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Structure of the Precision Agriculture Research in Italy from 2000 to 2016: a Term Mapping Approach

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Italy has a fragmented reality with an extremely rich and diverse territory; however, it has nowadays started to embrace precision farming techniques and several research activities are being carried out. This study followed a survey proposed by the Italian Ministry of Agricultural, Food and Forestry Policies (Mipaaf) promoted to explore and evidence weaknesses and strengths of the Italian panorama regarding precision farming researches and studies. The survey interested all the Italian Research Institutes and Universities, which include agricultural aspects within their missions.This study aims at conducting the first term mapping analysis of the precision agriculture research in Italy to elucidate its research structure. We applied a science mapping approach based on co-terms and citations analyses to a set of scientific publications retrieved from the Elsevier's Scopus database over the period 2000–2016. The key terms used for the Scopus search were "precision agriculture, precision farming, precision viticulture, precision forestry and precision aquaculture". The Scopus search retrieved 800 research papers and reviews published by 118 peer-reviewed journals. The total number of publications was around 21.2% (N = 170) during the cumulative period 2000–2009 and they exponentially increase reaching 18% (N = 150) on 2015 (it must be considered that for 2016 Scopus do not yet complete the publications input). The term mapping approach on precision agriculture papers from Italian authors produced a term map showing 4 well separated clusters. Each cluster groups together close scientific investigated topics. The first one is based on technology; within this cluster is possible to observe terms linked to food, sensors and animal farming (evident sub-cluster). The second cluster is related with indices and algorithmic approaches. The third one is related to spatial variability and soil related terms. The fourth and smaller one, between the first and the second, regards viticulture related terms.
Keywords: precision farming; term mapping; networking.

1. Introduction

In Italy, the advent of Precision Agriculture (PA) represents a new agricultural revolution taking advantage of global positioning systems, the development and applications of digital technologies in general to automate farm tasks, measure crop and animal performances and carry out several other tasks (Eastwood et al., 2017). The technologies that will be implemented in PA started to appear in late 1980's initially in United States and Australia, and undergone a constant growth till now with the appearance on the market of new technologies such as small sensors or positioning systems with increased accuracy and precision.
In 1990, the NAVSTAR Global Positioning System (GPS) became available for civilian and thus agricultural use for accurately locate a vehicle and navigate generating a wide variety of activities while electronic controllers for Variable Rate Applications (VRA) were developed to use the positioning information and crop yield monitors started to appear on the market.
Following Taylor and Whelan (2005) When yield data were linked with maps regarding soil nutrients spatial and temporal variability determined the true beginning of PA, firstly in field crops. Nowadays, the real aids coming from the applications truly implemented are many and point to maximize the production efficiency,

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minimize the environmental impact and the risks connected with the agricultural practices (Whelan, 2007). At the moment, many researches have been published or are being conducted to push the PA growth or investigate its practical benefits or with the effort to develop new technologies able to improve the whole farm management keeping in mind an increased sustainability. The firsts international research papers started to appear at the beginning of 21st century. In the research panorama, sometimes the work efforts focus on some major topics while minor nevertheless important aspect, as could be the case of the implementation of VRA on minor crop, might be investigated. Indeed, might be interesting to analyze the relative scientific research.
Bibliometric mapping is a powerful tool for studying the structure and the dynamics of scientific fields (Van Eck et al., 2010). Researchers can utilize bibliometric maps to obtain a better understanding of the field in which they are working. In addition, bibliometric maps can provide valuable insights for science policy purposes (Noyons 2004). The term mapping approach aimed at: *i*. identifying trends in scientific publication outputs, and number of publications published by journals, countries and research institutions; *ii*. providing a general field overview by visualizing main research areas, their relations and how they developed over time; *iii*. identifying the most cited terms (Nardi et al., 2016).
The aim of this work is to analyze the Italian research landscape regarding PA using a software tool for constructing and visualizing bibliometric networks (*i.e.* VOSviewer). These networks include journals, researchers, or individual publications, etc., and could be based on co-citation, bibliographic coupling, or co-authorship relations.

