PATENT TRENDS IN AGRICULTURAL ENGINEERING

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Abstract. Inventions play an important role in all sectors of our society, including the agricultural sector. As they have played an essential role in the development of our agricultural system in the past, inventions can and should be of importance as a driver for innovations towards sustainable development of agriculture in the future. The present paper analyses the current status of agricultural and bioresource engineering patents, with the aim to define the current trends and potentials of agricultural engineering. The research takes advantage of the EspaceNet patent database, which has indexed more than 38900 patents in agricultural engineering since the beginning of the century. The analysis starts from a selection of most recurrent words in this database, and proposes a clusterization in thematic groups. Then, comparisons are carried out both on thematic groups and on single terms, in order to determine trends, recognise correlations, and eventually identifying most strategic areas. The results highlight a growing attention on machinery, on data and automation, while lower relevance is progressively covered by chemical treatments. Specifically, a clear relevance is noticed on agricultural vehicles and implements, on irrigation systems and on greenhouses.

Keywords: patents, agricultural engineering, meta-analysis, technologies.

Introduction

Since the beginning of the last century, agriculture and agricultural markets have been evolving very rapidly. Research and development in food and agricultural sectors have been pushed not only by governments and public organizations funding, but also by private investments. In such development situation, patents can provide an important infrastructure allowing protection of innovations and enabling agricultural progress [1]. From the point of view of the scientific community, patents can constitute an interesting reference for some different reasons: the completeness and level of detail of the technical information, the accessibility through open access search engines, the timeliness of submissions and publications with respect to the new findings [2]. Additionally, patents are often implemented as an effective approach to quantify inventive activity, and to understand latest trends and needs, mainly from the market point of view.

Intellectual property in agriculture covers many different fields, following and sometime anticipating most relevant advances of scientific research. Much activity is carried on new machinery [3] and in general on new equipment, which can be integrated on agricultural implements and vehicles [4]. A lot of efforts are spent in particular on new sensors [5, 6], which have the potential to allow frequent monitoring [7], automation of operations and support to the decision making process [8]. Research is also done for the development of new highly performing materials, especially with biodegradable properties [9], in accordance with a common attention for the environment [10]. The growing attention on environment [11-12] has brought noticeable drawbacks in the development or evolution of treatments with sustainable management approaches [13], optimized treatments and fertilizers distributions [7, 14], organic productions and in general products, which are less impacting on soil, air and water [15-17]. Reduction of impacts passes through the optimization of energy resources: many works have been recently done to find new resources [18; 19] and to minimize energy consumptions related to different agricultural processes [20].

The aim of the present research is to provide an analysis of the patent behavior in the agricultural field, in order to understand the evolution from the beginning of the 21st century and possibly trace some short forecast for future progress, starting from reference data set of 500 documents and then extending the study to more than 38000 documents.

Materials and methods

Reference patents data set

To define an appropriate set of relevant words, the last 500 documents indexed by the Espacenet (European Patent Office searching engine) and including “agricult*” in the title (i.e. agriculture, agricultures, agricultural and agriculturally) were considered. Specifically, a text analysis of the titles was carried out, mainly taking advantage of frequency functions available within Microsoft Excel

software package. A total of over 3200 words (including repetitions) were then defined, and those exhibiting higher occurrence were isolated and grouped in conceptual clusters, as reported also in the following Table 1. Words with two or three repetitions in general have not been reported in the table for the sake of simplicity. A number of words (over 700) exhibited only one occurrence over the 500 patents: they were considered to be not relevant or secondary for the analysis: therefore, they have not been included in the classification scheme.

