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Characteristics of “work in agriculture” scientific communities. A bibliometric review

Priscila Duarte Malanski¹ · Sandra Schiavi² · Benoît Dedieu¹

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Abstract

Work is a central concern for sustainable farming systems and rural communities, especially regarding specific issues of the agricultural sector, as the strong decrease in rural employment and the less attractive working conditions. Many articles covering diverse related topics have been published. However, the few studies analyzing the state of worldwide scientific research on work in agriculture give only a fragmented view, since they focus on specialized topics and disciplines. To fill this knowledge gap, the aim of this study was to review the state of research on work in agriculture addressed by the scientific literature, through a bibliometric analysis by country, institution, journal, author, and keywords. Our main finds are that (1) work in agriculture issues is divided into six main research domains: occupational health and safety, labor market and rural employment, labor and farm sustainability, work organization, agricultural policy and agrarian changes, and labor and family farms; (2) these research domains are analyzed by five scientific communities: ergonomics, agricultural economics, livestock farming systems, rural sociology, and agricultural policy; (3) the reference authors, most-cited articles, and main journals were identified for each scientific community; (4) USA, France, and China arise as leaders in the scientific landscape. We show for the first time the characteristics of the main scientific communities worldwide that have performed the most relevant research related to work in agriculture over the past 10 years. This review provides a benchmark for future research on agricultural work-related topics and encourages collaborations between researchers from different scientific communities for interdisciplinary innovation, which support sustainable working conditions in agriculture.

Keywords Work · Agriculture · Bibliometric analysis · Communities

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1 Introduction

Work is a major concern for the future of agriculture around the world, since agriculture is a labor-intensive sector

employing 27% of the world's working population in 2017 and generates income for most rural families and feeds the world through auto-consumption and markets (World Bank 2018). Nonetheless, the agricultural sector is facing a large decline in employment (− 50% since 1990) and lower attractiveness than other sectors, with long working hours, precarious working conditions, and low wages (World Bank 2008, 2018).

Several studies have stressed the importance of work for sustainable farming systems and rural communities (Jafry and O'Neill 2000; Lebacqz et al. 2013; Santhanam-Martin and Nettle 2014; Navarrete et al. 2015) (Fig. 1). Nonetheless, the few studies analyzing the state of worldwide scientific research on work in agriculture give only a fragmented view, since they focus on specialized topics and disciplines (e.g., assessing workload on dairy farms (Oliveira et al. 2017), importance of rural labor in agricultural economics (Chen et al. 2018)). An overall view of the literature can provide benchmark knowledge about the scientific communities researching work in agriculture. We define a scientific community as a group of the main institutions, reference authors, most-cited articles, related keywords, and journals related to a specific research domain. Reflecting on the future of agriculture around the world requires knowing the contribution of each scientific community in order to develop frameworks that better integrate the many aspects of work, since each discipline analyzes related topics according to its own approaches and methods. Interdisciplinary approaches are useful to consider the linkages of different aspects of work (e.g. gender, employment, labor productivity, etc), which can renew frameworks by closing the gaps between the current knowledge and matters in the farmers' work (e.g. labor allocation choices,



Fig. 1 Family farmers and temporary employees harvesting high-quality coffee in Paraná, South region of Brazil. Coffee production generates income for workers and contributes to the development of the local community. Photo: Sandra Schiavi

working conditions, work organization, etc.) (Dedieu and Damasceno 2016).

The aim of this study was to review the state of research on work in agriculture addressed in the scientific literature, through a bibliometric analysis by country, institution, journal, author, and keyword. We first describe how data from the scientific literature on work in agriculture were obtained from a bibliographical database. We then describe the scientific articles identified, which allowed us to characterize the main scientific communities worldwide performing the most relevant research on work in agriculture over the past 10 years.

2 Building and analyzing the database

The database was built by retrieving 562 articles from the Web of Science Core Collection citation index, particularly the Science citation index, and the Social Science citation index. Raw data were composed of authors, title, journal, keywords, funding agencies, and citation frequency of each article.

A query was used to retrieve the articles. To highlight recent international research on work in agriculture, the query was limited to articles published in the past 10 years (2008–2018). Although English was the target language of the query, we recognized the richness of vocabulary related to work in other languages (e.g., “trabalho”, “tarefas”, and “atividade” in Portuguese; “travail” and “taches” in French). Since these words could be translated as “work” or “labor”, we restricted the language of the query to English to avoid potential bias in the keyword analysis. Two steps were followed to define the terms of the query: identify a set of standardized vocabulary related to “work” and “agriculture” in the AGROVOC thesaurus, and then enrich the vocabulary with non-standardized related terms. Ultimately, the Web of Science query was the following: “(work OR labor OR labour OR task OR tasks) AND (agriculture OR agricultural OR livestock OR crops OR fishing OR horticulture OR farm OR farming OR rural)”. Thus, the articles retrieved contained at least two of these terms in article titles.

Terms such as “activity OR activities” used in ergonomics and “practice OR practices” used in agricultural sciences were excluded from the query. Their association with terms such as “agriculture OR agricultural” resulted in many off-topic articles related to agronomics, such as impacts of agricultural practices on soil conservation. The query was focused in general terms related to work in order to decrease the misrepresentation of groups of specific terms, since the research in the bibliographical database is keyword-oriented. For example, adding in the query terms like “employment”, “employer”, and “employee” could result in an over-representation of employment relations or human resources management.

Bibliometric analysis of the raw data was performed using the “Analyze Results” tool of the Web of Science. Analysis

was based on the number of articles published according to the following criteria: country, funding agency, journal, author, and most-cited articles. Network analysis of keywords was performed using the CorText Platform (IFRIS and INRA, <https://www.cortext.net/>) to identify the main research domains related to work in agriculture in the scientific literature. The Louvain algorithm was used to calculate distributional metrics and detect communities based on the frequency of co-occurrence of keywords (Tancoigne et al. 2014). Results were displayed in a map composed of nodes (i.e., keywords) and links between nodes. Nodes are represented by triangles whose size indicates the number of connections with other nodes. Lines linking nodes indicate mutual citation, and their shade of gray indicates the intensity of linkages. The distance between nodes represents how frequently they are associated, short distance means that nodes are most often associated. Communities (groups of nodes) are grouped within colored circles, which indicate a high density of internal links among nodes. Scientific communities were identified by linking the reference authors, main institutions, most-cited articles and main journals of each research domain.

