AGRI-FOOD 4.0

Innovations, Challenges and Strategies

Edited by Dr. Rahul S Mor,
Dr. Dinesh Kumar and Dr. Anupama Singh

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ADVANCED SERIES IN MANAGEMENT VOLUME 27

AGRI-FOOD 4.0: INNOVATIONS, CHALLENGES AND STRATEGIES

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FOREWORD

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कुलपति
Dr. Chindi Vasudevappa
Vice Chancellor

राष्ट्रीय खाद्य प्रौद्योगिकी उद्यमशीलता एवं प्रबंधन संस्थान
यूजीसी अधिनियम, 1956 की धारा 3 के तहत सम विश्वविद्यालय (डी–नोवो श्रेणी)
एवं खाद्य प्रसंस्करण उद्योग मंत्रालय, भारत सरकार के अन्तर्गत एक स्वायत्त संस्थान
National Institute of Food Technology Entrepreneurship and Management
(Deemed to be University under Section 3 of UGC Act 1956)
(UNDER MINISTRY OF FOOD PROCESSING INDUSTRIES, GOVERNMENT OF INDIA)

The agri-food industry faces many challenges like food safety, security, demand and supply gaps, maintaining product quality, product traceability, etc. In the current scenario, intelligent digital technologies, including AI, IoT, big data analytics, blockchain, etc., have a complete paradigm shift towards safe, resilient, sustainable, and eventually profit-driven agri-food supply chains. Digital technologies also pave a path to reduce constraints in the supply chain by reducing human interference and improving data accuracy. In this context, the book "Agri-Food 4.0: Innovations, Challenges and Strategies" is scholarly, where researchers from various domains have contributed practice-oriented, case studies based, empirical research and review work.

The concept of 'Agri-Food 4.0' can bring significant changes by reducing food wastage, real-time product monitoring, and reducing scalability issues. The challenges and complexities in the implementation of such technologies have also been addressed well. The book will guide the supply chain and agri-food industry professionals to develop conventional supply chain operations while designing digital technologies. Academicians and researchers will surely be benefitted from this book towards converting the challenges into opportunities through technology-driven smart operations in the agri-be food sector.

(Dr. Chindi Vasudevappa)

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PREFACE

Cost-effectiveness, high productivity and quality are fundamental requirements of any sustainable value chain and have become more crucial with rapid industrialization. In this line, ‘Agri-Food 4.0’ aims to achieve optimum value chain performance through digitized, resilient, innovative systems along with real-time monitoring and control while achieving sustainability. The term ‘Agri-Food 4.0’ is analogous to ‘Industry 4.0’ integrating modern tools and technologies to attain these performance indicators. Such tools and technologies include big data analytics, artificial intelligence, machine learning, IoT, information and communications technology (ICT), blockchain, smart sensors, advanced robotics, and modern drones. This book presents the introduction and applications of such technologies and the practices to reduce food losses and attain a circular economy.

Agri-food quality is crucial to making the product saleable and eventually generating revenue throughout the value chain. Hence, this book elaborates on the implementation of smart technologies like drones to effectively monitor crop quality in real-time. The drone-based quality monitoring system collects image data sets of crop products and classifies them using machine learning methods based on chromatic features, contour features, and texture features.

The integration of IoT in agri-food and supporting hardware tools are most important to achieve agri-food 4.0 and are presented in this book. An IoT-based intelligent irrigation system that controls the water flow based on soil moisture and temperature is also a part of this book. Further, the advancement in food packaging technologies, including smart packaging sensors, is discussed in the book.

Organization of the book: This book is organized as follows.

Chapter 1 describes thematic relationships within the sustainability of agri-food chains oriented toward Industry 4.0, focusing on analyzing scientific production through research articles and technological output according to patents worldwide. Chapter 2 highlights the digitalization of the agri-food supply chain through the implementation of IoT, blockchain, and artificial intelligence and challenges the agri-food supply chain participants perceive in implementing digital technologies. In this line, the Challenges of adopting supply chain 4.0 (SC 4.0) for the agri-food sector and using the total interpretive structural modeling (TISM) tool to analyze those challenges are discussed in Chapter 3. Further, wastage of food is a matter of grave concern, so searching how food waste or food loss could be reduced throughout a supply chain network is addressed in chapter 4. Furthermore, chapter 5 describes, due to growing environmental concern, how Industry 4.0 and blockchain technology (BCT) are transforming circular economy practices and, by employing CB-SEM modeling, provides three key findings. Finally, the role of blockchain technology and most disparate IoT devices in agriculture and the food supply chain for food tracing to address quality and safety is discussed in chapter 6. In Chapter 7, a vision system is introduced that monitors crop product quality with the help of Drone and vision camera technology. Mainly three vegetable crops such as tomato, cauliflower, and eggplant are considered for quality monitoring; hence image data sets are collected for those vegetables only. This chapter extracts three different features information, such as chromatic features, contour features, and texture features, from the data set to train the Gaussian support vector machine-learning algorithm to identify the product quality.

