total patents is disclosed.
In the following table, some rows are highlighted in light green; besides being expected and, hence, scarcely relevant, IPC classes contained in said rows have been omitted from the subsequent bubble chart, because of their scale is an order of magnitude greater than the others. Their presence in the bubble chart would flatten the signal of the subsequent relevant classes.

#	IPC Class	Class description	# Patent families	# Patents
1	A01G	*HUMAN NECESSITIES || HORTICULTURE; CULTIVATION OF VEGETABLES, FLOWERS, RICE, FRUIT, VINES, HOPS, OR SEAWEED; FORESTRY; WATERING.*	551	1537
2	A01C	*HUMAN NECESSITIES || PLANTING; SOWING; FERTILISING.*	77	142
3	G05D	*PHYSICS || SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES.*	75	185
4	B05B	*PERFORMING OPERATIONS; TRANSPORTING || SPRAYING APPARATUS; ATOMISING APPARATUS; NOZZLES.*	64	239
5	G05B	*PHYSICS || CONTROL OR REGULATING SYSTEMS IN GENERAL; FUNCTIONAL ELEMENTS OF SUCH SYSTEMS; MONITORING OR TESTING ARRANGEMENTS FOR SUCH SYSTEMS OR ELEMENTS.*	51	111
6	A01B	*HUMAN NECESSITIES || SOIL WORKING IN AGRICULTURE OR FORESTRY; PARTS, DETAILS, OR ACCESSORIES OF AGRICULTURAL MACHINES OR IMPLEMENTS, IN GENERAL.*	27	56
7	G01N	*PHYSICS || INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES.*	27	59
8	G06F	*PHYSICS || ELECTRIC DIGITAL DATA PROCESSING.*	26	46
9	A01M	*HUMAN NECESSITIES || CATCHING, TRAPPING OR SCARING OF ANIMALS; APPARATUS FOR THE DESTRUCTION OF NOXIOUS ANIMALS OR NOXIOUS PLANTS.*	22	94
10	G06Q	*PHYSICS || DATA PROCESSING SYSTEMS OR METHODS.*	19	41
11	E02B	*FIXED CONSTRUCTIONS || HYDRAULIC ENGINEERING.*	14	24

Table 37. Main IPC classes

The following bubble chart depicts the evolution in time of patent activity in the main IPC classes. The bubble's dimension is proportional to the number of patents filed in a specific IPC class in a certain year.

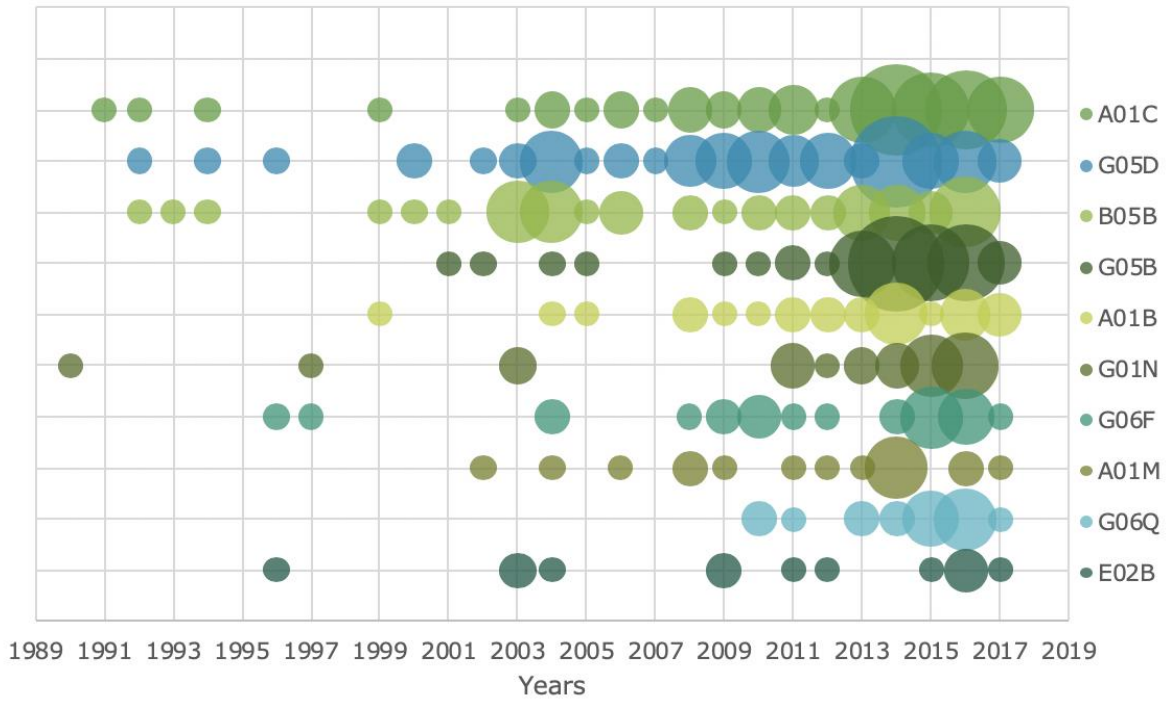

Figure 114. Evolution in time of main IPC classes

Starting from 2010, even in irrigation and fertigation technological field, solutions regarding data processing (G06Q) have been introduced. The only other growing classes are B05B and G01N respectively connected to spraying systems and sensing systems.

Terminology

In the next figures, two tag clouds are introduced that display the most frequent terminology detected in patents. For the extraction of the tags, the patent set has been stratified on the basis of the filing year. The two tag clouds show the most relevant expressions respectively between 2000 and 2010, and from 2011 to 2018; the dimension of tags is proportional to their frequency in patents that have been filed in said periods of time.

