In search of maturity models in agritechs

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Abstract. The agribusiness sector has great importance in the economy, and in order to remain competitive, the number of investments in disruptive technologies and concepts, such as Internet of Things, Physical Cyber Systems, Artificial Intelligence, among others, grows. These concepts are often applied by agribusiness startups, known as Agritechs. To help these startups spread their technologies, and mitigate their high mortality level, the use of a maturity model is a good tool, as maturity models help to identify factors that need to be worked on and improved. The creation of a maturity model for Agritechs is innovative, which makes the definition of possible maturity models to be combined and adapted to develop a maturity model specific for Agritechs. The initial dimensions developed for this model were: Change management dimension, Strategic dimension, Technological dimension, and Sustainability dimension.

Keywords: Agritech; Maturity Model; Sustainability.

1. Introduction
World population is likely to reach the mark of 9.6 billion people by 2050 and 68% of this population is going to be living in urban areas [1]. In this scenario, the production of food has an immense challenge ahead, with food production is expected to increase by 70% to satisfy the new demands of a growing population [2], meaning that the agribusiness sector’s focus is geared towards competitiveness and modernity, with the permanent use of technology as a path to sustainability [3]. Thus, there is great concern about the risks of some agricultural practices and efforts focusing on finding agricultural
solutions in regards to the environment, natural resources and sustainable agricultural systems in the long term [4].

Sustainable agriculture must be ecologically correct, economically viable and socially responsible, and these three dimensions, in so far as they are related to sustainability, are inseparable [5], as sustainable agriculture must nurture healthy ecosystems and support the sustainable management of land, water and natural resources, ensuring global food security [6]. In this context, startups of the agribusiness sector, known as AgTechs, emerged, with focus on sustainable agricultural technology as a way of answering the demands raised after international agreements such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs) [7].

AgTechs have also been called Agritechs [8] or Agrotechs [9] in literature. In this work, from now on, we will use the term “Agritech”. Agritechs can be regarded as startups in the agriculture, horticulture and aquaculture sectors, which are working in the areas of: automation, drones, big data, automated irrigation, georeferencing of machinery, internet of things (IoT), artificial intelligence, sensors, biotechnology and urban farms, with the emerging potential to completely reshape global agriculture, dramatically increasing the productivity of the agricultural system and reducing the environmental and social costs of current agricultural production practices, dialoguing directly with the SDGs 2 (Zero Hunger), 9 (Industry, Innovation and Infrastructure), 12 (Responsible consumption and production) and 13 (Climate Action) [7-10].

The Agritechs ecosystem is fomented by many actors, but there is still a broad scope about Agritechs’ processes, practices and the overall disruption of this concept to be explored [11]. Despite the intense interest on Agritechs, their mortality rate remains high, which can be explained due to a myriad of reasons, such as: the fact that Agritechs are, at their heart, startups, which means they usually lack standardization, have weak organizational structure, and depend on strong leadership to achieve high performance [12]; the difficulties of selling their technologies to farmers, which many times lack digital literacy [13-17], and the fact that many of their projects and products are designed with a technology-driven approach, instead of a more user friendly approach [18]. One way to help Agritechs to grow their business in a sustainable way, while at the same time, mitigating their high mortality rate, would be the development of a maturity model, which can assess the points, strategies, technologies and skills that need to be worked on, helping an entity (or individual) to reach a more sophisticated level of maturity in: people and culture, processes and structures, and objects and technologies, following a step-by-step process of continuous improvement [19]. This model would have the potential to help Agritechs to spread their technologies in a more efficient way, as well as strengthening their organizational structure and leadership.

The principles of a maturity model are structured into three categories: basic, descriptive and prescriptive, however, all maturity models must meet the basic principles [20-21]. The basic principles of a maturity model are: they encompass essential information about the model, as well as the definition of the core constructs related to maturity, maturation and domain of application, and documentation aimed at the model's target audience [21]. To the best of the authors knowledge, there are no maturity models geared towards Agritechs (or their ecosystem). However, whenever possible, a new maturity model should be composed of elements of other (related) maturity models [22-23]. Thus, the goal of this paper is to present the core constructs related to Agritechs in order to create a new maturity model, specific for Agritechs, by first, identifying possible maturity models that can be used as a steppingstone in creating this new maturity model.