A holistic overview of the latest trends of IoT in agriculture and other aspects of the ecosystem like storage, warehouse ambiance control, agri-data analytics and decision control, logistics, environmental safety, etc., is highlighted in chapter 8. Further application of IoT in irrigation is discussed in chapter 9, which focuses on how the Internet of Things develops a Smart Irrigation system that leads to the optimization of water resources.

Chapter 10 aims to study artificial intelligence (AI) based product benefits and problems of the agritech industry. The study shows that the topmost AI benefit is better information for faster decision making and the topmost AI problem is resistance to change from employees and internal culture. Packaging plays a crucial role in satisfying consumer's demand for safe and quality foods; the same is discussed in Chapter 11, which focuses on different types of Active and intelligent packaging and its advantage over conventional packaging. In line with the Industry 4.0 technologies, chapter 12 explores the key performance indicators of agri-food supply chain. Finally, chapter 13 covers the innovation and challenges of implementing robotics and authomation technologies toward agri-food 4.0.

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We acknowledge all those people who were involved and helped in completing this book project. Firstly, we would like to thank the authors for contributing their valued time and expertise. Special thanks are due to the reviewers' valuable contributions regarding the improvement of quality, coherence, and content demonstration of the chapters. We also appreciate the referees for reviewing the manuscripts and scholars for editing & organizing the chapters. Finally, the editors are grateful to their parent institutes, National Institute of Food Technology Entrepreneurship and Management, Kundli, Sonepat - 131028 (Haryana), India, and National Institute of Technology, Jamshedpur (Jharkhand), India, for providing essential facilities to conduct this research work smoothly.

Rahul S Mor
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RESEARCH TRENDS AND INNOVATION PERSPECTIVES ABOUT SUSTAINABILITY AND AGRI-FOOD 4.0

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Ricardo Alberto Cravero,
Alejandro Alfredo Regodesebes Urrutia, Marcelo Grabois and María del Pilar Casado Belmonte

ABSTRACT

This study explores the thematic relationships within the field of sustainability of agri-food chains oriented toward Industry 4.0, focusing on the analysis of scientific production, through research articles and technological output according to patents worldwide. Agri-food Industry 4.0 is an expanding interdisciplinary field in which science and technology interactions are increasingly intensifying with a strong link to sustainable development.

This study has used high impact indexed publications (Web of science) and patents as proxy indicators of innovation, which are transformed into two sets of data, reflecting the scientific and technical backgrounds, respectively. On the one hand, both quantitative and qualitative analysis methodologies were used to examine the scientific papers through descriptive analysis, focused on collaborations networks by authors, institutions, and countries, as well as a content analysis of keywords. On the other hand, the analysis of technical background on patent families shows the temporal evolution of technologies with future challenging trends, text mining, main applicants, and geographical examination.

The results show that in the field of sustainability in agri-food chains oriented to Industry 4.0, most research is in the agricultural field in scientific articles, with high impact in climate-smart agriculture. Patent analysis reveals a marked increase in the patenting rate from 2012 and 2013, coinciding with the start of scientific production in this field of knowledge. In spite of the fact that China is the leader country in this technological field, India shows a significant change. Moreover, India is a country that

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is currently showing significant progress, both in the field of scientific production and in its categorization as an innovative country due to its growth in patent filings.

Keywords: Bibliometrics; patentometrics; agri-food chain; technology 4.0; sustainable development; innovation

1. INTRODUCTION

Agri-food chain has undergone an accelerated process of technological evolution over the last decades, becoming sustainable development a key component in the evolution of the system. In this regard, Karwacka, Ciurzyńska, Lenart, and Janowicz (2020) reviewed the literature on carbon footprint of the agri-food sector, highlighting the importance of the impact on the environment due to the requirements of water, energy, land, and chemical compounds that support agricultural, processing, and packaging processes. Therefore, it is vital to understand the causes and at least minimize their occurrence to ensure a future providing of goods for people. Accordingly, the analysis of the technologies used for agri-food processes and the identification of the weakest steps in the chain stand out as an important aspect in order to improve their sustainable performance.