Figure 115. Tag cloud 2000-2010

Figure 116. Tag cloud 2011-2018

In both the tag clouds, terminology referred to control and management of irrigation/fertigation systems is present.

Involved subjects

The following table shows the 15 top Assignees.

#	Assignee	# Patent families	# Patents	% Patent families
1	John Deere	13	54	2,3
2	Lindsay Corporation	11	52	2
3	Skydrop	10	50	1,8
4	China Agricultural University	7	10	1,2
5	Rain Bird Corporation	7	29	1,2
6	Chinese Academy Of Sciences	6	8	1,1
7	Ibm	6	31	1,1
8	Aqua Conservation Systems	6	8	1,1
9	Trimble Navigation	5	11	0,9
10	Rockwool International	5	21	0,9
11	The United States Of America As Represented By The Secretary Of Agriculture	3	5	0,5
12	Syngenta Participation	3	16	0,5
13	Valmont Industries	3	9	0,5
14	Shihezi University	3	4	0,5
15	Living Greens Farm	3	22	0,5

Table 38. Top Assignees

The subsequent table shows the first 10 inventors per number of inventions.

#	Inventor	# Patents families	# Patents
1	Romney Matt	10	39
2	Endrizzi Clark	9	48
3	Addink Sylvan	7	8
4	Alexanian George	6	19
5	Chapin Richard	6	7
6	Ruan Shucheng	6	12
7	Anderson Noel Wane	5	20
8	Vikre Merie A	5	5
9	Hamann Hendrik F	4	24
10	Addink John W	4	5

Table 39. Top Inventors

6.7.2. SCIENTIFIC LITERATURE ANALYSIS

The set of papers about irrigation and fertigation is composed by 1970 documents. In the following section, the statistical analysis of said documents is disclosed.

Temporal distribution

The following figure shows the distribution in time of the scientific papers, according to the publication date.

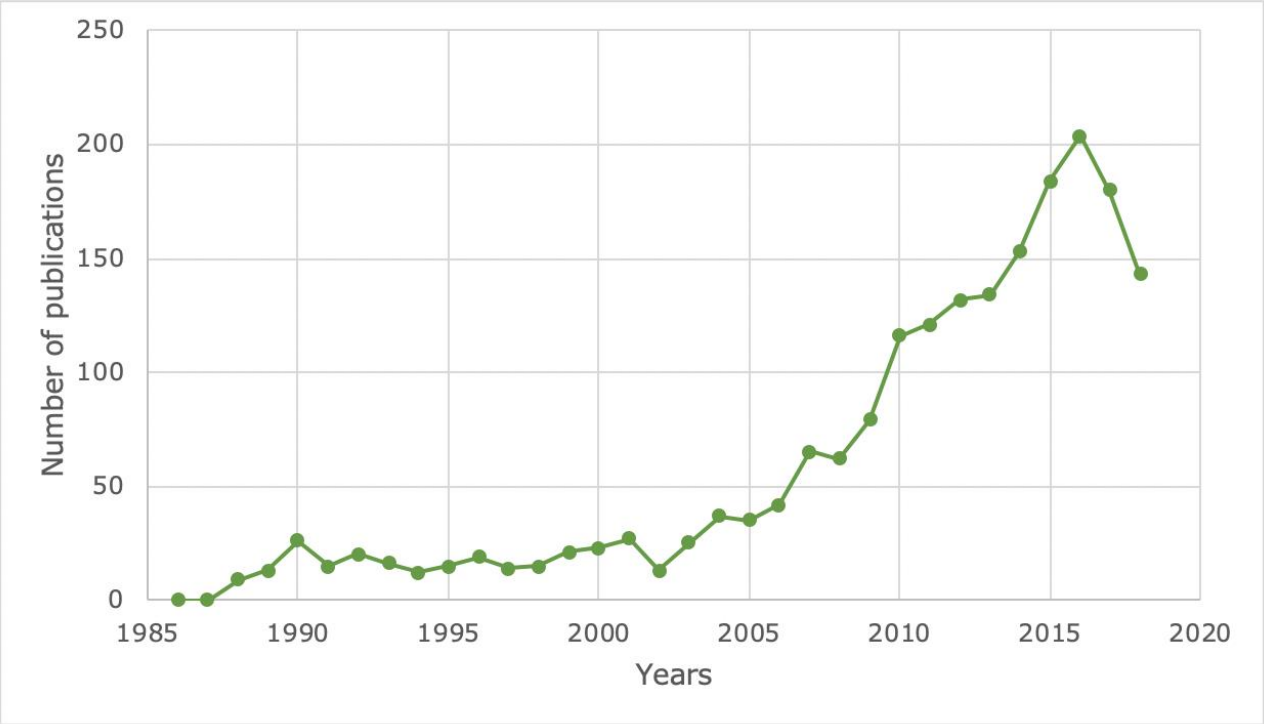

Figure 117. Distribution of the scientific literature according to publication dates

The diagram shows an increasing number of publications in the years until 2016, when around 200 papers have been published. On the contrary, in the last two years a drop is detected; in 2018 the number of articles is below 150. Said drop, detectable in the diagram, is indeed in accordance with the trend of patent filings in time.

Terminology

ScienceDirect makes available, for each paper, some tags describing the main object of the article; said tags have been processed in order to discover the most frequent topics in the analysed data set. The two subsequent figures show the results of this analysis in the forms of histogram and tag cloud.