2. Materials & Methods

2.1 Scopus search

Scopus database was used to retrieve bibliographic records related to precision agriculture research for the period 2000-2016. We did not use Web of Science because it was not available to us, whereas Google Scholar offers results of inconsistent accuracy (Aguillo, 2011).
To identify relevant precision agriculture publications in Italy, we used the following keywords in the combined field of title, abstract and keywords: precision PRE/3 agriculture OR precision PRE/3 forestry OR precision PRE/3 viticulture OR precision PRE/3 farming OR precision PRE/3 aquaculture.
The Scopus search was conducted on January 2017 and for this reason 2016 publications were not yet completely introduced in the Scopus DB by the Scopus staff and could result underestimated. The search was restricted to publications written in English and collected using only the Scopus database.

2.2 Bibliometric mapping and clustering

We constructed several bibliometric maps based on retrieved publications, using the VOSviewer software (freely available at www.vosviewer.com). The software was specifically developed for creating, visualizing and exploring science's bibliometric maps (van Eck and Waltman, 2010). The software can produce different outputs: the term-map, the term citation maps and the term year map.
First, we produced the so-called term maps, also referred as co-word maps (Peters and Van Raan, 1993). A term map is a two-dimensional representation of a research field, in which strongly related terms are located close to each other and less strongly related terms are located further away from each other. Thus, term maps provide overviews for identifying the structure of a field. Thanks to natural language processing techniques employed by the software, all terms occurring in titles, abstracts and keywords of publications were analysed. A linguistic filter is then applied to filter out not relevant terms as well as terms occurring in a small number of publications (van Eck and Waltman, 2011).
To display the elements on maps, the software uses the VOS mapping technique (van Eck and Waltman, 2010). The idea of VOS mapping technique is to minimize a weighted sum of squared Euclidean distances between all pairs of items through an optimization process.
This mapping approach allows lying out terms on the map in a way that the distance between each pair of terms represents their similarity as accurately as possible. Specifically, similarities among terms are calculated based on their number of co-occurrences in the title or abstract of the same publication (for further explanation on the method see van Eck and Waltman, 2010). The larger the number of publications in which two terms co-occur, the stronger the terms are related to each other. Therefore, terms that often co-occur in the same publications are located close to each other in a term map and less strongly related terms (low co-occurrence) are located further away from each other. Each term is represented by a circle, where its diameter and the size of its label indicate the number of publications that have the corresponding term in their title, abstract or keyword.
To identify clusters of related terms, the software uses a weighted and parameterized variant of modularity-based clustering, that is the VOS clustering technique (Waltman et al., 2010; Waltman and Van Eck, 2013). A

cluster can be understood as a research theme in which one or more research topics can be identified. Hereafter, we will refer to maps displaying clusters as term maps. We adopted a resolution of 0.85.
We produced also the term year maps. In the term year maps the colour of a term is determined by the first year when the term occurs. The year was normalized ranging from -2 to 2, where the colors are assigned according to these scores. The colours ranged from blue (average score of 2) to green (average score of 0) to red (average score of 2). Therefore, the earlier (blue) or later (red) years when the term appears.
To avoid overlapping labels, only a subset of all labels is displayed in the maps. In addition, a thesaurus file (text file) for VOSviewer was created to ensure consistency for different spelling and synonyms (an example: Real Time Kinematic is changed with RTK). Before obtaining maps, VOSviewer offers the possibility to clean out the data by omitting those terms considered not relevant for analyses. Therefore, we performed the cleaning by omitting terms related to time, publishers' names and geographical locations (i.e., names of cities or countries) or terms that could be used ambiguously (an example: addition or view).
It should be noticed however, that a term maps represents a simplified version of reality and this can lead to loss of information and to a partial representation of the investigated field. This limitation should be considered when interpreting a term map.