2. Methods
To analyze and identify relevant aspects of scientific production on Agritechs, this study adopted bibliometric techniques as recommended by Cobo et al. [24]. The main sources for bibliometric studies are data from bibliographic platforms [25]. Thus, for data collection, the Web of Science (WoS) and Scopus databases were used due to their multidisciplinary nature, worldwide coverage and the volume of indexed works they have.
To understand how the Agritechs research field has developed in scientific production, a search was made on the Scopus and WoS basis, searching in the Keywords, title and abstract fields. The string was simple and used the following keywords: “agritech OR agtech OR agrotech”. As a result, counted until May 15, 2021, 150 articles were obtained, covering the periods from 2003 to 2021, whose information extracted for analysis are: title of the article, authors, keywords, abstract, journal where it was published, year of publication, institution to which the authors belong, number of citations, and h-index, which is an indicator for quantifying productivity and scientific impact, based on the number of citations and publications [26].

The data obtained from Scopus and WoS were then transported to be processed by the scientific mapping tool Science Mapping Analysis software tool (SciMAT), developed by Cobo et al. [24]. This was done to find the most important thematic areas of research involving Agritechs, and, based on that, define which types of maturity models would be more interesting to constitute the thematic basis of a maturity model aimed at Agritechs. In SciMAT, the periods of analysis were defined as followed:

- First Period: From 2003 to 2006. In this period, 3 articles were found;
- Second Period: From 2007 to 2010. In this period, 9 articles were found;
- Third Period: From 2011 to 2014. In this period, 6 articles were found;
- Fourth Period: From 2015 to 2018. In this period, 47 articles were found;
- Fifth Period: From 2019 to 2021. In this period, 82 articles were found.

Since the most significative growth occurred on the last two periods, the thematic areas were chosen from them. The results of this analysis were presented in the following topic.

3. Results

3.1. Core constructs related to Agritechs

The SciMAT software, through a holistic analysis of the Agritech area in the periods of 2015-2018 and 2019-2021, showed that some of the concepts that are being most researched are (figure 1): Agriculture 4.0, Smart Farming, Digital Agriculture, Sustainability and Startups. These concepts were considered the most researched ones given the size of their sphere and the thickness of their lines (see figure 1).

As for the technologies being researched in this field (figure 2), the main ones being researched are: Agricultural Robots, Internet-Of-Thing-(IoT), Big-Data, ICT (Information and Communication Technologies), Sensors, Artificial-Intelligence, Blockchain, Cloud-Fog-Computing, Smartphone. All these technologies are part of the technologies that characterized the concept of Industry 4.0 (I 4.0) [27-28]. To understand figures 1 and 2, it is worth noting that the more solid and larger the line, the more connected the thematic clusters are, while the absence of a line means that no relations were found between the thematic clusters. The thickness of the lines is proportional to the inclusion index, and the volume of the spheres is proportional to the number of published documents associated with each cluster [24].

Agritechs have been associated with the application of the recent approach to innovation ecosystems to the agricultural context. These innovation ecosystems have been used to study the generation of new knowledge, technologies and innovation for the agricultural sector. Therefore, Agritechs and their ecosystem are formed to develop and commercialize agricultural technologies and innovations for the agricultural sector [29].

The term “Agritech”, acronym for “agricultural technology” in English, has come to be used more intensively since 2010, to designate: (a) nascent companies with agricultural technology base (agribusiness startups), (b) new emerging economic sector (Agritechs sector) and (c) innovation ecosystem in the agricultural context [30]. Then, startups can be defined as a group of people in search of a repeatable and scalable business model operating in an environment of extreme uncertainty [31]. Like other startups, Agritechs look for business models with such characteristics, being organizations that somehow work to solve problems whose solutions are not obvious, with no guarantee of success,
but, because they focus on agricultural activities, which by nature work with specific climatic, biological and market uncertainties, Agritechs comprise a study phenomenon with particular characteristics [7].