In addition, Ruben and Verhagen (2019) emphasized the analysis of food systems to identify programs that reinforce responsibility, resilience, and inclusiveness in new foods and nutritional aspects, in the framework of food security that should be contemplated by food policies. This analysis entails exploring the trade-offs between production and nutritional goals that exist among stakeholders (producers, traders, processors, consumers, legislators, among others). In such a way, there exists an improvement in the performance of food systems, highlighting the interest in the technology applied in the food chain and the way it can contribute to sustainability and food security.

The 2030 Agenda for sustainable development promotes the 17 Sustainable Development Goals (SDGs) to achieve a more balanced world in peace and prosperity for the planet. This proposal recognizes a key milestone: the report of the "World Commission on Environment and Development: Our Common Future" or "Brundtland Report" of the United Nations (Brundtland et al., 1987). In the 1990s, proposals for action such as cleaner production and eco-efficiency focused on optimizing the use of resources. In the early 2010s, the Food and Agriculture Organization (FAO, 2011) promoted awareness of food waste through the "Global Initiative on Food Loss and Waste Reduction – Save Food", in line with SDG 12.3. Subsequently, Circular Economy (MacArthur, 2013) appears as a way to save waste and use it as food for another part of the food chain, with concepts such as eco-design and "cradle to cradle."

Barrett, Reardon, Swinnen, and Zilberman (2019) identified that the revolution in the agri-food chain, started recently, revolves around innovations in how companies sell to consumers, how they enter the market, the business practices they apply, and a series of technologies such as biophysical, digital, mechanical, among others, being developed, adapted, and diffused. Economists have paid attention to how the agro farms have adopted these technologies. Notwithstanding, the focus should be on the welfare aspects of these revolutions within the agri-food system, such as the cost of food and its quality. Besides, attention must be paid to the power of the market to induce and adopt new technologies. This point should be accompanied by the impact on sustainable development of these new technologies, for instance, those linked to agri-food 4.0. In this regard, Soosay and Kannusamy (2018) analyzed the scope of Industry 4.0 technologies in the agri-food chain in the Australian context, finding that leaders adopt technologies aimed at inter-operational efficiencies and B2B transactions. In addition, the authors claimed the potential vulnerability of small businesses that are somewhat behind in these digital age practices.

In this line, Corallo, Latino, and Menegoli (2018) focused on the relationship of Industry 4.0 to Agriculture 4.0 in terms of data traceability, which would allow the creation of a system of more efficient and sustainable companies. Accordingly, they evaluated a smart supply chain, from a smart factory to a smart farm, where the analysis of data would allow sustainable products and services to reach a smart lifecycle that is implemented through Internet of Things (IoT) applications, analytics, cloud platforms, Artificial Intelligence, and so on. In this regard, food safety can benefit from the transparency brought by technology, low transaction costs, and instant applications as promoted by blockchain (Antonucci et al., 2019).

Additionally, Renda (2019) explored FoodTech as the practice of innovative technologies in the agri-food chain with capacity to take part in the SDGs proposed in the 2030 Agenda, specifically to struggle to reduce hunger and avoid increasing food production. In such a way, precision agriculture, integrity in the value chain, personalized nutrition, and the decrease and restraints on food losses. It is a technology package that integrates sensors, big data analytics, 5G, blockchain, and Artificial Intelligence. It highlights that FoodTech requires the development in a way consistent with all SGDs.

In this regard, Lezoche, Hernandez, Alemany-Díaz, Panetto, and Kacprzyk (2020) conceptualized that Agri-Food 4.0 is a synonym of the term Industry 4.0, coming from Agriculture 4.0 terms such as smart factory, smart farm, FoodTech, among others. According to their analysis, these technologies would make it possible to conserve soil, save water, reduce emissions of carbon, and increase productivity by doing more with less. The authors pay particular attention to the four most innovative technologies: IoT, blockchain, big data, and Artificial Intelligence. For each, they explored the types of functional, economic, environmental, and social impacts that their use as well as the challenges that each brings. They identified that the biggest problem is poor management because it negatively impacts on safety, quality, quantity, unused production and resources, namely human, technological, and natural ones.