3. Results & discussion

3.1 Publication trends

We retrieved a total of 802 scientific publications from Scopus database over 17. Figure 1, depicts the precision agriculture publication frequencies from 2000 to 2016 in Italy. The number of publications generally increased exponentially after 2008.

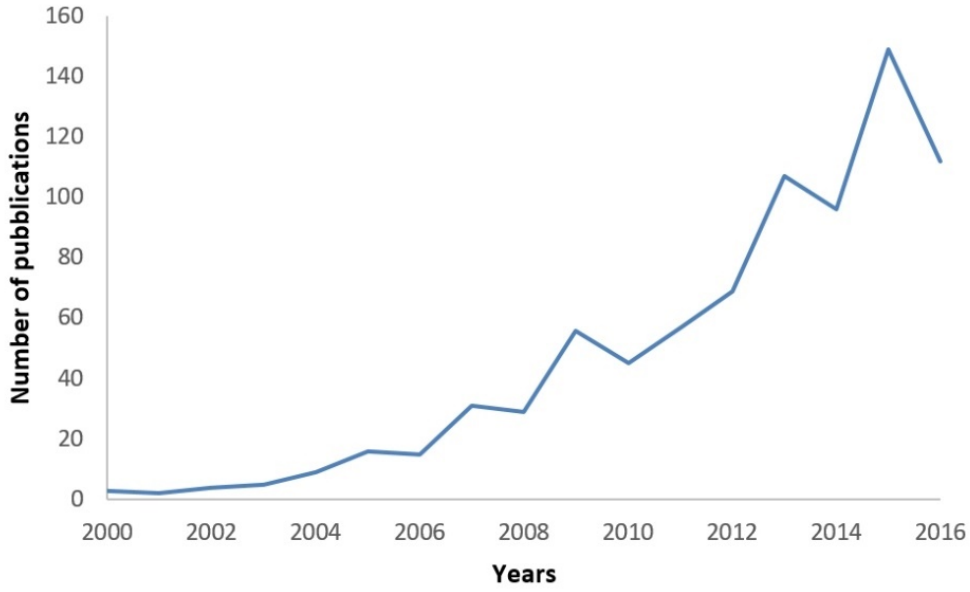

Figure 1: Trends in precision agriculture publications from 2000 to 2016 in Italy.

3.2 Italy evolution of research topics and their citation impacts

Figures 2 and 3 display the term maps (Fig. 2) and term year map (Fig. 3) from 2000 to 2016.
We should note that in term maps colours are used to identify clusters of related terms, while in citation map the colours indicate the average citation impact of publications in which the term occurs and in year map the colours indicate the timing when the term occurs.
Figure 2 shows the Italian term maps constructed for the period 2000-2016. The about 200 terms displayed on the maps are grouped in four clusters. The clusters appear to be clearly distinct and without overlapping. The Red cluster (69 terms) mainly represents research inherent technology and its direct applications, thus "quality", "production" and "monitoring". The terms "quality" is crucial in the Italian agri-food panorama, being connected to the main typical production chain. In addition, animal farming terms clusterise graphically almost as a separate area on the extreme right while forestry (Corona et al., 2017) does not appear.

The Blue one (60 terms) include terms mainly grouping topics related to “spatial variability” and “yield” embracing the geostatistics. It is interesting to see how “proximal sensing” is included in such cluster while the Green cluster (64 terms) normally implement terms related to spectral data acquisition, “mapping”, “index” and spectral data management in general. Moreover, the Green cluster includes statistical terms as well.
The last and smallest cluster is represented by the yellow one (7 terms) is extremely focused on viticulture and wine which is an Italian distinctive production.
Since the lines connecting the terms marks indicate co-occurrences, is interesting to notice as the Yellow viticultural sector appear to be linked with the term “quality”. On its side “quality” is also strongly linked, besides many terms of its own cluster, to “yield” and “spatial variability” of the Blue one. Is than present the natural connection between “spatial variability” and “index”.