Figure 1. Thematic Clusters One.

Terms commonly associated with Agritechs, as seen in figure 1, are: Digital Agriculture, Smart Farming/Smart Agriculture and Agriculture 4.0. Digital Agriculture refers to the intensive use of data and the digitalization of processes along the agricultural value chain, aiming to boost complex farm decision making through data analysis, which is the focus of many Agritechs, that seek to find solutions to increase the digitalization capacity of farms through models of digital agriculture based on data [32]. Smart Agriculture refers to the science that incorporates technological advances mentioned above into the body of solutions of the traditional agricultural industry, aiming at new intelligent models of farms with intensive application of information and communication technologies [2]. Finally, the terminology “Agriculture 4.0” refers to the fourth agricultural revolution supported by the great technological advances that created models of intelligent farms [33; 34]. There is a strong association between Agritechs and cutting edge technology and new business models, which can be fomented by universities, as they provide a catalyst for: “innovation, knowledge transfer, entrepreneur development and a well-trained workforce” [7]. Thus, the Agritech ecosystem follows the path of improvement from university to agritechs, from agritechs to the countryside, and from the countryside to the cities, with the goal of maintaining sustainable objectives on this whole ecosystem.

All these different terminologies (Smart Farm, Digital Agriculture, Agriculture 4.0) are intertwine and highlight Agritechs as important agents in the context of innovation and transformation in agricultural production models, however, in our analysis, we found that the one that has the most connection with the concept of Agritech as startups of Agribusiness is the term Agriculture 4.0, as the concept of it includes all available means of automation of production, backed up by the Internet of things, big data, blockchain and other disruptive technologies that need to penetrate into all areas of agricultural production [16] in order to create a more sustainable and efficient agribusiness environment. figure 2 presents the main technologies being researched, in connection with the concept of Agritech. The main technologies were chosen given the size of their sphere and the thickness of their lines (see figure 2), as presented by the SciMAT software.
Figure 2. Thematic Clusters Two.

Each of the main technologies are briefly explained.

- Internet of Things (IoT) appeared to provide coverage for the growing number of heterogeneous Smart Objects that are becoming part of our daily activities [35], allowing the provision of services via the Internet, consisting of business models, infrastructure services and own services [36].
- Smartphones, which are one of the most famous, Smart Devices, have a high potential for the realization of end-to-end digital integration and, later, for a paradigm shift in manufacturing, being key to future scenarios in sector 4.0. Additionally, intelligent objects can interact with the physical world by performing forms of computation, as well as communicating with the outside world and with other intelligent objects [37; 38].
- Big Data refers to information assets of high volume, speed and variety [39], therefore requiring analysis and interpretation of large volumes of highly variable data and which therefore require specific solutions to treat them. them in a timely manner [40].
- Cloud Computing can be understood as a tool that allows access to a shared platform of configurable computational information that can be quickly accessed, transferred and communicated through networks, servers, storage cloud, applications, among others [41].
- Agricultural Robots are basically the robots being used in agricultural processes, seeking to cause minimum mechanical damage to the products, while at the same time, increasing the productivity and safety of agriculture as a whole [42].
- Blockchain, which are event logs (proven to be untouched) and automatically executes transactions without the help of intermediaries [43].
- ICT (Information and Communication Technologies), such as the technologies used in Cyber Physical Systems (CPS), used to connect of the physical world (eg, agricultural activities) with computing, information and communication technologies through networked applications [43].
- Sensors. There are several types of sensors being used in agriculture, such as location sensors (GPS), optical sensors, used mainly to measure soil properties, electrochemical sensors, which provide essential information, such as pH and soil nutrient levels, mechanical sensors, which use a probe that penetrates the soil and registers resistive forces through the use of load cells and capacitive sensors, used mainly to assess soil moisture levels [44]. Thus, the sensors allow you to have quality information about the cultivation, local climate and the soil, obtaining information that goes beyond human perception.
- Artificial-Intelligence, which are intelligence applications for activities that may require unstructured judgments and commands [43].
3.2. Possible Maturity Models to help in the development of an Agritech maturity model