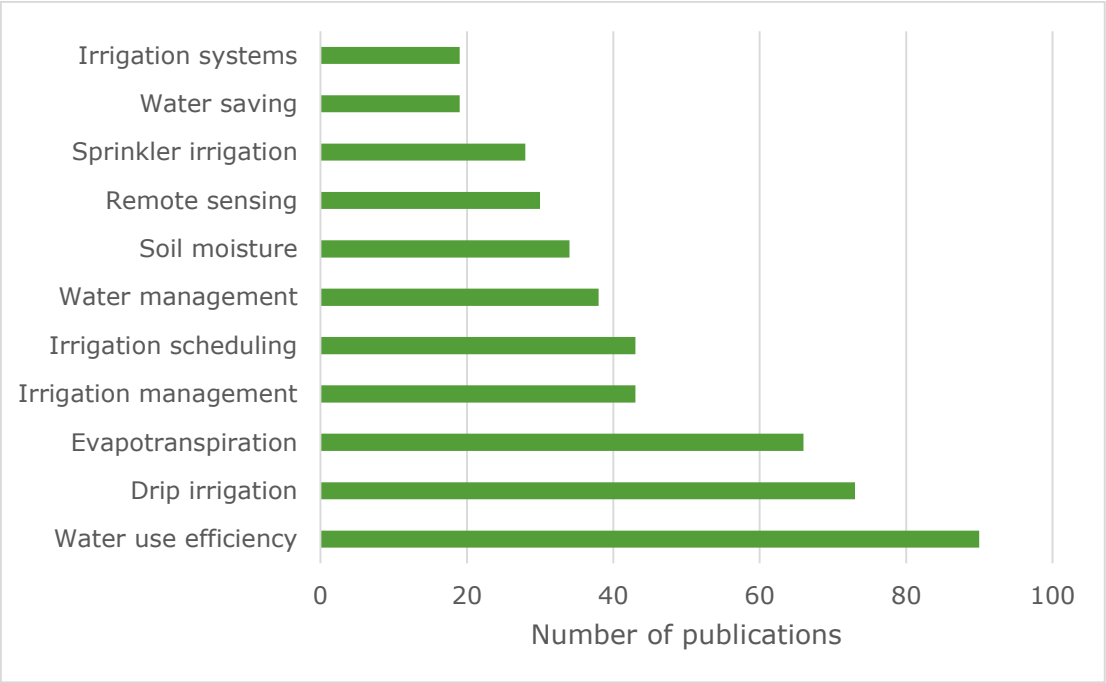

Figure 118. Papers' tags histogram

Figure 119. Papers' tag cloud

The terminology is focused mainly on control and management of irrigation/fertigation systems and on efficiency of said systems

Involved subjects

The next two figures show the main authors and main authors' affiliations for the analysed documents.

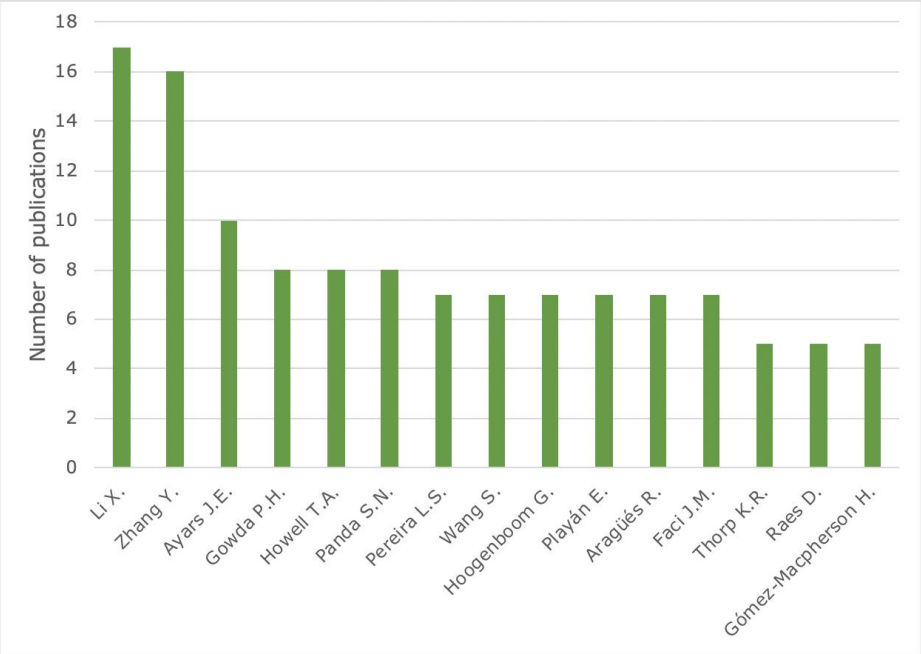

Figure 120. Top 15 authors

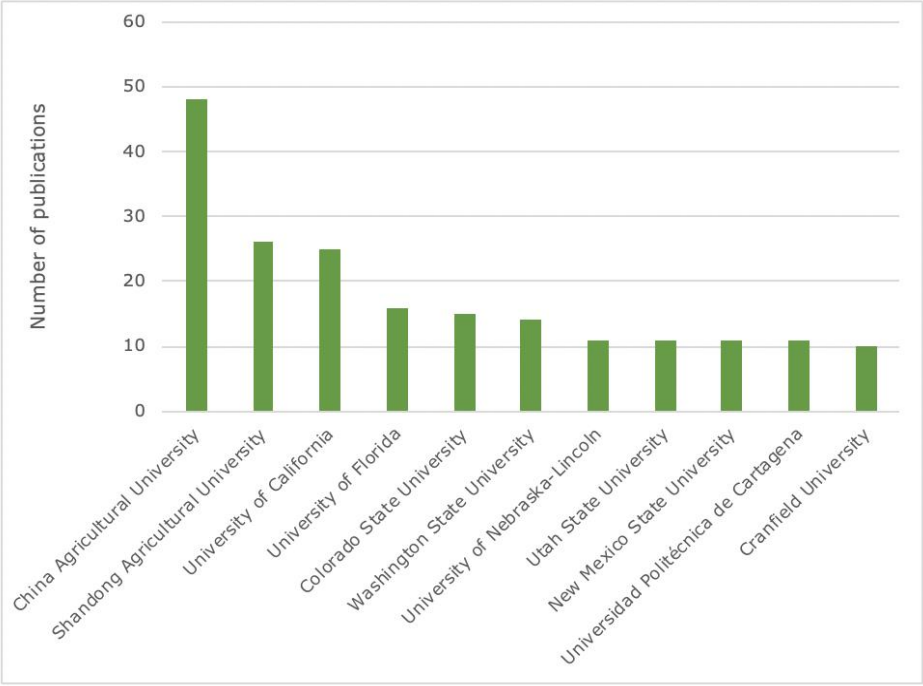

Figure 121. Top Affiliations

Almost all the top Universities are located in China and USA.