3 Characteristics of literature on work in agriculture

3.1 Institutional context of research: countries, institutions, and funding agencies

Both developed and developing countries were concerned by work issues in agriculture from 2008 to 2018. Among the 75 countries identified, the United States (USA), England, and

China were the main contributors, with 54% of articles (Fig. 2). Almost 750 institutions researched work in agriculture. The top 15 institutions published 28% of the articles. American universities and French research institutes published the most (Fig. 3). More than 400 agencies funded research on work issues in agriculture, but North American and Chinese agencies were the leaders (Table 1). The three agencies that funded the most were the National Natural Science Foundation of China (12 articles), the USA's National Institute for Occupational Safety and Health (9 articles) and the USA's National Science Foundation (5 articles). Nearly half of the funding agencies that published the most were focused on health, two funded research in social sciences, but the others did not specify a target discipline.

3.2 Overview of journals and disciplines

Articles were published in 326 journals, of which 17% were published in the 15 journals that published the most articles (Fig. 4). Two main journal groups were distinguished: (1) disciplinary journals in agricultural medicine (health and ergonomics) and agricultural economics (the two dominant disciplines) and (2) multidisciplinary journals associating social sciences and agricultural sciences.

3.3 Productive authors, their affiliation, and the journals of publication

More than 1565 authors published research on work in agriculture. The 15 most productive authors (Table 2) produced 15% of the articles in the past 10 years. Except for C. Stringer and J.E. Taylor, all authors published with one or more co-

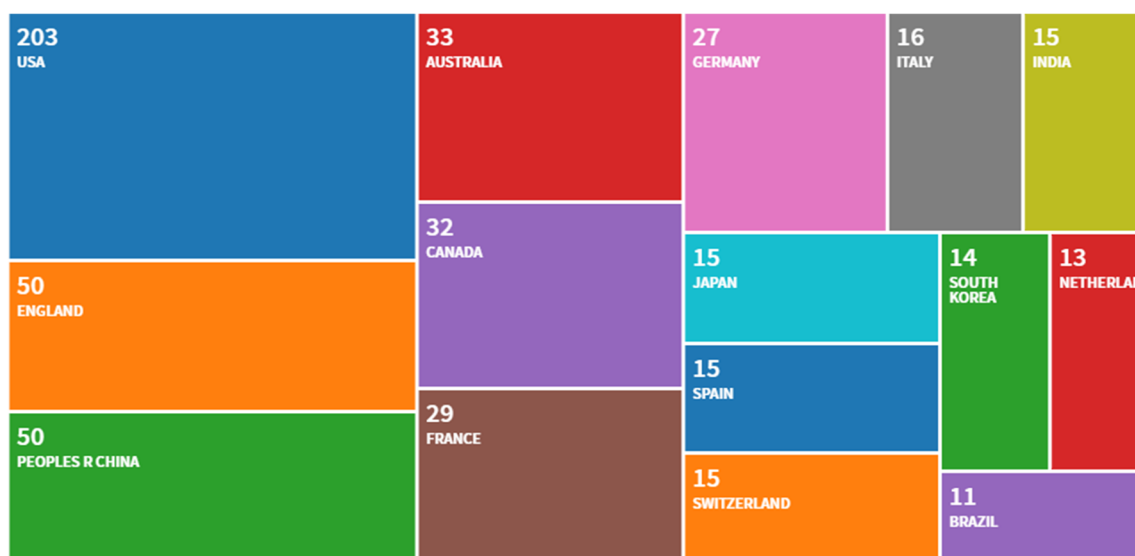


Fig. 2 The top 15 countries publishing articles on work in agriculture from 2008 to 2018. The size of each rectangle represents the relative number of publications by country. The number of publications is indicated above the country's name



Fig. 3 The top 15 institutions publishing articles on work in agriculture from 2008 to 2018. The size of each rectangle represents the relative number of publications by institution. The number of publications is indicated above the institution's name

authors. Co-author partnership followed two strategies: intra-institution (i.e., same institution but different departments) or inter-institution (i.e., different national or international institutions). Ten of the most productive authors (Table 2) worked in the six universities or research institutes that published the most research on work in agriculture (Fig. 3).

American authors were dominant in the top 15 list. T.A. Arcury and S.A. Quandt (both Wake Forest School of Medicine) were the most productive authors, focusing on occupational injury. This theme is the main topic among the most productive authors over the past 10 years. The next most productive were A.K. Mishra and H.H. Chang (Louisiana State University and National Taiwan University,

respectively), who contributed to economic analysis of off-farm work and farm income. They were followed by B. Dedieu and N. Hostiou (French National Institute for Agronomic Research (INRA)), who researched work organization in livestock farming systems.

Contributions of the most productive authors were characterized by empirical studies or analysis of survey data. Only four of the most productive authors wrote methodological or review articles. Three methodological articles were published by B. Dedieu and N. Hostiou on assessing work organization in livestock farming systems (Madelrieux and Dedieu 2008; Madelrieux et al. 2009; Hostiou and Dedieu 2012). Two review articles were published, one with L. Stallones as a co-

Table 1 The top 15 agencies funding research on work in agriculture from 2008 to 2018 by number of publications

Institution	No. of publications funded	Country
National Natural Science Foundation of China	12	People's Republic of China
National Institute for Occupational Safety and Health	9	USA
National Science Foundation	6	USA
National Institute of Environmental Health Sciences	5	USA
European Union	4	European Union countries
Canadian Institutes of Health Research	3	Canada
East Carolina University	3	USA
Louisiana State University	3	USA
Fogarty International Center - National Institutes of Health	3	USA
National Social Science Foundation of China	3	People's Republic of China
Swiss National Science Foundation	3	Switzerland
French National Research Agency	2	France
Canadian Centre for Health and Safety in Agriculture	2	Canada
Economic And Social Research Council	2	USA
Wake Forest School of Medicine	2	USA



Fig. 4 The top 15 journals publishing articles on work in agriculture from 2008 to 2018. The size of each rectangle represents the relative number of publications by journal. The number of publications is indicated above the journal's title

author about fatal and non-fatal injuries on dairy farms (Doughrte et al. 2013), and the other by J.E. Taylor on migration policy and agricultural labor (Taylor 2010).

Most articles by the most productive authors were published in 17 journals, which were classified into four disciplines:

- Occupational health, with six journals (i.e., Journal of Agromedicine, American Journal of Industrial Medicine, American Journal of Public Health, Journal of Safety Research, Annals of Agricultural and Environmental Medicine, and Occupational and Environmental Medicine)
- Agronomy and animal science, with five journals (i.e., Animal, Livestock Science, Agronomy for Sustainable Development, Tropical Animal Health and Production, and Cahiers Agriculture)
- Agricultural economics, with three specialized journals (i.e., Journal of Agricultural and Resource Economics, Agricultural Economics, and Applied Economics)
- Policy, with three journals (i.e., Food Policy, Marine Policy, and Journal of Policy Modeling).