Given the thematic clusters showed in figure 1 and figure 2, we have determined that the development of a basic design of a maturity model geared towards Agritechs must include research on maturity models of Startups, maturity models of Sustainability and maturity models of I 4.0. The latter will be included given the similarities of the concepts of Agriculture 4.0 and I 4.0, and the fact that, at the moment, there are no maturity models for agriculture 4.0.

3.2.1. Maturity Models for Sustainability. Four of the most cited maturity models, that analysed sustainability (as their main focus) were presented.

The maturity model of Kurnia et al. [45] proposed to analyse the maturity, in regards to sustainability, with the use of 6 types of capabilities (and 4 maturity levels): sustainable data collection, which evaluates the ability of a company to gather data related to sustainable practices and its impacts on the organization (and the supply chain); sustainability reporting, which sees the ability of the organization to generate reports on the aspects of sustainable practices (these reports are then send to internal and external stakeholders, as well as the government, whenever necessary); sustainability benchmarking, or the indicators used to compare the sustainability performance on the company and the supply chain; sustainability training, meaning the ability to foment awareness on sustainable practices in their employees and stakeholders; sustainability risk analysis, which identifies and evaluates possible negative consequences of implementing sustainable practices; and sustainability governance, which analyses how the sustainability goals are managed. The model of Babin et al. [46] used three levels of maturity and two elements: a sustainability score, which analyses the compliance with sustainability standards, such as Global Reporting Initiative (GRI), Carbon Disclosure Project (CDP), or ISO 26000; and sustainable capabilities, defined through the use of interviews. The maturity model of Okongwu et al. [47] analysed four levels of maturity attained by organizations in reporting their sustainability initiatives in eight areas (use of standards, performance management, life cycle management, pollution management, relationship management of suppliers, customers and society, employee management, profitability management, and economic value distribution management). The maturity model of Hynds et al. [48] was made for organizations that create innovative and sustainable products (using 4 maturity levels), with two main areas, “strategy” and “design tools”, subdivided into 14 dimensions, corporate sustainability policy, government policy and regulation, green labelling, and sustainability design for the environment). To analyse the maturity of each dimension, it was applied a survey, with the score being evaluated by the sum of the positive responses.

In common, all the maturity models used indicators of sustainability as a tool to help measure the maturity of an organization.

3.2.2. Maturity Models for Industry 4.0. Three of the most relevant models to analyse maturity in Industry 4.0 is presented. The maturity model of Ganzarain and Errasti [49] was created based on three stages: Envision 4.0, a stage in which Vision 4.0 occupies the center of the stage, dedicating itself to construction, based on the company's own understanding of the concepts Industry 4.0, a specific view of the company's capabilities and needs, but focused on a 4.0 environment; Enable 4.0, in this step, the objective is to develop a roadmap to allow the adoption of 4.0 technologies and the improvement of workers' capacities; and Enact 4.0, at this stage, projects related to the adoption of Sector 4.0 are implemented, as well as capacity building and risk management. The maturity model most cited in the literature in the context of Industry 4.0 is the model of Schumacher et al. [50], and uses 9 dimensions to analyse maturity in regards of Industry 4.0, 4 of these dimensions were used to evaluate the basic facilitators of I 4.0 ("Products", "Customers", "Operations" and "Technology") and 5 of them to evaluate organizational aspects (Strategy, where the resources available to carry out a roadmap; Leadership, where the disposition of leaders, managerial skills and methods are analysed; Governance, where labour regulations for I 4.0 are analysed, the adequacy of technological standards and the protection of intellectual property; Culture, where knowledge sharing, open innovation and collaboration between companies is analysed, the value of ICT in the company; and People, where employees' skills in
information and communication technology are analysed, employees are open to new technologies, employees' autonomy employees) [50]. The SM²E maturity model, developed by Mittal et al. [51] seeks to meet the specific needs of small and medium-sized companies, and uses 5 dimensions (Financial, where cost-benefit analysis budgeting and sub-cost control, investments and risk management and returns; People, where leadership is analysed; customer feedback, safety and ergonomics; and, training and education; Strategy, where knowledge management, decision support, organization standards, legal / tax policies are analysed, the sustainability guidelines and government regulations; Process where it is analysed: quality control, work scheduling, repair and maintenance, machine operation and flexibility; Product, where aspects of logistics, development of new products, packaging and, modularity) [51].