7. COMPARISON BETWEEN TECHNOLOGICAL CLUSTERS

In this chapter, a comparison between the technological clusters in both viticulture and arable crops will be shown.

7.1. VITICULTURE

The following graphs show a comparison between temporal distributions of each technological cluster retrieved in viticulture. In the following figure, the diagrams related to all the clusters are gathered and normalized on the basis of the respective mean value[4].

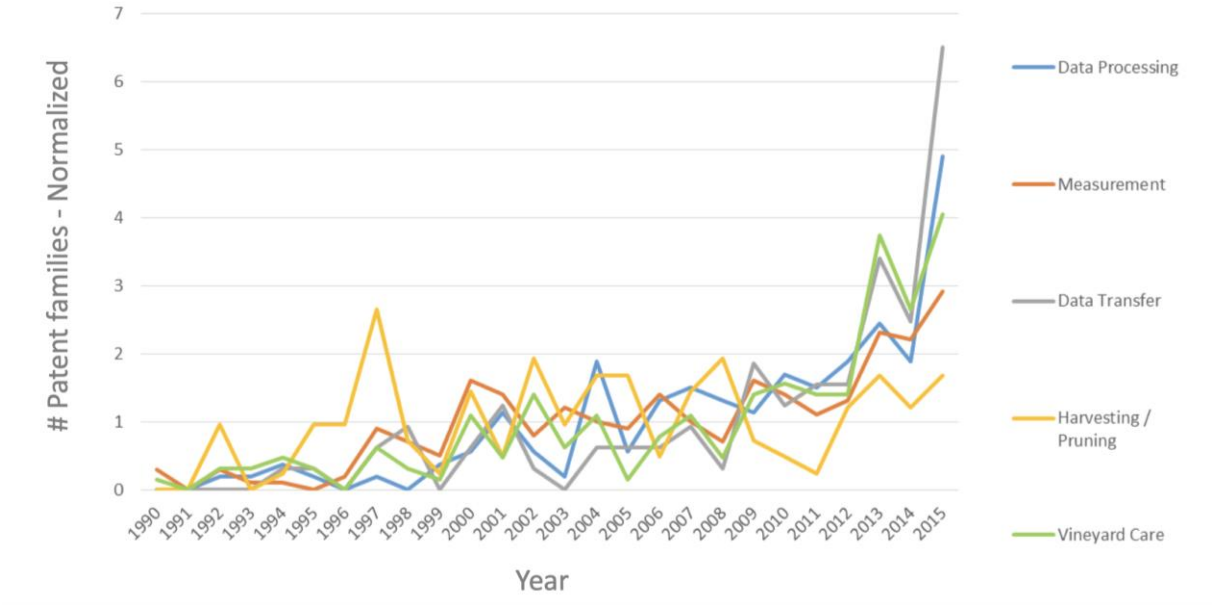

Figure 122. Distribution of the normalized patent families' count according to filing dates for each identified technological cluster

Said normalized values have been processed in order to extract the tendencies in the temporal window 2005-2015 with the aim of detecting the most growing technologies in the last years. The next graph shows the comparison among trends.

[4] The mean value of each technological cluster is computed on the interval 1990-2015.

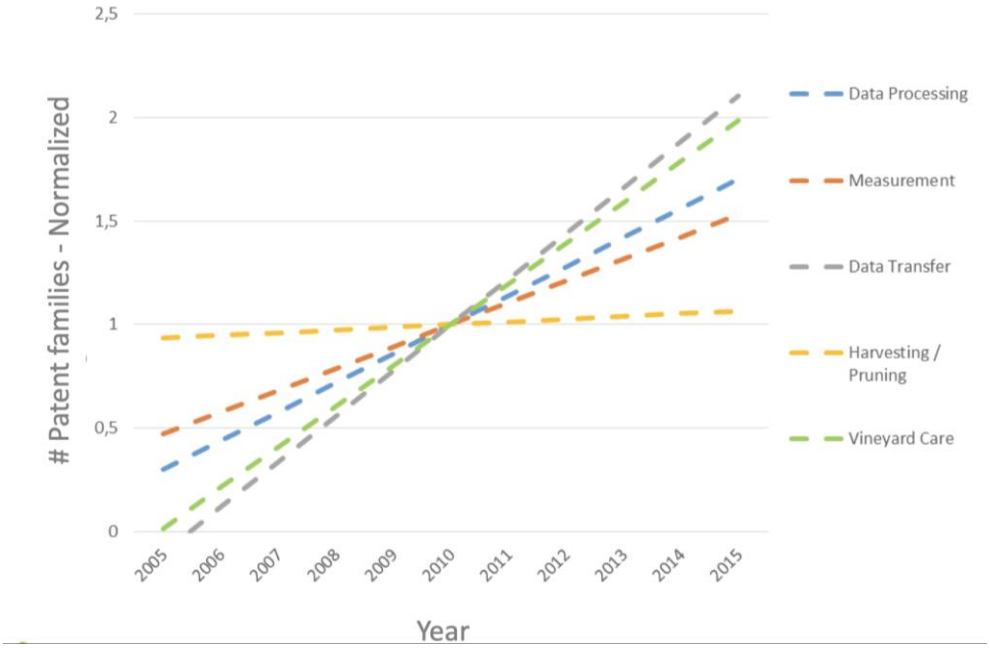

Figure 123. Temporal trend for each identified technological cluster in interval 2005-2015

The figures show that some clusters have increasing trends, in particular, the ones related to data transfer and vineyard care show a high rate of growth; secondarily and with a lower slope, measurement and data processing. The remaining cluster, harvesting and pruning, does not have a growing trend; though the respective diagram shows a noisy line and a small number of filings per year: no trends can be detected because of the low statistical reliability of data in this cluster.