3.4 Most-cited articles

Articles presenting results of empirical studies or database analysis were cited more frequently than methodological or review articles. Only the review article by F.A. Fathallah (University of California Davis, USA) and the methodological article by S. Madelrieux and B. Dedieu (INRA, France) figured among the top 15 most-cited articles (Table 3). K.

Preibisch (University of Guelph, Canada) was the only author who published two most-cited articles. In comparison, T.A. Arcury (Wake Forest School of Medicine, USA) and B. Dedieu (INRA, France) were the only authors in the top 15 lists of both most-cited articles (Table 3) and most productive authors (Table 2).

Most journals that published the most-cited articles were related to agricultural medicine (including ergonomics) and agricultural economics, while some journals emerged that addressed diverse topics, such as migration, gender, and policy (Table 3). Among the 15 most-cited articles, most came from developed countries, and more than half came from North America, mainly the USA (Table 3). American universities were the main institutions behind the most-cited articles.

3.5 The domains of research from keywords to linkages and pools

Approximately 1800 keywords were identified in the 562 articles, showing the diversity of the vocabulary used to describe the topics related to work in agriculture. The most common keywords (Table 4) allowed us to identify the topics researched:

- Gender and generation: “child labor”, “gender”
- On-farm work, workers and labor productivity: “farmers”, “farm workers”, “farm labor”, “work organization”, “labor productivity”, “technical efficiency”, “efficiency”, “mechanization”
- Health at work: “injury”, “occupational health”, “occupational exposure”
- Off-farm work: “off-farm work”, “off-farm labor supply”
- Migration and unemployment: “migration”, “labor migration”, “poverty”, “unemployment”

Table 2 The 15 most productive authors publishing about work in agriculture from 2008 to 2018. Authors are grouped according to the presence of co-authors and the number of articles published on work in agriculture. The position of co-authors (first, second, etc.) was not considered

Author	Co-authors	No. of articles	Keywords	Journals	Affiliation	Country
Arcury TA	Yes	9	Agricultural safety; Occupational health; Migrant farmworkers	- <i>American Journal of Public Health</i> - <i>Journal of Agromedicine</i>	Wake Forest Sch. Med., Dept. Family & Community Med.	USA
Quandt SA		9	Agricultural safety; Occupational health; Migrant farmworkers	- <i>American Journal of Public Health</i> - <i>Journal of Agromedicine</i>	Wake Forest Sch. Med., Dept. Epidemiol. & Prevent.	USA
Mishra AK	Yes	7	Off-farm work; Agricultural policy; Household income	- <i>Journal Of Agricultural And Resource Economics</i> - <i>Agricultural Economics</i> - <i>Journal of Policy Modeling</i>	Louisiana State Univ., Dept. Agr. Econ. & Agribusiness	USA
Chang HH		6	Off-farm work; Labor allocation decision; Household income	- <i>Agricultural Economics</i> - <i>Applied Economics</i> - <i>Food Policy</i>	Natl. Taiwan Univ., Dept. Agr. Econ.	Taiwan
Dedieu B	Yes	6	Work organization; Labor assessment; Livestock farming systems	- <i>Livestock Science</i> - <i>Animal</i>	French Natl. Inst. Agron. Res., Dept. Sci. Action and Dev.	France
Hostiou N		5	Work organization; Labor assessment; Livestock farming systems	- <i>Animal</i> - <i>Agronomy for Sustainable Development</i> - <i>Tropical Animal Health and Production</i> - <i>Cahiers Agriculture</i>	French Natl. Inst. Agron. Res., UMR Territoires	France
Stallones L	Yes	6	Occupational injury; Rural health; Chinese farmers	- <i>Journal of Agromedicine</i> - <i>American Journal of Industrial Medicine</i>	Colorado State Univ., Dept. Psychol.	USA
Xiang HY		5	Occupational injury; Rural health; Chinese farmers	- <i>Journal of Agromedicine</i> - <i>American Journal of Industrial Medicine</i>	Ohio State Univ., Ctr. Injury Res. & Policy	USA
Browning SR	Yes	4	Occupational injury; Children; Aging farmer	- <i>Annals of Agricultural and Environmental Medicine</i> - <i>Journal of Agromedicine</i>	Univ. Kentucky, Dept. Epidemiol.	USA
Reed DB		4	Occupational injury; Children; Aging farmer	- <i>Journal of Safety Research</i> - <i>Journal of Agromedicine</i>	Univ. Kentucky, Coll. Nursing	USA
Westneat S		4	Occupational injury; Safety; Latino farm workers	- <i>American Journal Of Industrial Medicine</i> - <i>Journal of Safety Research</i>	Univ. Kentucky, Coll. Publ. Hlth.	USA
Hagel L	Yes	4	Occupational injury; Safety; Agriculture	- <i>American Journal of Industrial Medicine</i> - <i>Journal of Agromedicine</i> - <i>Occupational and Environmental Medicine</i>	Univ. Saskatchewan, Canadian Ctr. Hlth. & Safety Agr.	Canada
Pickett W		4	Occupational injury; Safety; Agriculture	- <i>Journal Of Agromedicine</i> - <i>American Journal Of Industrial Medicine</i>	Queens Univ., Dept. Publ. Hlth. Sci.	Canada
Stringer C	No	4	Forced labor; Fishing industry; Global value chains	- <i>Marine Policy</i>	Univ. Auckland, Dept. Management & Int. Business	New Zealand
Taylor JE	No	4	Labor supply; Immigration policy; Farm labor	- <i>Journal of Agricultural And Resource Economics</i>	Univ. Calif. Davis, Dept. Agr. & Resource Econ.	USA

- Developing countries in an empirical context: “China”, “India” and African countries (“Kenya”, “Ghana”, “South Africa”)

Six main research domains were identified when analyzing the linkages among keywords (Fig. 5): occupational health and safety, labor market and rural employment, labor and farm

sustainability, agricultural policy and agrarian changes, and labor and family farms.