Table 1

Main words occurrence in the last indexed 500 agricultural patents

Field	Main words and relative occurrence, %			Group percentage
Machinery	Vehicle 4.4 %	Machines 1.4 %	Trailer 0.6 %	51 %
	Equipment 4.4 %	Harvester 1.4 %	Pulverization 0.6 %	
	Implement 4.2 %	Tractor 1.0 %	Fan 0.6 %	
	Harvesting 4.0 %	Mulching 1.0 %	Cart 0.6 %	
	Spray 3.4 %	Spreader 0.8 %	Cabin 0.6 %	
	Machinery 2.6 %	Mechanical 0.8 %	Belt 0.6 %	
	Planting 2.2 %	Hitch 0.8 %	Baler 0.6 %	
	Irrigation 2.0 %	Electric 0.8 %	Applicator 0.6 %	
	Wheel 1.6 %	Distribution 0.8 %	Cleaning 0.6 %	
	Sowing 1.4 %	Transportation 0.6 %	-	
Data and automation	Monitoring 2.0 %	Sensing 1.0 %	Information 0.8 %	20 %
	Automatic 2.0 %	Precision 1.0 %	Traceability 0.6 %	
	Autonomous 1.4 %	Metering 1.0 %	Detection 0.6 %	
	Drone 1.4 %	Unmanned 0.8 %	-	
	Data 1.2 %	Robot 0.8 %	-	
Materials and products	Seed 4.4 %	Biodegradable 1.0 %	Waste 0.6 %	18 %
	Film 3.8 %	Grain 0.8 %	Salt 0.6 %	
	Greenhouse 1.0 %	Plastic 0.8 %	Oil 0.6 %	
Transversal	Management 2.6 %	Water 1.6 %	Land 0.8 %	16 %
	Air 2.6 %	Crops 1.2 %	Green 0.6 %	
	Soil 1.6 %	Plants 1.0 %	Organic 0.6 %	
Treatments	Chemical 3.2 %	Pest 1.4 %	Insecticide 1.0 %	16 %
	Pesticide 2.2 %	Disease 1.2 %	Fungicide 1.0 %	
	Fertilizer 2.0 %	Fungi 1.0 %	Microbial 0.8 %	
Energy	Drying 2.4	Gas 0.8 %	Heat 0.6 %	6 %

Patent trends

Each word from the list of selected words (mainly reported in Table 1) was used for an advanced search in the European Patent Office Espacenet. Selected word and "agricult*" were searched in the title text string, while the publication date was ranged between 2000 and 2017. A total of 38911 indexed documents were eventually considered.

It is worth noting that in the chosen time interval, the total number of indexed published patents in all production fields has been constantly and naturally increasing, with an average 10.6 %-year growth in the case of agricultural documents (from 1256 to 6253 respectively in 2000 and 2017, Fig. 1). On the other hand, natural oscillations are present year by year due to different uncontrolled influencing factors. These factors are mainly ascribable to research and industry events (progress, international economic crisis, ...) or socio-political actions (wars, terrorism, embargos, ...). Additionally, due to the length of the submission process especially for some countries, the indexing process has not been completed yet for the last two years (2017 and 2018). To get rid of such variations, the numbers of patents quantified for the different selected words and fields have been normalized by a coefficient estimated as the rate between the total number of patents deposited year by year and the number of patents deposited in 2000 (the first considered year). Such normalization allows not only comparing

different targeted patenting fields, but also classifying and defining the most promising research and production fields for the near future.