The World Economic Forum (WEF) in collaboration with Mckinsey & Co (WEF&-MacKinsey, 2018) conducted a comprehensive work based on the right actions to enable the power of technological innovation, called the Fourth Industrial Revolution (4IR), to collaborate in the transformation of the global food system, aligned with the SDGs of the 2030 Agenda. Therefore, its emergence should be analyzed in a holistic context in order to contribute to the SDGs.

Therefore, this study aims to explore the thematic relationships within the field of sustainability of agri-food chains oriented toward Industry 4.0 (AF4&S), focusing on the analysis of scientific production, through research articles, and technological output according to patents worldwide. Agri-food Industry 4.0 is an expanding interdisciplinary field in which science and technology (S&T) interactions are increasingly intensifying with a strong link to sustainable development. To achieve this research goal, bibliometrics is undertaken so as to obtain the social and cognitive network of scientific production of the field. In addition, the analysis of patents allows the detection of the temporal evolution of technologies with future challenging trends, main applicants, and geographical distribution worldwide.

This study is structured as follows. The next section is a description of the methodology used. Following, the main results and discussion are shown. Finally, this study presents the main conclusions and implications.

2. METHODOLOGY

2.1 Bibliometrics

As previous bibliometric studies (Castillo-Vergara, Alvarez-Marin, & Placencio-Hidalgo, 2018; Capobianco-Uriarte, Casado-Belmonte, Marín-Carrillo, & Terán-Yépez, 2020; Teran-Yepez, Marın-Carrillo, Casado-Belmonte, & Capobianco-Uriarte, 2020), this research follows these five steps: (1) establishment of the field of study; (2) database, (3) research criteria adjustment, (4) codification of retrieved data, and (5) analysis of the information. The definition of the field of this study will be agri-food 4.0 in a sustainable context. The database selection avoids omitting important manuscripts in the search; this work used the major indexed scientific database, Web of Science (WoS) by Singh, Singh, Karmakar, Leta, and Mayr (2020). Then, the research criteria adjustment tries to be as unrestrictive as possible, a wide range of keywords were used for the search grouped in three blocks. The first one included all terms about agri-food sectors, the second block of terms is composed of all definitions concerned with the fourth industrial revolution, and finally, the third block gives the sustainable context. The following parameters were employed to retrieve the search: TITLE-ABSTRACT-KEYWORD ((((“agricult*” OR “agri*food” OR “agro*food” OR “food” OR “food*industr*” OR “food*processing” OR “food*chain” OR “food*supply*chain” OR “food*value*chain” OR “agri*chain” OR “agri*supply*chain” OR “agri*value*chain” OR “agri*food*chain” OR “agri*-food*supply*chain” OR “agri*food*value*chain” OR “AFSC” OR “AFVC”) AND (“fourth industr* revolution” OR “4th industr* revolution” OR “4IR” OR “industr* 4” OR “technolog* 4” OR “industr* 4.0” OR “technolog* 4.0”)) OR (“agriculture 4” OR “agro 4” OR “agri*food 4” OR “agro*food 4” OR “agro*industr* 4” OR “agri*industr* 4” OR “food*industr* 4” OR “agro*industr* complex 4” OR “AIC 4” OR “smart agriculture” OR “smart agro” OR “smart agri*food” OR “smart agro*food” OR “smart agro*industr*” OR “smart agri*industr*” OR “smart food*industr*” OR “smart agro*-industr* complex”)) AND ((“sustain*”) OR (“sustainable technolog*”) OR (“sustainable development”) OR (“circular economy”) OR (“eco*efficienc*”) OR (“cleaner product*”) OR (“cradle*to*cradle”) OR (“eco*design”)). In terms of the search period, once again, to avoid being restrictive and to keep the data as up-to-date as possible, documents published until December 2020 were included. The search was carried on in March 2021 and the period selected was from 2000 to 2020 since the earliest manuscript was located in 2013, including only original articles, book chapters, and reviews. The codification of retrieved data from WoS was using Excel (version 2013). Then, the estimation of performance (e.g., h-index) and identification of productivity indicators, tables, descriptive graphs, and the processing of data before using bibliometric software was carried out. Finally, the analysis of the information (e.g., calculation of performance indicators or the identification of productivity indicators) was carried out using Excel (e.g., calculation formulas). Nevertheless, taking into account the purpose of this research, the most important bibliometric software program was used, namely VOSviewer, v1.6.9, for the illustration, visualization, and discovery of scientific maps (Waltman & van Eck, 2012; Waltman, van Eck, Dekker, & van den Berg, 2010). VOSviewer is a widely used bibliometric tool for creating spatial representations that facilitate the understanding and interpreting of linking networks between keywords, authors, institutions, countries, and journals (Castillo-Vergara et al. 2018; Cobo, Lo´pez-Herrera, Herrera-Viedma, & Herrera, 2011).