The first research domain, occupational health and safety, was divided into two types of occupational injuries in agriculture (including fishing): fatal and non-fatal (the latter in the large red circle, Fig. 5). Three types of workers were

Table 3 Most-cited articles about work in agriculture from 2008 to 2018

Times cited	Author(s)	Title	Journal	Year	First author's affiliation	Country
74	Uchida, E et al.	Conservation payments, liquidity constraints, and off-farm labor: impact of the Grain-for-Green program on rural households in China	<i>American Journal of Agricultural Economics</i>	2009	Univ. Rhode Isl., Dept. Environm. & Nat. Resource Econ.	USA
67	Preibisch, K	Pick-your-own labor: migrant workers and flexibility in Canadian agriculture	<i>International Migration Review</i>	2010	Univ. Guelph, Dept. Sociol. & Anthropol.	Canada
59	Fathallah, FA	Musculoskeletal disorders in labor-intensive agriculture	<i>Applied Ergonomics</i>	2010	Univ. Calif. Davis, Dept. Biol. & Agr. Engn.	USA
59	Brown, S and Getz, C	Privatizing farm worker justice: regulating labor through voluntary certification and labeling	<i>Geoforum</i>	2008	Univ. Calif. Berkeley, Dept. Geog.	USA
47	Arcury, TA et al.	Work safety climate, musculoskeletal discomfort, working while injured, and depression among migrant farmworkers in North Carolina	<i>American Journal of Public Health</i>	2012	Wake Forest Sch. Med., Dept. Family & Community Med.	USA
44	Larson, BA et al.	Early effects of antiretroviral therapy on work performance: preliminary results from a cohort study of Kenyan agricultural workers	<i>Aids</i>	2008	Boston Univ., Ctr. Int. Hlth. & Dev.	USA
35	Alvarez-Cuadrado, F and Poschke, M	Structural change out of agriculture: labor push versus labor pull	<i>American Economic Journal: Macroeconomics</i>	2011	McGill Univ., Dept. Econ.	Canada
32	Preibisch, KL and Grez, EE	The other side of el Otro Lado: Mexican migrant women and labor flexibility in Canadian agriculture	<i>Signs: Journal of Women in Culture and Society</i>	2010	Univ. Guelph, Dept. Sociol. & Anthropol.	Canada
32	Zhang, QF and Donaldson, JA	From peasants to farmers: peasant differentiation, labor regimes, and land-rights institutions in China's agrarian transition	<i>Politics & Society</i>	2010	Singapore Management Univ., Dept. Sociol.	Singapore
32	Maldonado, MM	'It is their nature to do menial labour': the racialization of 'Latino/a workers' by agricultural employers	<i>Ethnic and Racial Studies</i>	2009	Iowa State Univ., Dept. Sociol.	USA
30	Brandth, B and Haugen, MS	Doing farm tourism: the intertwining practices of gender and work	<i>Signs: Journal of Women in Culture and Society</i>	2010	Norwegian Univ. Sci. & Technol., Dept. Sociol. & Polit. Sci.	Norway
30	Day, L et al.	Risk factors for work related injury among male farmers	<i>Occupational and Environmental Medicine</i>	2009	Monash Univ., Accid. Res. Ctr.	Australia
28	Owusu, V et al.	Non-farm work and food security among farm households in Northern Ghana	<i>Food Policy</i>	2011	Kwame Nkrumah Univ. Sci & Technol.	Ghana
28	Huang, JK et al.	Moving off the farm and intensifying agricultural production in Shandong: a case study of rural labor market linkages in China	<i>Agricultural Economics</i>	2009	Chinese Acad. Sci., Ctr. Chinese Agr. Policy	Peoples Republic of China
27	Madelrieux, S and Dedieu, B	Qualification and assessment of work organization in livestock farms	<i>Animal</i>	2008	Irstea, Dev. Mt. Territories Res. Unit.	France

highlighted in studies of non-fatal injuries: migrants, children, and farmers. Migrant Latino workers were strongly related to ergonomic analysis of work on dairy farms, mainly musculoskeletal disorders. Child labor was related to occupational exposure to risk and safety on family farms. This topic was related to gender and labor allocation on small-scale farms in developing countries (e.g., South Africa, Ethiopia, India) with strong socio-economic limitations, such as poverty and unemployment (medium-sized red circle, Fig. 5). Farmers' health was studied in its physical and psychological dimensions,

particularly musculoskeletal disorders, hearing loss, and exposure to pesticides. Special attention was paid to Chinese farms (right-side green circles, Fig. 5, linked to "agriculture" and "China").

In the second research domain, labor market and rural employment, labor demand, and labor supply, including off-farm labor supply, were analyzed according to economic theories (e.g., Lewis turning point) and methods (e.g., stochastic frontier analysis, multinomial logit) (purple circle, Fig. 5). Labor market dynamics were examined by considering labor force

Table 4 The 30 most frequent keywords related to work in agriculture from 2008 to 2018

Keyword	Frequency	Keyword	Frequency
Agriculture	70	Off-farm labor supply	6
Labor	24	Occupational health	6
China	18	Work organization	5
Farmers	14	Agricultural labor	5
Child labor	13	Labor migration	4
Gender	11	Occupational exposure	4
Labor productivity	11	Technical efficiency	4
Farm workers	11	Ghana	4
India	9	South Africa	4
Injury	9	Mechanization	4
Migration	9	Common Agricultural Policy	4
Farm labor	9	Poverty	4
Off-farm work	8	Organic farming	4
Africa	8	Efficiency	3
Kenya	7	Unemployment	3

mobility and age of the population (right-side purple and green circles, Fig. 5, linked to “China”). Studies focused on Chinese agriculture, which is facing substantial structural changes, such as land fragmentation, development of large-scale agriculture, investment in mechanization and increasing agricultural productivity. Links between labor demand, rural employment, and migrant labor were observed (connections between purple circles, Fig. 5). These studies highlighted the precarious labor of migrant. Latino workers working on farms in the USA, while studies in Europe focused on the influence of the Common Agricultural Policy on rural employment.

The third research domain, labor and farm sustainability, was divided into two topics (large yellow circle, Fig. 5). The first topic was labor efficiency in large-scale agriculture, especially in Europe and Africa. Because large-scale farms must be efficient to optimize profits, farm management and labor management were key issues for increasing labor productivity. Economic approaches (e.g., convention theory) and statistical models (e.g., double-hurdle model) were used in analysis. The second topic concerned off-farm labor and food security in households, which was related to agricultural and non-agricultural activities developed by farmers to obtain or diversify sources of income, such as off-farm work and agritourism.

The fourth research domain, work organization (left-side blue circle, Fig. 5), was characterized by the use of farming systems approach to assess work organization on livestock farms, especially dairy farms.

The fifth research domain was agricultural policy and agrarian changes (orange circle, Fig. 5). Agrarian changes were related to employment of migrant labor, mainly in the USA and Brazil. Agricultural policies influence the stability of farm income, a lack of which can be one reason to migrate.

The sixth research domain was labor and family farms (left-side light-green circle, Fig. 5). Allocation of family labor was divided into off-farm labor (e.g., off-farm work, off-farm employment) and on-farm labor. Division of labor was analyzed by gender, generation (e.g., child labor), and family membership (e.g., family labor, hired labor).