The next graph introduces the aggregated distribution of patents in the different countries' offices for all the gathered technological clusters.

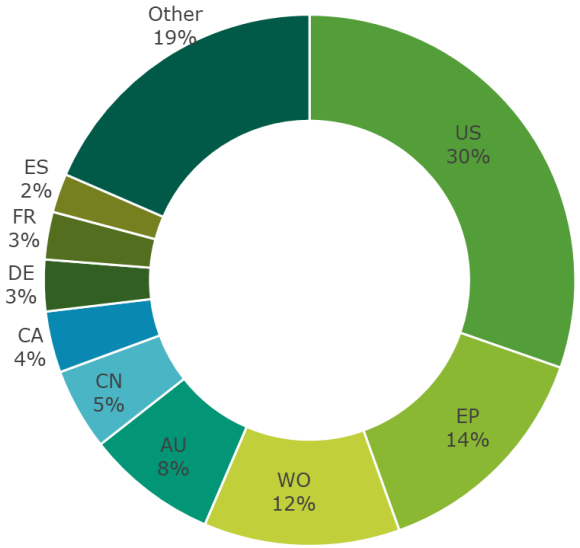

Figure 124. Aggregated percentage distribution of patents in the patent offices

In the following table, a synthetic view of documents' technological content is provided. The table underlines differences and similarities between academic research, witnessed by papers[5], and the industrial applications, witnessed by patents. The comparison is carried out by considering the terminology of both the types of documents, and, in addition, the most important IPC classes for each cluster.

Cluster	Patents terminology	Relevant IPCs	Papers terminology	Comparison
Data processing	• Mobile utility vehicle • Computer fertigation controller • Target fruit • Evaluation device • Distance sensor • Computing system	• G06T – image processing • G01C – navigation	• Simulation • Computer vision • Artificial neural networks • Image segmentation • Image processing	There are several differences between patents and papers terminology, though the IPC class G06T suggest the presence of a link between them. For both patents and papers, there is a remarkable interest upon image processing and vision systems.
Measurement and data collection	• Light source • Light detector • Optical Sensor • Light beam	• G05D – control systems • G06F – data processing • G06K – data recognition • G06T – image processing	• Remote sensing • Digital soil mapper • Unmanned aerial vehicle • Yield proximal sensing • Remote monitoring environment	Patents are strongly focused on photonics, while papers' terminology is focused on remote sensing in general. The presence of the tag "unmanned aerial vehicle" in the cluster measurement and data collection is particularly interesting.

Table 40. Patents and papers comparison in viticulture

[5] The lack of a unique and complete source, does not allow to perform a thorough analysis on scientific literature. Having this in mind, ScienceDirect has been chosen as a representative and statistically significant sample of the precision agriculture technological field.

Data transfer	• Mobile utility vehicle • Remote location • Sensors system • Photosensitive element • Sensor signal • Light beam	-	• Wireless sensor network • Vineyard navigation • Information transfer • Data communications • Iterative receiver • Acquisition device	The focus of patents' terminology is at most upon optical devices, in addition to remote communication ("Mobile utility vehicle" and "Remote location"). The papers' terminology, among some very general tags, is instead more focused on wireless sensor networks.
Harvesting / pruning	• Central computing system • Cut station • Scout robot • Harvest machine • Agricultural machine • Crop management plan	-	• Harvesting robot • Grapevine pruning • Vineyard mechanization • Mechanical harvest • Position control	Technologies in harvesting / pruning are, for both the types of documentation, at most correlated to robots and their control systems
Vineyard care	• Individual plant • Mobile utility vehicle • Water source • Light beam • Image sensor array	• G01N – sensing systems	• Intercropping • Evapotranspiration • Sprinkler irrigation • Planting geometry • Soil management • LiDAR	In this cluster, the terminology is referred to heterogeneous technologies. Once more, both in patents and in papers, light technologies are between the most important.

Table 40. Patents and papers comparison in viticulture - Continuation

7.2. ARABLE CROPS

The following graphs show a comparison between temporal distributions of each technological cluster retrieved in arable crops. In the following figure, the diagrams related to all the clusters are gathered and normalized on the basis of the respective mean value[6].