The final sample of this bibliometric study has been obtained to analyze the relationship between the agri-food sector and sustainability in the context of the fourth industrial revolution (AF4&S) as reflected in the published scientific production. This study analyzes 382 scientific papers (67% articles, 18% reviews, and 15% book chapters) indexed by Web of Science from 2013 to 2020, cited 3,764 times. These scientific papers have been generated by 1,433 authors affiliated to 698 academic, governmental, and private institutions, located in 95 countries and published in 204 different scientific journals.

2.2 Patentometrics

In this study, some basic concepts should be taken into account, namely patents, patent family, priority, applicants, the International Patent Classification (IPC), and the Cooperative Patent Classification (CPC). Firstly, a patent is an intellectual right granted by a state to exercise a monopoly over an inventive object within the country. Since a patent is valid only within the country that granted it, to obtain an international monopoly, a patent must be applied for in each country of interest. Secondly, the set of patents corresponding to the same inventive object applied for in different countries is called a patent family. Therefore, the study of the geographical scope of patent families stands as an indicator of the potential market. Thirdly, the priority is the first patent of a family that was applied for, and usually corresponds to the country of origin of the assignee, so that the analysis of priorities is an indicator of the degree of innovation of a country. Fourthly, the IPC gives a hierarchical system of language independent symbols so as to classify patents and utility models in conformity with the different areas of technology to which they belong. Every patent is classified by IPC. More than one ICP can be assigned to the same patent. Finally, the CPC is an extension of the IPC and is managed in conjunction by the European Patent Office (EPO) and the US Patent and Trademark Office. CPC is more complete than IPC and describes technologies with a higher level of detail, but only a few intellectual property offices use CPC to classify their patent documents.

The search and analysis of patents was performed using Questel Orbit Intelligence. To obtain the corpus of patent families analyzed, the intersection of three primary corpora was performed, one corresponding to technologies related to agri-food, one corresponding to technologies related to Industry 4.0, and one corresponding to technologies related to sustainability. Subsequently, and after verifying the temporal evolution of the number of patent families per year, the corpus was limited to families whose priorities are after 12/31/2000. This time limit makes it possible to analyze families with potentially valid patents, and at the same time, it is compatible with the time horizon of coining the concepts of Industry 4.0 and sustainability. The strategy chosen to obtain the three primary corpora was an IPC and CPC search. The IPC/CPC search allows obtaining a large corpus of patent families belonging to the chosen group of technologies, whose contents can be analyzed by means of text-mining techniques without introducing bias due to the use of keywords. The primary corpus related to agri-food was obtained using the IPC codes recommended by the UK Intellectual Property Office. The primary corpus of technologies related to sustainability was obtained using the IPCs corresponding to the IPC Green Inventory published by the World Intellectual Property Organization (WIPO), after verifying that, although they describe the range of environmentally friendly technologies, they are compatible with the chosen definition of the concept of sustainability. On the other hand, for the primary corpus of technologies related to Industry 4.0, a selection of

IPCs and CPCs was made by searching for patents where terms related to Industry 4.0 appear, analyzing the IPCs and CPCs with the highest frequency of appearance, truncated at the group level, and adding the IPCs and CPCs that, although they do not correspond to those with the highest frequency of appearance, are clearly relevant to Industry 4.0. This approach is necessary because the use of terms related to Industry 4.0 limits the corpus to those patents where the writer has decided to use them and which also have all their parts indexed in patent databases, since the use of nontechnological terms is common only in the part of the patent document where the state of the art is presented, a part that is not indexed in most patent document databases. To obtain the corpus of patent families analyzed, the intersection of three primary corpora was performed, one corresponding to technologies related to agri-food, one corresponding to technologies related to industry 4.0, and one corresponding to technologies related to sustainability.