4 Scientific communities researching work in agriculture over the past 10 years

Five main scientific communities were identified: ergonomics, agricultural economics, livestock farming systems, rural sociology, and agricultural policy.

Ergonomics focusing on occupational health and safety on farms was the first scientific community. North Americans were the reference authors. In the USA, T.A. Arcuty and S.A. Quandt, (both Wake Forest School of Medicine) specialized in injuries of migrant workers. L. Stallones (Colorado State University) and H.Y. Xiang (Ohio State University) focused on injuries on Chinese farms. S.R. Browning, D.B. Reed and S. Westneat (all University of Kentucky) focused on injuries in different generations (children and elderly people). In Canada, L. Hagel and W. Pickett (University of Saskatchewan and Queens University, respectively) were the reference authors. The reference articles were the review of F.A. Fathallah, “Musculoskeletal disorders in labor-intensive agriculture”, published in *Applied Ergonomics*, and the article of Arcuty et al., “Work safety climate, musculoskeletal discomfort, working while injured, and depression among migrant farm-workers in North Carolina”, published in *American*

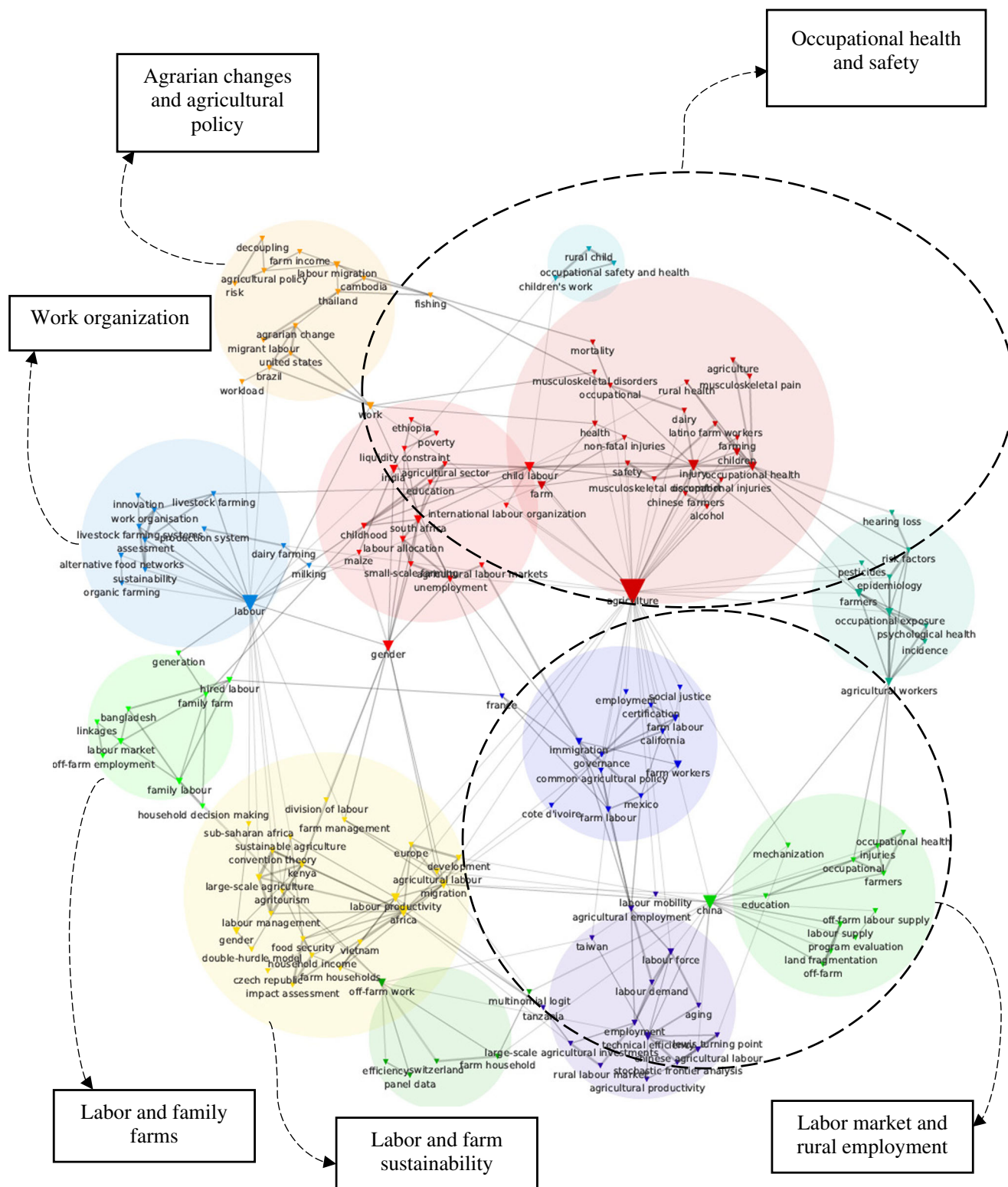


Fig. 5 The six main research domains distinguished according to the keyword network: occupational health and safety, labor market and rural employment, labor and farm sustainability, work organization, agrarian changes and agricultural policy, and labor and family farms

Journal of Public Health. The main journals were *Journal of Agromedicine*, *American Journal of*

Industrial Medicine and *American Journal of Agricultural and Environmental Medicine*.

Agricultural economics, the second scientific community, addressed research on two main topics. For off-farm work and income, the reference authors were A.K. Mishra and H.H. Chang (Louisiana State University and National Taiwan University, respectively). Uchida et al. wrote the reference article, “Conservation payments, liquidity constraints, and off-farm labor: impact of the Grain-for-Green program on rural households in China”, published in *American Journal of Agricultural Economics*. For labor market and rural employment, the reference author was J.E. Taylor. The reference articles were “Structural change out of agriculture: labor push versus labor pull” of Alvarez-Cuadrado and Poshke, published in *American Economic Journal: Macroeconomics*, and “Moving off the farm and intensifying agricultural production in Shandong: a case study of rural labor market linkages in China” of Huang et al., published in *Agricultural Economics*. The main journals were *Agricultural Economics*, *American Journal of Agricultural Economics* and *European Review of Agricultural Economics*.

The third scientific community was characterized by livestock farming system scientists focusing on work organization. The reference authors were B. Dedieu and N. Hostiou (INRA). The reference article was the methodological contribution of Madelrieux and Dedieu “Qualification and assessment of work organisation in livestock farms”, published in *Animal*. The main journals were *Agricultural Systems*, *Animal* and *Livestock Science*.