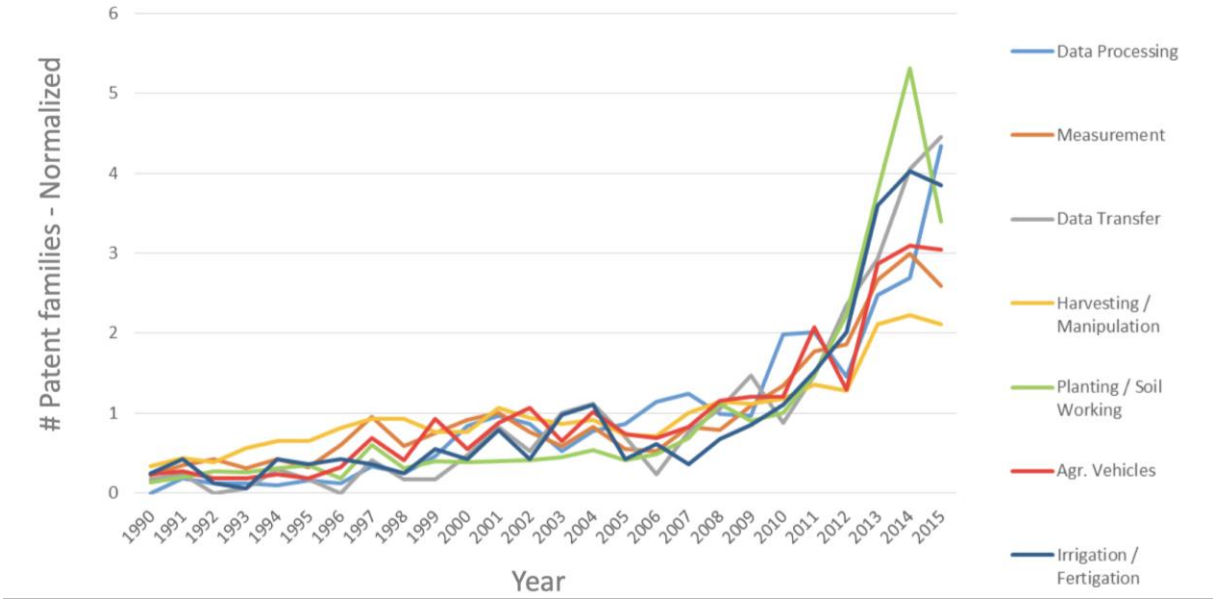

Figure 125. Distribution of the normalized patent families' count according to filing dates for each identified technological cluster

Said normalized values have been processed in order to extract the tendencies in the temporal window 2005-2015 with the aim of detecting the most growing technologies in the last years. The next graph shows the comparison among trends.

[6] The mean value of each technological cluster is computed on the interval 1990-2015.

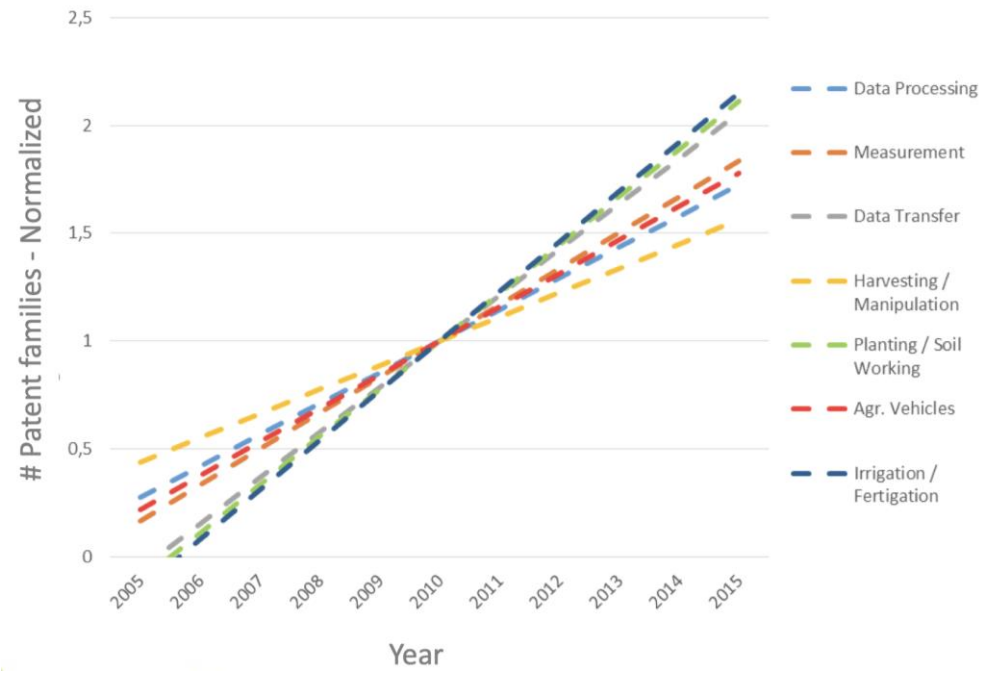

Figure 126. Temporal trend for each identified technological cluster in interval 2005-2015

The figures show that all the analysed technological clusters have a growing tendency; hence, enabling technologies and technological applications have similar behaviours of development. The fastest growing technological clusters are "planting / soil working", "irrigation / fertigation" and "data transfer", very similarly to the most increasing trends in viticulture ("vineyard care" and "data transfer").

The next graph introduces the aggregated distribution of patents in the different countries' offices for all the gathered technological clusters.

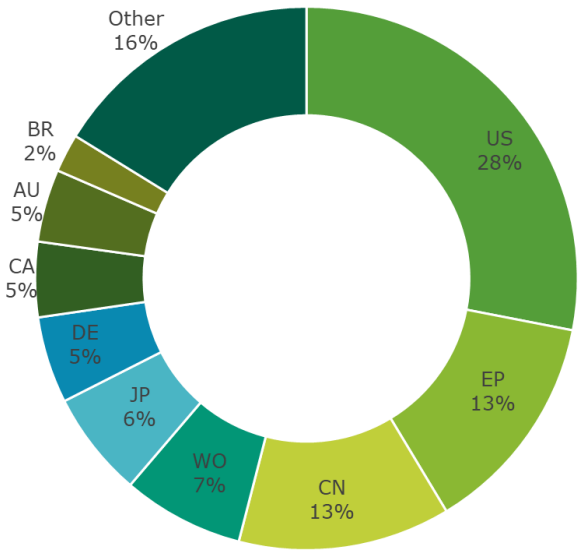

Figure 127. Aggregated percentage distribution of patents in the patent offices

In the following table, a synthetic view of documents' technological content is provided. The table underlines differences and similarities between academic research, witnessed by papers[7], and the industrial applications, witnessed by patents. The comparison is carried out by considering the terminology of both the types of documents, and, in addition, the most important IPC classes for each cluster.