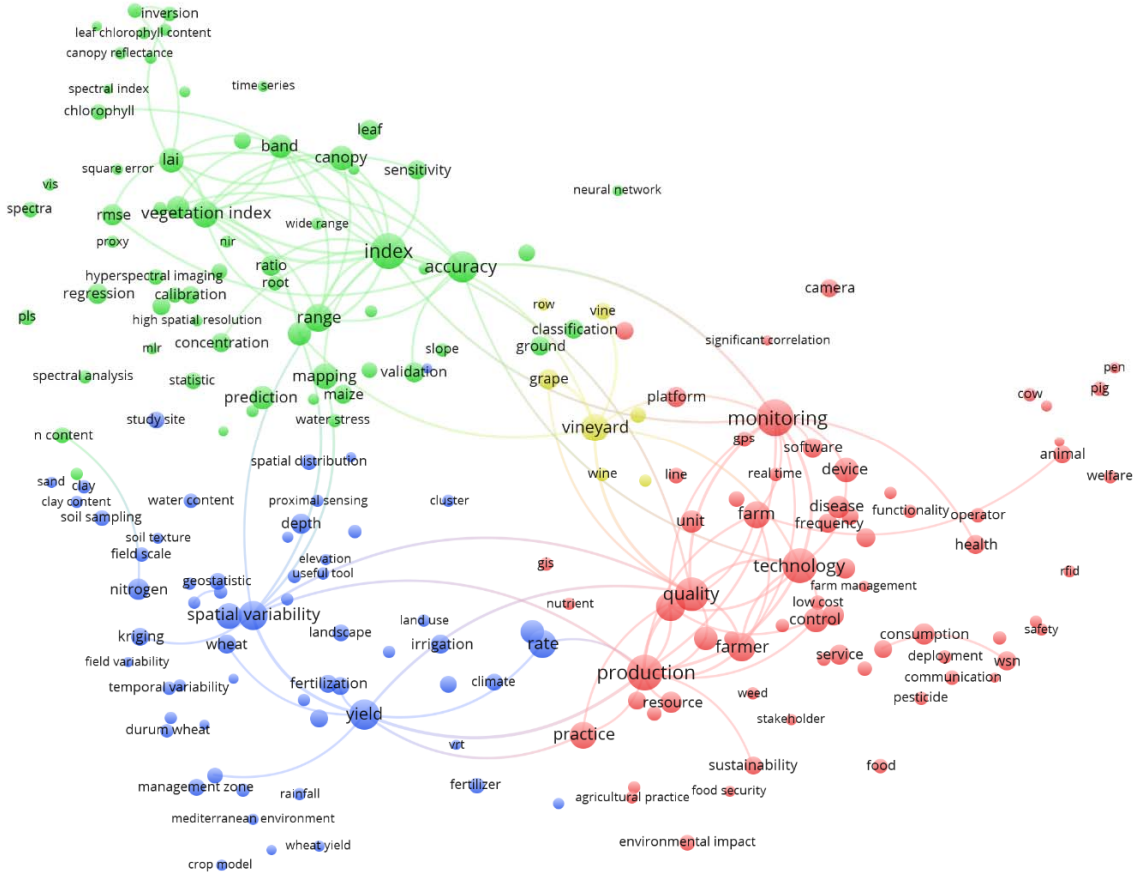

Figure 2: Term maps based on Italian precision agriculture publications for the period 2000–2016. Lines (100) indicate co-occurrence links between terms.

Figure 3 shows the Italian term year maps constructed on the period 2000-2016. It is possible to observe how some of the earlier terms (bluish in Figure 3) embrace area of study like geostatistics (*e.g.,* “kriging”; bottom left side) and topics related to canopy spectral analysis (*e.g.,* “lai” “band” and “canopy reflectance”; upper left side).
The later terms (reddish in Figure 3) appear to be sparse with some crucial focus points raising in the lasts years such as “animal” “welfare”, “operator” “health” and “food” “security” and “sustainability”.