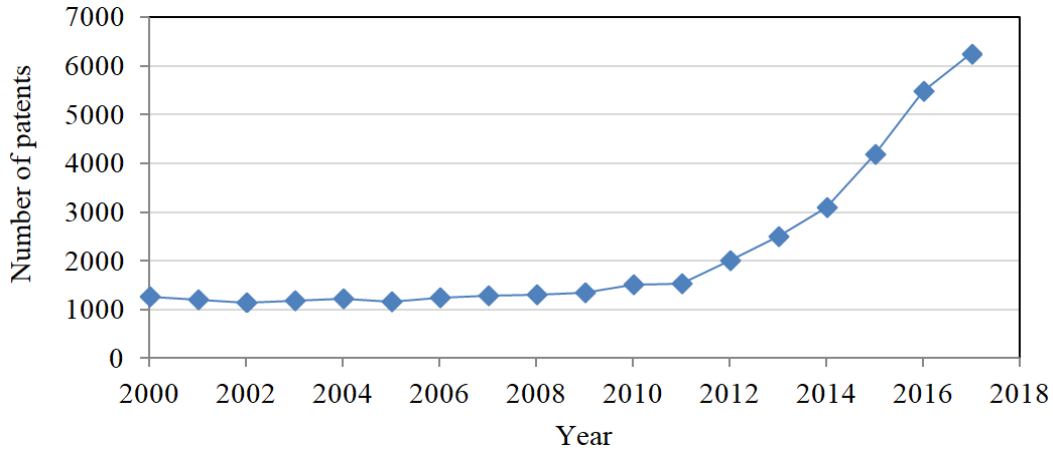

Fig. 1. **Number of deposited patents since 2000**

Results and discussion

The analysis allowed a few considerations to be carried out with respect to patent trends. First results can be represented through the graph in Figure 2, where occurrences for different patent groups are reported since 2000. According with Table 1 partitions, patents focused on developments of new agricultural machinery since the beginning of the century cover on average about 38 % of the total number of deposited documents in the agricultural field, new materials and products are reported by 13 % of the new inventions, while new systems and devices for data management and automation are the target point in 7 % of the documents. Transversal new findings cover about 13 % of the total, while treatments and energy are relevant respectively in the 9 % and 4 % of the cases. However, more than the absolute values, it is important to recognise the different trends associated with different development fields. Comparing the last years (2015-2017) with the first three years of the century (2000-2002), it can be noticed how different tendencies can be recognised (see Figure 2 and Table 2).