In common, the three maturity models analysed aspects of: technology, people (culture/leadership) and strategy.

3.2.3. Maturity Models for Startups. The most cited maturity model that deals with startups was developed by Cuckier et al. [52] and analyses the maturity of the startup ecosystem of São Paulo (Brazil) and Tel Aviv (Israel). The dimensions analysed are: accessible markets, human capital workforce, funding and finance, mentors and advisors support system, regulatory framework and infrastructure, education and training, major universities as catalysts, and cultural support [52].

The similarities between the models of Cuckier et al. [52] and Mittal et al. [50] support the need for the inclusion of sustainability aspects, technology, strategy and people for advancing the maturity in startups.

3.3. Initial Dimensions of an Agritech Maturity Model
Using the information acquired from the works of [45-52], we have synthesized four initial dimensions for a maturity model geared towards Agritechs, as described below.

Change management dimension: In this dimension, the culture, leadership, and behavior of workers in the face of changes will be analyzed. This will require the expansion mindsets, commitment and cooperation between leaders and workers, envision, communication, elimination of obstacles and coordination the change, as indicated by Yang et al. [53].

Strategic dimension: Factors such as knowledge management, Governance (mainly ecosystem governance), Decision Support / Decision Making will be analyzed, which would include business modeling practices, resuming the bottleneck pointed out by the author [12], and, once again related to the ecosystem, it would include practices (like marketing) for approaching partners (investors) and presenting the technology in the consumer market; Standards. We highlight that the integration with the ecosystem (especially with universities, cited by author [7]) is usually related to knowledge management, which will be investigated in this dimension.

Technological dimension: The use of digital resources, of machine-to-machine communication, as well as other technologies used will be analyzed. This will include the use of technology in an integrated and “personalized/optimized” way for the producer's needs and focus on sustainability; accessibility to technology (open innovation [50]). In this dimension, the usability of technology is also highlighted, as pointed out by the authors [13, 17-18]. This dimension also includes user training, complementing the knowledge management of the "strategic" dimension.

Sustainability dimension: The importance given to environmental sustainability policies will be analyzed. One way to achieve sustainability can occur through the "customization/optimization" of technology to the user's needs, which would link this dimension with the technology dimension.

4. Conclusion
Maturity models are of fundamental importance for understanding what needs to be improved in an organization, as they assist in the assessment of factors such as organizational culture, strategy, technological management, often ways of prioritizing improvement measures and monitoring progress. Thus, it is believed that the adoption of disruptive technologies in agribusiness, at the heart of the
adoption of agribusiness 4.0, can be facilitated through the development of specific maturity models for this context.

In this paper, a bibliometric analysis, done with the SciMAT software, identified the main thematic areas of importance of the works that deal with Agritechs. From this, it was possible to realize an exploratory analysis of maturity models that could be the basis of an Agritech maturity model. The Agritech maturity model being developed is still incipient, but has the potential to bring great contributions, both to the academic field and for real world applications. For future research, a systematic review of the literature should be made, to identify more relevant maturity models. Additionally, in order to collect data for the improvement of the maturity model, questionnaires should be applied with Agritechs leaders.

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