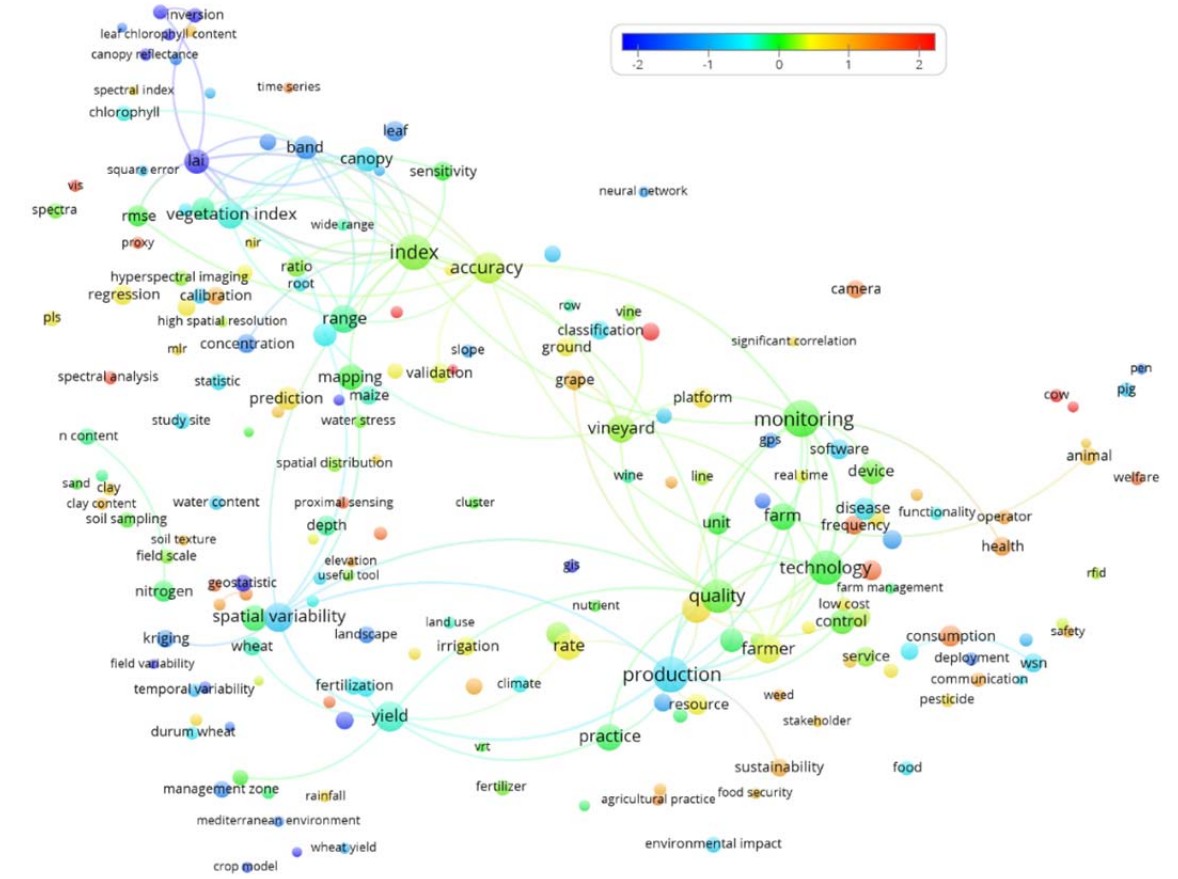

Figure 3: Term year map based on Italian precision agriculture publications for the period 2000–2016. The scale represented the earlier (blue) or later (red) years when the term appeared. Lines (100) indicate co-occurrence links between terms.

4. Conclusions

The PA research panorama appeared to be diversified with some focal point on new technologies and upcoming topics relevant to the agricultural and food scene like “animal” “welfare”, “operator” “health” and “food” “security” and “sustainability”. Moreover, the viticultural sector appear to be neatly distinguished from other terms clustering on its own as a typical Italian high quality production.

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