Cluster	Patents terminology	Relevant IPCs	Papers terminology	Comparison
Data processing	• Datum object • Irrigation controller • Computer system • Rf network node • Control system • Processing module	• G06T – image processing	• Machine vision • Simulation • Wireless sensor network • Agricultural machinery • Image processing	There are several similarities between patents and papers. The main theme, for both of them, particularly considering the most significant IPC class of the cluster, is focused on image processing and vision systems. In papers' terminology, the term "simulation" is particularly significant and recurrent.
Measurement and data collection	• Control system • Agricultural vehicle • Light source • Irrigation controller	• G05B – control systems	• Remote sensing • GIS • NDVI • Soil moisture • Image processing • Satellite data	Patents are mainly referring to measurement technologies connected to control systems, while papers' terminology is focused on technologies enabling remote sensing and geographical characterization.

Table 41. Patents and papers comparison in arable crops

[7] The lack of a unique and complete source, does not allow to perform a thorough analysis on scientific literature. Having this in mind, ScienceDirect has been chosen as a representative and statistically significant sample of the precision agriculture technological field.

Data transfer	• Rf network node • Light source • Sense unit • Transmit datum • Soil sensor unit	• G05B – control systems • G01N – sensing systems	• Wireless sensor network • Data acquisition • Data transmission • Data collection • Iterative receiver • Transmission system	There are several differences between patents and papers. In particular, patents are referring to technologies that can be considered general purpose enabling technologies. However, It is interesting to highlight the presence of terminology related to optical devices. On papers' side, wireless sensor networks are the most recurrent technology.
Harvesting / Manipulation	• Transport vehicle • Harvest machine • Control system • Robotic device	• G06F – data processing • G05D e G05B – control systems • B25J – manipulators	• Mechanization • Agricultural machinery • Harvesting system • Mechanical harvest • Harvesting robot	For both the types of documentation, the terminology is focused to control systems and robotics.
Planting/ Soil working	• Seeding machine • Plant unit • Seed tube • Seed meter • Control system • Autonomous vehicle platform	• G05B e G05D – control systems	• Soil compaction • Tractor • Agricultural vehicle • GPS • Ploughing • Navigation	While the patents' terminology refers mainly to seeding systems but also to automation and control systems, the papers are related mainly to agricultural vehicles and navigation systems.

Table 41. Patents and papers comparison in arable crops - Continuation

Agricultural vehicles	• Agricultural vehicle • Device resonator • Drive motor • Autonomous vehicle • Unmanned aerial vehicle • Communication device	• B64C – aerial vehicle • G05D – control systems	• UAV • Agricultural vehicle • Remote sensing • Tractor • GPS • Navigation • Image processing	The tag “unmanned aerial vehicle” is particularly interesting. The growing trend of the IPC class B64C underlines the similarity between academic and industrial world in this technological cluster.
Irrigation/ Fertigation	• Irrigation controller • Water irrigation systems • Sense unit • Sprinkler management system • Sprinkler head	• B05B – spraying systems • G01N – sensing systems	• Water use efficiency • Drip irrigation • Evapotranspiration • Irrigation management • Water management	No differences between papers and patents, since in both the cases the terminology is focused on the management of resources

Table 41. Patents and papers comparison in arable crops – Continuation

7.3. RECURRENT TECHNOLOGIES

The following table gives a final synthetic view of technologies retrieved in the various clusters both in viticulture and arable crops. The slots of the table containing the same patterns are painted in identical colours in order to highlight the recurrent technologies.

	Cluster	Technology				
Viticulture	Data processing	Control Systems	Image Processing	Navigation		
	Measurement	Control Systems	Image Processing	Optical Systems	Remote Sensing	
	Data transfer	Optical Systems	Sensing Systems	Navigation	Satellite Technology	
	Harvesting / Pruning	Robotics	Sensing Systems	Image Processing		
	Vineyard Care	Irrigation	Optical Systems	Aerial Vehicle	Sensing Systems	
Arable Crops	Data processing	Image Processing	Optical Systems			
	Measurement	Control Systems	Optical Systems	Aerial Vehicle	Image Processing	Satellite Technology
	Data transfer	Control Systems	Sensing Systems			
	Harvesting / Manipulation	Control Systems	Manipulators	Robotics		
	Planting / Soil Working	Control Systems	Autonomous Vehicles	Navigation		
	Agricultural Vehicles	Control Systems	Autonomous Vehicles	Aerial Vehicle	Remote Sensing	Image Processing
	Irrigation / Fertigation	Control Systems	Sensing Systems	Efficiency		

Table 42. Most frequent technologies across the analysed clusters

Except for very general technological groups (e.g. “control systems” and “sensing systems”), at a deeper level of detail, the most frequent technologies are firstly “image processing” and “optical systems”. Secondarily, “navigation” solutions and “aerial vehicles” are the most trending topics.

8. CONCLUSIONS

Since patents and scientific papers represent the most significant sources of technological information, the innovative methodology, followed to perform the quantitative analysis, allows the exploration of both of them, with the aim to offer a comparison between the results of R&D achieved by the industrial and academic world. Precision agriculture turned out to be a topic of interest both in industrial and academic environments. The main technological trends in patents are related to products on which the companies are investing, hence they are the main trends in the current market. Technological tendencies in scientific papers, instead, are more likely connected to solutions that probably will be on the market in the near future[8].

Going into data findings, a cluster analysis discovered the presence of five and seven technological groups respectively in viticulture and arable crops. Among the identified clusters, it is possible to distinguish between enabling technologies and application technologies. The enabling technologies are the basis on which the applications are developed and are the same in viticulture and arable crops ("Data processing", "Measurement and data detection", "Data transfer"). The remaining clusters are related to technological applications and are focused on different phases of cultivation (harvesting/pruning and vineyard care in viticulture, planting/soil working, harvesting/manipulation and irrigation/fertigation in arable crops) and on agricultural vehicles.