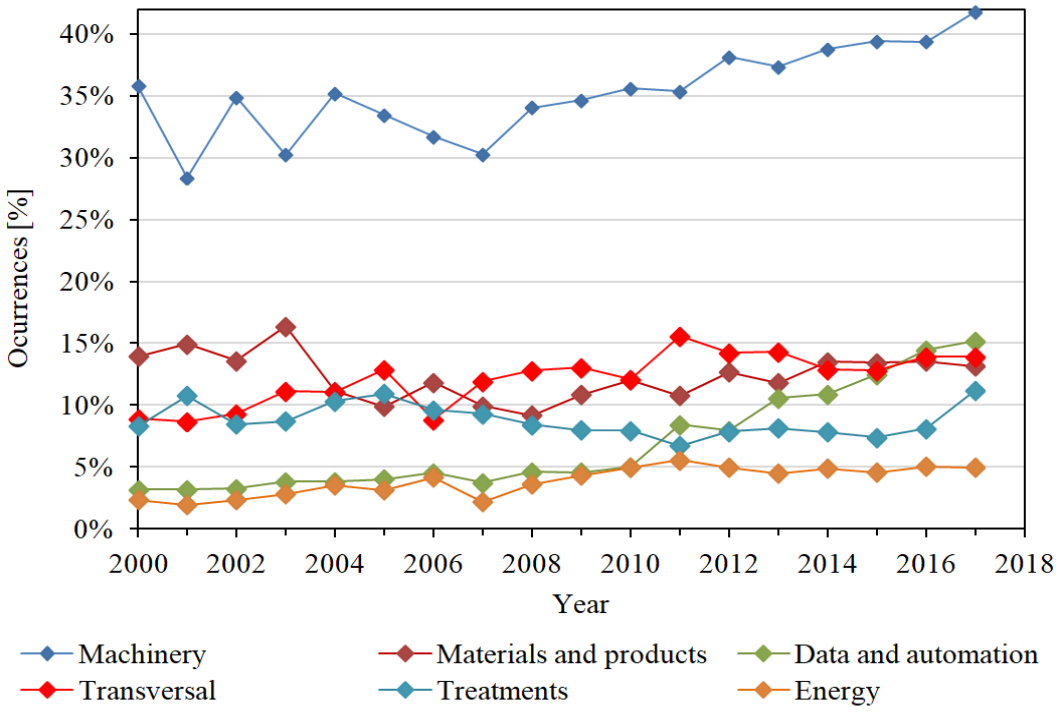

Fig. 2. **Occurrences since 2000 for different patents groups**

Agricultural machinery has exhibited an increase of about 20 %: a little smaller if compared to the group of transversal patents, and definitely higher if compared to the materials and products (-6 %) or to the treatments group (-8 %). On the other hand, the highest growth rates were highlighted in the case of data and automation (+ 269 %) and in case of energy (+ 86 %). Going into the detail of most patents, some evolution can be recognised in Table 2, which highlights the terms, which had an average occurrence higher than 2 % in the whole considered period or at least in the last three years. The most frequent objects of patenting in agriculture have been and are still the vehicles, together with implements, small equipment or more generically machinery, often modified and adapted to specific crops and latitudes needs.

Table 2

Average patent occurrences for most frequent terms

Terms: "agricult*" + ...	Period					
	2000-2002	2003-2005	2006-2008	2009-2011	2012-2014	2015-2017
Vehicle	5.8 %	6.6 %	6.1 %	6.0 %	6.3 %	5.6 %
Machinery	1.7 %	1.4 %	1.2 %	1.7 %	2.9 %	4.3 %
Irrigation	0.5 %	0.4 %	0.9 %	1.0 %	2.0 %	4.3 %
Greenhouse	0.7 %	0.6 %	0.9 %	2.1 %	3.1 %	3.8 %
Equipment	1.2 %	0.9 %	1.3 %	1.2 %	1.5 %	3.8 %
Water	2.3 %	2.6 %	2.4 %	3.3 %	3.1 %	3.6 %
Fertilizer	0.8 %	1.8 %	1.2 %	1.0 %	1.7 %	3.1 %
Implement	3.0 %	3.3 %	3.0 %	4.1 %	4.2 %	2.8 %
Film	7.3 %	5.1 %	3.1 %	3.1 %	3.0 %	2.4 %
Monitoring	0.4 %	0.4 %	0.5 %	1.1 %	2.2 %	2.5 %
Automatic	0.9 %	0.8 %	0.7 %	1.3 %	1.6 %	2.6 %
Soil	1.2 %	1.8 %	1.8 %	1.8 %	1.7 %	2.3 %
Chemical	3.3 %	2.7 %	3.2 %	1.8 %	1.1 %	0.8 %
Tractor	2.8 %	2.7 %	2.7 %	2.3 %	2.0 %	0.6 %

The need for adaptation has pushed also a growing interest toward greenhouses, which have almost doubled patents since 2010, and also toward new materials as, for instance, polymer films. A slightly decreasing interest is conversely determined by tractors and implements, which gave evidence of a contraction in the percentage of new developments in the last years. A growing attention is being paid on optimization of resources, as highlighted by water and irrigation terms.

Also soil confirms to be the object of many attentions, and fertilization is certainly one of the most relevant practices; clearly, the attention of the customer toward more sustainable products has clearly caused a contraction of new chemical product developments, especially in the last decade. Sustainability can be improved implementing precision farming approaches, therefore monitoring and automation innovations have been rapidly increasing, particularly in the last few years.

Conclusions

In the present paper a wide analysis is carried out on the terms, which are mostly recursive in the title of deposited patents.

1. A contraction can be recognised for the development of patents dealing with chemical products and treatment.
2. A clear need for precision monitoring tools is reflecting in the development of new sensors and equipment minded to increase pervasive automation in agricultural operations.
3. Machinery still plays an important role in agricultural intellectual property, but attention is moving from the tractors to the implements or to equipment components, which can be implemented and integrated in agricultural operations.

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