3. RESULTS AND DISCUSSION

3.1 Bibliometrics

3.1.1 Descriptive Analysis

The scientific production until 2016 was characterized with a slow growth, then it was increasing from 2016 and 2019 and from 2019 its growth has skyrocketed, accumulating more than 65% of the total production in only two years. The first article published in this area of knowledge entitled *Sustainable food production in marginal lands-Case of GDLA member countries* written by Shahid, SA and Al-Shankiti, A, published in the journal of *International Soil and Water Conservation Research*. This article explains how sustainable food production deals with the changing climate and diminishing water resources in countries belonging to the Global Dry Land Alliance (GDLA). What is more, it includes the concept of CSA. According to Lipper et al. (2014), CSA is deemed as a strategy for changing agricultural development taking into account climate change (Lipper et al., 2014). In addition, Food and Agricultural Organization of the United Nations (FAO) considers CSA as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes Greenhouse gases (mitigation) where possible, and enhances achievement of national food security and development goals." In this concept, the key aim of CSA is highlighted as food safety and development (FAO, 2013); whereas productivity, adaptation, and mitigation are thought to be the three interconnected pillars needed to reach this aim.

The top three authors in publication of articles focused on AF4&S (Fig. 1a), both in production and citations, are Thierfelder, C affiliated with Int Maize & Wheat Improvement Ctr (Zimbabwe), Campbell, BM of Int Ctr Trop Agr CIAT (Colombia) and Univ Copenhagen (Denmark), and Zougmore, RB of Int Crops Res Inst Semi Arid Trop (Mali). These authors have published 8 and 9 articles respectively with an average citation index per article of 28.42 and focused on cereal crop improvement (maize and wheat), in tropical crops and in semiarid zones. In addition, these three authors are part of one of the most extensive interinstitutional and international research collaboration networks. In contrast, the network formed by Meinel, T of the Amazonen Werke H Dreyer GmbH & Co KG, the most productive author with 11 published papers, Grunwald, LC of the Bodenbearbeitungsgerate Leipzig GmbH & Co KG, with six papers, Lentz, S affiliated to Leibniz Inst Reg Geog, Fruhauf M. and Schmidt, G, both belonging to Martin Luther Univ Halle Wittenberg. This network of authors is the most recent creation, basically national (Germany). Finally, the least extensive national and interinstitutional network is formed of