According to both the used sources, except for a few cases in which the data are not statistically significant[9] due to low number of documents per year, all the identified clusters are growing in time. The fastest growing technological clusters are respectively "planting/soil working", "irrigation/fertigation" and "data transfer" in arable crops and, similarly, "vineyard care" and again "data transfer" in viticulture.

Although the interest of the scientific community on the topic of precision agriculture is growing in time, it is remarkable that the number of documents and, in particular, of patents, in this technological field is rather low, especially in viticulture. The fact witnesses the youth of the technological field; this statement is strengthened by comparing the number of patent families respect to the number of papers. For several technological clusters, the number of papers is higher than the number of patent families; while when a technology is in "maturity" phase, the latter overcomes the first one by far, usually.

[8] The lack of a unique and complete source, does not allow to perform a thorough analysis on scientific literature. Having this in mind, ScienceDirect has been chosen as a representative and statistically significant sample of the precision agriculture technological field.

[9] All the temporal data extracted from patents are significant except for "Harvesting / pruning" in viticulture. The time data extracted from scientific literature are not significant for "Measurement and data collection", "Data transfer", "Harvesting / pruning" in viticulture and for "Harvesting / manipulation" in arable crops.
All the data are reliable in a general sense, though in the aforesaid cases, they are not significant for the specific task of extracting a trend and interpret it on the basis of the technology lifecycle theory.

Analysing the distribution of patents in the world, it is interesting to highlight that US (USA) and EP (Europe) are the main patent jurisdictions for both viticulture and arable crops[10]. Moreover, while in the first one the presence of the Australian jurisdiction is remarkable, in the second one the Chinese effort is high. Furthermore, considering academic affiliations in scientific publications, the most productive Universities belong to the same countries.

Focussing more in depth on technological data, except for very general and frequent technological solutions ("control systems" and "sensing systems"), the most recurrent technologies found across the analysed clusters are firstly "image processing" and "optical systems" and secondarily, "navigational solutions" and "aerial vehicles".

With reference to the following steps of Sparkle Project, in particular WP3, related to the e-learning training educational package preparation, this analysis, as the other WP2 activities, is meant to be a guide for the definition of technological learning contents. More in detail, since the educational package will be deployed in 4 units (see the document R3.4 *"Design Action Plan"* for further details) and the second unit (*"Tech-ing"*) deals with technological issues in PA and since every analysed technological field turn out to be important and growing in time, it is important for the course to give a full overview on the technological landscape of PA. Furthermore, a greater attention should be paid for the most growing technologies (respectively, "planting/soil working", "irrigation/fertigation" and "data transfer" in arable crops; "vineyard care" and "data transfer" in viticulture) and for the aforesaid most recurrent technologies ("image processing", "optical systems", "navigational solutions" and "aerial vehicles") that turned out to be mentioned transversally in many of the growing technological fields.

[10] This behaviour is observable in every average patent set.

ANNEX A – GLOSSARY

Assignee: Owner of the intellectual property rights given by a patent. A patent can have more than one assignee: in this case, they are called co-assignees.

Cluster analysis: technique for grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar (in some sense) to each other than to those in other groups (clusters). In this analysis it is used in order to examine the main technologies in viticulture and arable crops data sets.

DOC-DB patent family: "*Generally speaking, if two applications claim exactly the same prior applications as priorities (these can be e. g. Paris Convention priorities or technical relation priorities […]) then they are defined by the EPO as belonging to the same DOCDB simple family.*"
Source: Data Catalog – Patstat

Enabling technology: Technology at the basis of technological applications.

Inventor: Person who contributed to the development of the invention disclosed in a patent. A patent can have more than one inventor.

International Patent Classification (IPC): It is a hierarchical patent classification system used in over 100 countries to classify the content of patents in a uniform manner. The classification is a system of sorting inventions and their documents into technical fields covering all areas of technology. To every patent document, regardless of whether it is an application or a granted patent, is given a classification symbol by the examiner indicating its allocation to a specific area of technology; moreover, a patent can be classified in more than one different classes if the invention embraces different areas of technology.

No-sql query: Query based on keywords and regular expressions organised according to a functional deployment, which enables the research of data and information in a non-relational database. A Non-Relational database is any database that does not follow the relational model offered by traditional relational database management systems.

Patent: The term patent has to be intended in a generic and undifferentiated sense and it is valid whether for patent applications or for granted patents.

Patent family: A patent family can be considered approximatively equivalent to an invention; hence, the numerical count of patent families estimates the quantity of inventions/R&D projects of a certain subject and/or in a certain interval of time.

Technology lifecycle theory (TLT): The TLT describes the evolution of a technology; it concerns the performance of a technology, the diffusion of the innovation, the number of invented solutions, the R&D expenditures ecc. It divides the vital life of a technology in 4 phases: emerging phase, growth phase, maturity and decline.

Technological Application: Solution that take advantage from enabling technologies in order to perform a specific function or for a specific application, e.g. Normalized Difference Vegetation Index (NDVI) is an application of satellite technology, which is in this case an enabling technology.

ANNEX B – SUMMARY OF PATENT OFFICES

The following table provides the name of the competent Patent Office for each country's acronym used in pie charts within the document.

Tag	Country
AR	Argentina
AU	Australia
BR	Brazil
CA	Canada
CN	China
DE	Germany
EP	Europe (European Patent Office - EPO)
ES	Spain
FR	France
GB	United Kingdom
IL	Israel
JP	Japan
KR	South Korea
RU	Russia
US	United States of America
WO	World (World Intellectual Property Organization - WIPO)

Table 43. Patent Offices with respective tags