The fourth scientific community was rural sociology, focusing on two main topics. For migrant workers and labor flexibility, the reference author was K. Preibisch (University of Guelph). She wrote the reference article “Pick-your-own labor: migrant workers and flexibility in Canadian agriculture”, published in *International Migration Review*. The other reference article was “‘It is their nature to do menial labour’: the racialization of ‘Latino/a workers’ by agricultural employers” of M.M. Maldonado, published in *Ethnic and Racial Studies*. For gender and labor, the reference authors were K. Preibisch and B. Brandth (Norwegian University of Science & Technology). They wrote the reference articles, “The other side of el Otro Lado: Mexican migrant women and labor flexibility in Canadian agriculture” of Preibisch and Grez and “Doing farm tourism: the intertwining practices of gender and work” of Brandth and Haugen, both published in *Signs: Journal of Women in Culture and Society*. The main journals were *Signs: Journal of Women in Culture and Society*, *Agriculture and Human Values* and *International Migration Review*.

The fifth scientific community was agricultural policy, which focused on two main topics. For labor and agrarian changes, Zhang and Donaldson write the reference article, “From peasants to farmers: peasant differentiation, labor regimes, and land-rights institutions in China’s agrarian

transition”, published in *Politics & Society*. For global value chains and labor, the reference author was C. Stringer (University of Auckland), however, none of the 15 most-cited articles came from this sub-community. The main journals were *Journal of Agrarian Changes*, *Food Policy* and *Marine Policy*.

The scientific communities show the variety of approaches possible for analyzing work in agriculture.

The most-cited article of each scientific community illustrated the different ways that work was analyzed in agriculture (Table 5). The context of structural changes and intensification of agricultural production was considered by macro-scale changes (e.g., global or national) or micro-scale changes (e.g., farm-level). The drivers of these changes had different natures: economic (e.g., competitiveness), social (e.g., health and working conditions), and technological. The diverse approaches used to understand their impacts on agricultural work were mainstream disciplinary approaches (e.g., economic development theories) or multidisciplinary approaches (e.g., including concepts from management science in a farming systems approach). Methodological procedures were also diverse, since quantitative and qualitative techniques for obtaining and analyzing data were identified. A wide variety of results was observed, including literature reviews (e.g., injuries in agriculture), frameworks (e.g., work organization in livestock farms), models (e.g., econometric model of labor dynamics in agricultural sector), methods (e.g., assessment of work organization), and typologies (e.g., types of non-peasantry farm according to labor supply). In addition to the discussion points about the topics in the articles, the need to cross disciplinary boundaries to address the complexity of work issues was recognized.

5 Scientific communities working towards interdisciplinary innovation

5.1 Major current issues addressed by the scientific communities

Our results reveal that five main scientific communities worldwide developed the most relevant research about six main domains related to work issues in agriculture over the past 10 years. Among them, ergonomics is the largest scientific community. Occupational health and safety are undoubtedly an important issue to improve working conditions on farms, since agriculture is one of the most hazardous sectors for workers in the world (Fathallah 2010). International bodies such as the International Labour Organization have developed standards to avoid hazardous work and to influence policies in its member states (Niu 2010).

This situation may explain why working conditions are the dimension of work that is included the most in frameworks for

analyzing farm sustainability (Lebacqz et al. 2013). Moreover, our results confirm that musculoskeletal disorders are the non-fatal injuries studied most in the agricultural sector (Fathallah 2010), mainly on dairy farms (Doughrati et al. 2013). However, studies have highlighted the importance of an adequate psychosocial work environment, and the influence of stress and depression, on the mental health of farm workers (Melberg 2003; Kolstrup et al. 2008; Wallis and Dollard 2008; Cezar-Vaz et al. 2015).

As expected, some work issues in agriculture remain strongly related to specific scientific communities. For example, the labor market, employment, and income are addressed mainly by agricultural economics (Pfeiffer et al. 2009; Alvarez-Cuadrado and Poschke 2011), while division of labor by gender is addressed mainly by rural sociology (Melberg 2003; Smyth et al. 2018). Our results indicate, however, that contemporary agricultural dynamics has renewed the entry point for discussing work issues, such as diversification of farmer activities (including off-farm work), and the increase in the number of hired workers, especially migrants.

Off-farm work is a major issue. On one hand, it is a strategy to diversify the source of income in households by diversifying farmers' on-farm and off-farm activities. The community surrounding livestock farming systems has developed frameworks to better consider the diversity of activities (e.g., rhythms, priorities) at the farm level and to understand implications of combining on-farm and off-farm activities on the organization of farm work (Madelrieux and Dedieu 2008) and on the perception of the meaning of farm work in such situations (Fiorelli et al. 2010). On the other hand, off-farm work is also a way to step outside the agricultural sector, which has increased the interest of agricultural economists in the allocation of surplus labor from the agricultural sector. Our results show that theories of economic growth were used to understand impacts of these changes on the labor market in both developed and developing countries, but special attention has been paid to countries facing rapid structural changes, such as demographic changes, industrialization, and urbanization. For example, the Lewis Model was used to evaluate surplus rural labor in China and estimate when the rural labor market will reach the turning point (e.g., labor shortage) (Kwan et al. 2018). Labor shortage is identified as an important limitation to development of the agricultural sector worldwide (Nelson 2011; Nettle 2018).

Hiring employees is one way to address this limitation, since hired workers represent 40% of the agricultural workforce worldwide (International Labour Organization 2007). Our results revealed great interest in migrant Latino workers working on dairy farms, notably in the USA, where they represent a large percentage of hired workers (e.g., 40% on Wisconsin

dairy farms (Harrison and Getz 2015)). Indeed, employment of migrant workers is a global trend, as shown by a large body of literature covering a variety of agricultural systems worldwide (Hanson and Bell 2007; Rogaly 2008; Maldonado 2009; Preibisch 2010; Harrison and Getz 2015; Baldoni et al. 2017; Rye 2017; Gómy and Kaczmarczyk 2018).

Combining farmers' activities and the farm workforce (number, type, and employment relations) is a mechanism for supporting farm sustainability. A flexible workforce composition (family workers, employees, contractors) increased labor efficiency on Irish dairy farms that had increased herd size, providing competitive advantages in a highly competitive market (Deming et al. 2018). In Australia, a flexible workforce composition on cotton farms improved farm adaptability to resource constraints in a context of climate variability (Nettle et al. 2018b).

Our results also highlighted important socioeconomic challenges related to work in agriculture. Child labor is one of them, since 75% of child workers in the world work in agriculture (International Labour Organization 2007). They work on commercial crop farms (Morrow and Vennam 2010; Das et al. 2013) and in traditional households (Adonteng-Kissi 2018). In the literature, there is debate around the difference between child labor and child work. Child labor is characterized by economic engagement of children involved in hazardous agricultural tasks; in contrast, child work is a form of socialization, since work is part of life on family farms, without economic engagement of children and no hazardous work affecting their health and development (Adonteng-Kissi 2018).