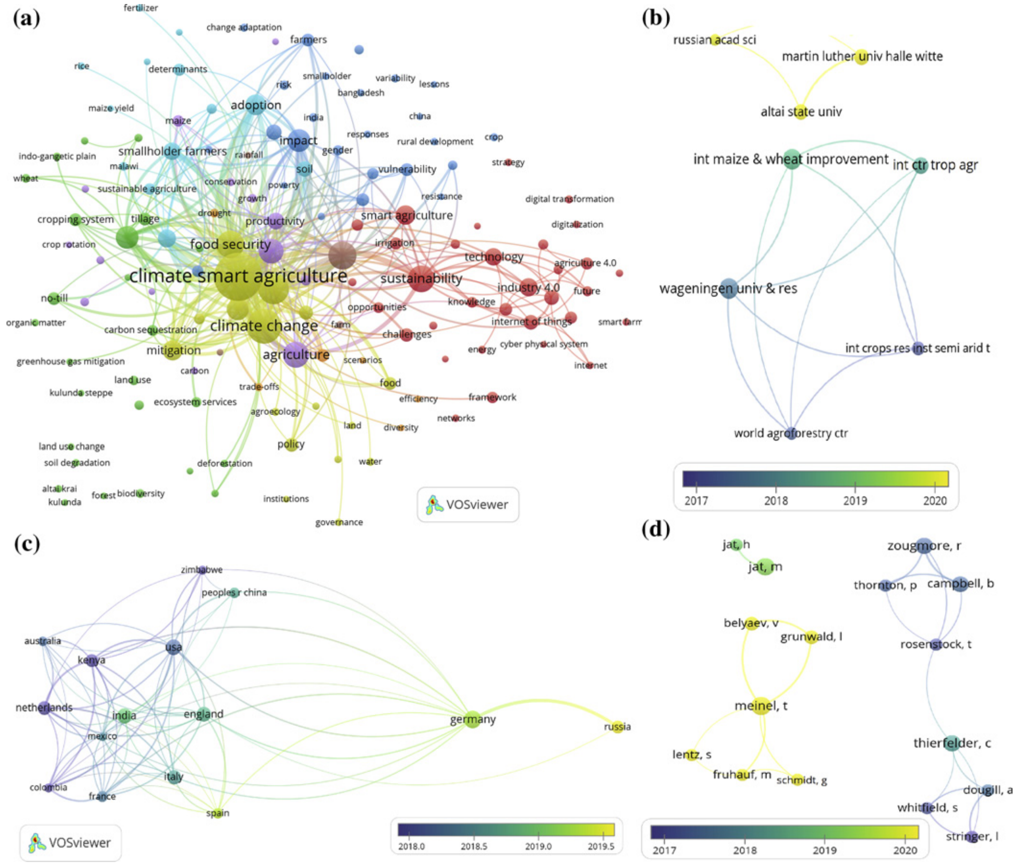

Fig. 1. Descriptive Analysis Focused on AF4&S Overlay (a) Keywords, and Collaborations Networks by (b) Countries, (c) Authors, (d) Institutions. Content Analysis of AF4&S (d). *Source:* Author.

two of the most productive authors, Jat, ML from Int Maize & Wheat Improvement Ctr with 10 published papers and Jat, HS affiliated to Chaudhary Charan Singh Haryana Agr Univ with five published papers.

According to the analysis of interinstitutional scientific production (Fig. 1b), the institutions that stand out are part of international networks. The network composed of Int Maize & Wheat Improvement Ctr, Int Ctr Trop Agr, Int Crops Res Inst Semi Arid Trop, mentioned above together with the most productive authors, to which are added World Agroforestry Ctr ICRAF and Wageningen Univ & Res (Netherlands). This network groups a production of more than 128 articles, with a C/A index of 16.13. The other interinstitutional collaboration network is formed by Russian Acad Sci (Russian), Altai State Univ (Russian), and Martin Luther Univ Halle Witte (Germany) with 47 articles but with a low C/A 0.47.Taking into consideration the production at country level (Fig. 1c), the top five countries are Germany with 61 publications, where more than half correspond to contributions from academic institutions, Martin Luther Univ Halle Wittenberg and Leibniz Inst Reg Geog, and private institutions Amazonen Werke H. Dreyer GmbH & Co KG and Bodenbearbeitungsgerate Leipzig GmbH & Co KG. Germany is closely followed by the USA with 49 publications and India with 48 publications. The scientific production in the USA is highly atomized among scientists, without interinstitutional collaboration networks. India, on the other hand, stands out mainly because of two of its scientists, Meinel T. and Jat H.S., who account for one-third of the total Indian production. The three most cited articles are of the international review type. The most cited is entitled *Sustainable intensification: what is its role in climate smart agriculture?* (Campbell, Thornton, Zougmoré, Van Asten, & Lipper, 2014) with 176 citations. Followed by the articles, both cited 145 times, *Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture* (Harvey et al. 2014), and *Beyond conservation agriculture* (Giller et al., 2015).

Finally, the scientific journals that publish the most in AF4&S with more than 10 articles published in this thematic area are Sustainability (Switzerland) with 20 articles but with a low citation level of 0.65 (C/A) and Agricultural systems (United Kingdom) with 11 articles and a better citation level of 9.36.

3.1.2 Content Analysis

The content analysis provides information regarding research trends on the relationship between agri-food 4.0 and sustainability (Fig. 1a). By analyzing the keywords most used by the authors, a visualization map based on their cooccurrence can be obtained. The analysis of Agri-food 4.0 and sustainability generates 7 keyword clusters.

The red cluster represents the close relationship between technological concepts (IoT, cyber physical system) linked to Industry 4.0 and sustainability, indicating that the application of the fourth industrial revolution is closely related to the sustainable development of agriculture (Smart agriculture, Smart farming, Agriculture 4.0). The yellow and green clusters are closely related to each other. The central yellow cluster is focused on a new concept of recent emergence, climate-smart agriculture (CSA). In the yellow cluster, this CSA concept is accompanied by the keywords climate change, its mitigation, food security and the policies applied to the sector. The green cluster, on the other hand, focuses on the various aspects of climate change (deforestation, soil degradation) and agricultural techniques specialized in mitigating global warming (carbon sequestration, no-till, greenhouse gas mitigation, land use change). The purple cluster is clearly focused on concepts related to agriculture, taking into account productivity and conservation. Finally, the blue