Poverty is the other challenge, since 767 million people live in extreme poverty, and 75% of them live in rural areas (FAO 2018). Several work-related conditions are related to rural poverty, such as unemployment, low wages, and low household income (Emran and Shilpi 2018; Leonardo et al. 2018). These precarious conditions are linked with child labor (Beegle et al. 2006) and migration for labor (Martin and Taylor 2003). Public policies for rural development and agricultural production are identified as strong mechanisms for addressing these challenges (Deininger et al. 2009; Helming and Tabeau 2018; Gamso and Yuldashev 2018).

5.2 Looking beyond limitations for further research on work in agriculture

Our results shed light on several subjects, although many others mentioned in the international literature were not highlighted. The literature identified some current and significant work-related changes in agriculture, such as technical and technological progress, especially precision agriculture. For example, precision livestock farming is impacting working routines on farms by decreasing the time needed to perform tasks, due to labor-saving technologies (Morgan-Davies et al. 2018), which in turn changes how farmers work with

Table 5 Description of scientific communities' reference articles, illustrating the diversity of topics and approaches to work in agriculture

Scientific community	Ergonomics	Agricultural economics	Livestock farming systems	Rural sociology	Agricultural policy
Title of article	Musculoskeletal disorders in labor- intensive agriculture	Structural change out of agriculture: labor push versus labor pull	Qualification and assessment of work organization in livestock farms	Pick-your-own labor: migrant workers and flexibility in Canadian agriculture	From peasants to farmers: peasant differentiation, labor regimes, and land-rights institutions in China's agrarian transition
Description of reference article					
Background	<ul style="list-style-type: none"> - Agriculture is one of the most hazardous industries in the world - Musculoskeletal disorders (MDS) are the most common non-fatal injury for farm workers 	<ul style="list-style-type: none"> - Decline in agricultural employment - Dynamics of agricultural employment during structural changes 	<ul style="list-style-type: none"> - Structural changes in agriculture (farms getting larger, decline in the family workforce) - Need to combine efficiency (work and production) and livability (working conditions) on farms 	<ul style="list-style-type: none"> - Changes in policies and flexibility in employment relations for temporary migrant workers in Canada 	<ul style="list-style-type: none"> - Contemporary Chinese agrarian transition - Differentiation of agricultural production according to labor supply and land owner or right of use
Driver of changes	Impact of labor- intensive agriculture on health of workers	Technological progress in agricultural and non- agricultural sectors	Request by farmers to help them solve work problems (working regular hours, having holidays, time off on Sundays, efficiency)	Competitiveness of farmers in global markets	- Entry of capitalism into Chinese agriculture leads to agrarian transition
Theoretical approaches or key concepts	Ergonomic intervention approaches to controlling and preventing MDS on farms	Economic development theories: <ul style="list-style-type: none"> - Lewis model - Nursek theory of balanced growth 	- Farming systems approach - Concept of work organization in management science	Concept of labor market flexibility	Concept of commoditization
Method	<ul style="list-style-type: none"> - Literature review of ergonomics - Focus on fresh fruits and vegetables sector 	<ul style="list-style-type: none"> - Temporal series analysis of the share of agricultural employment in developed countries - Econometric modeling 	Literature review of work organization in social sciences (rural sociology, rural economics, management and ergonomics)	<ul style="list-style-type: none"> - Empirical data from interviews with actors (employers, migrant workers, civil servant) - Focus on the horticultural sector 	<ul style="list-style-type: none"> - Empirical data from interviews with actors (farmers, entrepreneurs, managers, staff, government officials)
Main results and discussion	<ul style="list-style-type: none"> - Two approaches to intervention are identified: administrative (e.g. work organization) and engineering (e.g. tools and equipment) controls - Effective ergonomic intervention should include the farm workers' perspective and consider psychosocial and socio- cultural aspects of the work environment - Economic, social, cultural and legal constraints are factors limiting implementation of solutions in developing countries and on smaller family farms - Need for a multidisciplinary approach to deal with 	<ul style="list-style-type: none"> - A model to evaluate the attraction of labor to and out of the agricultural sector - Attracting labor out of agriculture matters more in countries in early stages of the structural change - Technological progress in both non-agricultural and agricultural sectors plays an import role in structural changes - A sequence was identified during structural changes: first labor is attracted out of agriculture, then labor is attracted to agriculture 	<ul style="list-style-type: none"> - Conceptual framework connecting the technical dimension of work organization and livestock farm management - French approach to work organization on livestock farms based on three principles - Two methods to analyze work organization: Work Assessment and ATELAGE - Multidisciplinary approaches could lead to better methods to support farms by improving working conditions 	<ul style="list-style-type: none"> - Political and social construction of vulnerability to ensure a timely and compliant labor force - Vulnerability is a condition to institute more flexible employment arrangements - Discriminatory preferences of employers when choosing the social composition of their workforce (gender and nationality) - Increasing profits by using a vulnerable labor force is the basis for maintaining competitiveness of the horticultural sector in global markets 	<ul style="list-style-type: none"> - Six types of non-peasant forms of agricultural production according to labor supply (family or employees), access to land (owning or renting individual or communal land), and market dependency (no, partial or full dependency) - Emergence of paths of de-peasantisation transforms rural social structure - Capitalist agrarian transition in China promotes rapid development of labor, land and capital markets (commoditization of factors of production)

Table 5 (continued)

Scientific community	Ergonomics	Agricultural economics	Livestock farming systems	Rural sociology	Agricultural policy
	risk management on farms				

animals by modifying interaction situations (visual, aural, and tactile) (Hostiou et al. 2016). In the same way, concerns about human resource management in agriculture are rising in the literature, including studies focusing on employees' skills and career development (Klupšas and Serva 2009; Moffatt 2016; Malanski et al. 2019), employers' management practices (Bitsch et al. 2006), advantages for farm performance (Mugera 2012), and adaptation of advisory services to respond to farmers' needs (Brasier et al. 2006; Nettle et al. 2018a; Dockès et al. 2019).

In line with our results, structural changes in agriculture drive several work-related changes (Lobao and Meyer 2001; Flaten 2002; Martin and Taylor 2003; Lobley and Potter 2004; Alvarez-Cuadrado and Poschke 2011); however, the drivers of these changes were not revealed in our synchronous analysis. Deep investigation into major drivers would help understand dynamics of work-related changes and how research could better support sustainable working conditions in agriculture. We need to deepen research on how agricultural models in territories have impacted work-related changes and agricultural dynamics over the past 10 years (Purseigle et al. 2017) by encouraging certain ones, such as agroecology on small-scale farms (Altieri 1999; Chizallet et al. 2018; Parodi 2018; Finley et al. 2018) and industrial agriculture on large-scale farms (Zlolski 2018; Palliere and Cochet 2018; Suzuki et al. 2018), or by discouraging others, such as communitarian agriculture (Zhang and Donaldson 2010).

This brief insight into relations between contemporary work-related changes exemplifies how work issues in agriculture are diverse and have complex connections, whether in terms of scales (e.g., farm, community, national rural labor market, international migration) or in terms of disciplinary theories and approaches. Such complexity, however, could encourage scientific communities to cooperate by connecting their research domains to promote theoretical and methodological innovation on an interdisciplinary basis (Stock and Burton 2011; Dedieu and Damasceno 2016). This could bring valuable contributions to think about the future of the agricultural sector by improving working conditions on farms while attracting and retaining people in rural communities.

We hypothesize that addressing agricultural work issues at the territorial level could allow researchers to build cooperation between scientific communities and connect different research domains through rural development scenarios aiming to enhance sustainable working conditions. The territory is the

interface level connecting farms, the community beyond farms, and the dynamics between rural and urban areas. Therefore, a territorial approach of work in agriculture could better consider interactions between 1) farming work (e.g., division of labor according to gender, family belonging, skills, employment relations, working conditions), (2) labor dynamics of local community (e.g., rates of employment and unemployment, attractive local structure for new entrants, local network for hiring employees), (3) labor dynamics between rural and urban areas (e.g., migration for labor, off-farm work, development of labor-saving technologies).

Moreover, the territory is the focus because it is the preferred level at which to think about development of rural areas, which concerns rural communities and considers the diversity of farming systems (Aubron 2015), social and agricultural innovation in networks (Audouin et al. 2018), connections between local and global levels through value chains (Bowen 2010), and agri-environmental policies (FAO 2018).

We identified two complementary steps aiming to reach this perspective. The first step is deep analysis of articles from each research domain to identify how work is analyzed; what main concepts, theories, approaches, and methods are used to describe and evaluate work; and what key drivers of changes influence work issues in agriculture. In this sense, some insights were provided by textual analysis of proceedings of the 1st International Symposium on Work in Agriculture, which highlighted issues in current multidisciplinary research, such as rural dynamics changing the involvement of women and younger in farm work, livestock and crop practices and their consequences on work organization at the farm level, supporting advisors' skills in human resource management on farms, and agricultural models driving work arrangements at both farm and territorial levels (Malanski et al. 2018). The second step is to build an interdisciplinary framework to better understand work dynamics at the territorial level and its drivers when considering local development plans and local actors from both agricultural and non-agricultural communities.

6 Drawing the scientific landscape of work in agriculture

Our results provide insights about characteristics of research on work in agriculture over the past 10 years. In the five main

scientific communities, researchers from universities and research institutes in the USA are the most productive authors publishing about work in agriculture. They have a strong influence on international research, given their large number of highly cited articles. Their research is supported by several national sources of funding. Similar results were identified for international research on labor relations in non-agricultural and agricultural sectors (Salmerón-Manzano and Manzano-Agugliaro 2017).

In Europe, research on work organization by French farming system researchers predominates in the scientific literature. INRA is the institution that published most in the analyzed topic. Its influence on animal and agronomic research is indicated by its having one of the most-cited articles and *Agricultural Systems* as one of the main journals. Its research is supported by public funding from France and the European Union. In line with our results, previous studies highlighted the major contribution of French farming system researchers to the study of workload on dairy farms (Oliveira et al. 2017).

China emerges as one of the main countries contributing to research on work in agriculture over the past 10 years, since it was one of the three most productive countries and has the institution that funded the most publications on work in agriculture. The impact of its research is shown by it having funded a most-cited article and the presence of the *China Agricultural Economic Review* among the main journals. The importance of China in the scientific landscape may increase greatly in the next several years because of increasing investment. Previous studies support our findings and indicate that rural labor is a major issue for Chinese research in agricultural economics (Chen et al. 2018).

African countries are common among the most frequent key words in studies of work in agriculture. Although Africa is a common region of study, the contribution of African authors is less visible among the most productive countries and authors, except for one most-cited article. Similarly, Latin America and Oceania have contributed to scientific analysis of work issues in agriculture. Brazil and Australia are among the most productive countries. Australia has one most-cited article, while one of the most productive authors works in New Zealand.

Drawing the scientific landscape of work in agriculture by summarizing this diversity in the literature is a challenge. Thus, limits of our method must be considered. The Web of Science indexes many journals from multiple disciplines and is widely used as a data source in bibliometric analysis in agriculture (Tancoigne et al. 2014; Oliveira et al. 2017). Nonetheless, since other bibliographic platforms, such as Scopus, index social and management sciences more widely than Web of Science, and social science researchers in particular publish widely in non-English languages, using platforms that index non-English articles, such as SciELO, could add valuable insights. Thus, further research is needed to improve

our findings, through a comparative bibliometric analysis of the literature indexed, as well as pointing pros and cons of bibliometric tool provided by the different bibliographic platforms and how these tools impact the analysis of data.

7 Conclusion

Work issues in agriculture are diverse, and their connections are complex. Through this bibliometric analysis of Web of Science articles, we identified five main scientific communities worldwide performing the most relevant research on work issues in agriculture over the past 10 years: ergonomics, agricultural economics, livestock farming systems, rural sociology, and agricultural policy. Reference authors, most-cited articles, and main journals were identified for each scientific community. We showed that work issues in agriculture are divided into six main research domains: occupational health and safety, labor market and rural employment, labor and farm sustainability, work organization, agricultural policy and agrarian changes, and labor and family farms. All of these domains are connected, even though division of the scientific communities implies the opposite. It may be easier to make these connections clear and active by thinking on work in agriculture in development scenarios at the territorial level.

Our bibliometric review provides a benchmark on the different frames of work analysis regarding agricultural research; it is a starting point to identify further research needs. In this sense, a depth investigation of the literature (e.g., textual analysis of articles content) could point research gaps and encourage collaborations between scientific communities to develop cutting-edge interdisciplinary approaches supporting sustainable working conditions in agriculture. Moreover, considering methodological limitations of this work, further bibliometric research is needed to improve our findings. In one hand, include terms in the query from a target topic within one scientific community could provide a specialized bibliometric analysis and specific knowledge gaps in concepts, frameworks and methodologies. In other hand, a comparative bibliometric analysis of literature indexed in other bibliographical database than Web of Science and in other languages than English could both reinforce our results and complement then, especially regarding contributions of social and management science related to work in agriculture.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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