


Review

Integrated-Smart Agriculture: Contexts and Assumptions for a Broader Concept

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Abstract: The innovative technologies developed in the different fields of science (nanotechnology, artificial intelligence, genetic modification, etc.) opened new and infinite possibilities for the several stakeholders that carry out their activities in the different economic sectors. For agriculture, these new approaches are particularly relevant and may bring interesting contributions, considering the specificities of the sector, often dealing with contexts of land abandonment and narrow profit margins. Nonetheless, the question in these unstoppable evolutions is about the interlinkages with sustainability. In this context, the objectives of this study are to highlight the main insights from the available scientific literature about the interrelationships between the new trends in the agriculture and the sustainability. To achieve these aims, a search on the Web of Science Core Collection (WoS) and Scopus databases was carried out, on 15 May 2021, for the topics ‘smart agriculture’ and ‘sustainability’. A total of 231 documents (102 from WoS and 129 from Scopus) were obtained, remaining 155 documents after removing the duplicated, which were surveyed through systematic review following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach. As main insights, the concerns of the researchers with the impacts on the sustainability from the transformations in the farming organization are highlighted. On the other hand, it was shown the relevance and the new opportunities, including in terms of food supply, arising from the precision agriculture, agricultural intelligence, vertical/urban farming, circular economy, internet of things, and crowdfarming. We suggest the new and wider concept of ‘integrated-smart agriculture’, better than ‘climate-smart agriculture’.

Keywords: agriculture; new technologies; sustainability; systematic review; PRISMA



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1. Introduction

The technological progress opens several opportunities for the different socioeconomic sectors, including the farming sector, in a perspective of smart agriculture, but brings, also, various challenges [1] threats that may compromise the sustainability of the development process worldwide. One example of this paradigm is the internet of things (IoT). The concept of IoT refers to the digital interconnection of everyday objects with the Internet, connecting objects instead of than people, allowing the intercommunication of data between sensors and digital controllers, for example. IoT is a set of networks which connect things capable of processing and communicating data between each other [2]. Hence, the IoT may contribute to increase the agricultural efficiency in the use of soil, water and energy (some agricultural resources where an efficient management is crucial); however, it also creates new risks associated with confidentiality and integrity [2].

In any case, the agriculture is faced with new challenges, such as the population rising, the urban agglomeration, scarcity of resources, climate change, and waste management. These tasks call for pioneering solutions. The technological development may play here a relevant and determinant role, namely with innovative practices associated with, for example, the vertical/urban farming, seawater and desert farming [3], as well as smart

agriculture [4]. The literature highlights the relevance of the smart agriculture concept and practices to increase the sustainability in the farms. Smart agriculture practices are envisaged as the most appropriate adaptation strategies that will allow achieving food security, while at the same time being able to mitigate climatic changes. This is achieved through the preservation of natural resources and sustainability of vital ecosystem services. Smart agriculture refers to a number of tools that help the management of agricultural resources and crop production. Smart agriculture is relating to the utilization of technologies such as the Internet of Things, sensors, geospatial location, robotics, and artificial intelligence.

Specifically, the artificial intelligence may be crucial for a more efficient use of the resources, but also, for a better disease and pest control, data analysis, productions' management and fill the gap between farmers and knowledge, allowing in this way higher productivities and competitiveness [5]. In general, the scientific community interlinks the artificial intelligence with sustainability and a more circular economy [6]. Potentialities of the artificial intelligence are referred for decades by the researchers [7]. The smart agriculture aims to promote more sustainability, increasing the farming productivity, dealing with the climate change implications and reducing the greenhouse gas emissions [8]. For these aims the artificial intelligence may bring interesting contributions, as well as, other new approaches and technologies, such as the IoT. In the current contexts of climate change [9], the innovation [10] is crucial to achieve sustainable development goals (SDGs) [11]. The agricultural institutions, namely the cooperatives, are fundamental to support the farmers in the process of agricultural digitalization [12] that is in course in the sector [13] in the different world countries. The cooperatives and the associations are important institutions in the farming sector, considering their proximity with the several agricultural stakeholders. To improve the sustainability in the agricultural sector through a smarter agriculture, the institutions (namely the associations and cooperatives) play a determinant role. The adaptability of farmers to the new technological demands might be difficult, especially for small dimension farms and family farmers. Hence the role of cooperatives might be of great help to connect them to the new technological demands. Other dimensions are related with the commitment of the farmers and the design of adjusted policy instruments to promote the adoption of innovative approaches in a sustainable perspective. Indeed, the agricultural policies and planning impact significantly the structure of the farms and the evolution of the sector, namely in the European Union through the CAP (Common Agricultural Policy). In fact, the CAP is the main driver of the European farming structures, including in the sustainability dimensions [14].

In parallel to this process of agricultural digitalization to promote smarter and sustainable farming practices, the public institutions should be able to implement strategies that increase the organization of the sector, improve the skills of the farmers and encourage the technological transfer from the scientific community to the farms and the sector. The organization of the sector and the skills of the farmers are, indeed, determinant for a more sustainable farming development [15]. These three dimensions will be crucial for an effective modernization of the agricultural sector in a perspective of a more sustainable development.

In this perspective, the main objective of this study is to highlight the main relationships between the smart agriculture (modern agricultural practices based on the new technologies, such as the IoT [16], that combine scientific research and innovation) and the sustainability (capacity to meet the present needs without compromise the future generations [17,18]). In practice the main question here is the following: what are the main relationships between the smart agriculture and the sustainability? Is the concept of 'climate-smart agriculture' (CSA) in general considered in the scientific literature sufficiently broader to capture the several interrelationships among the smart agriculture and the sustainability? CSA is a concept introduced by FAO (Food and Agricultural Organization) in 2010 and is known as the "triple win" approach [19]. CSA is an approach to the management of landscapes with the purpose of adapting crop and animal production to the climate changes originated by the human action on the planet. However, some

researchers argue that the CSA concept is a narrow approach about the current farming contexts and a broader statement [20], involving interdisciplinary dimensions [21], and using recent sustainability indicators [22] is needed. For that, a systematic literature review was carried out based on the PRISMA approach and on a preliminary bibliometric analysis. The PRISMA statement consists on a checklist with several items and on a flow diagram with few phases [23]. PRISMA is used as a guiding methodology for conduction reviews, in many fields of science, however with some degree of subjectivity. In fact, the scientific research involves always decisions that depend on the authors' perspective. Nonetheless, in order to deal with this subjectivity the PRISMA statement suggests transparency in the description of the decisions made. The literature review reveals that there are not many studies (or none) that consider the topics here addressed jointly with the PRISMA approach or bibliometric analysis, highlighting the novelty of this research.

2. Materials and Methods

To achieve the objectives proposed for this research 231 studies were obtained from the Web of Science Core Collection [24] and from Scopus [25] for the topics 'smart agriculture' and 'sustainability' in a search carried out on 15 May 2021, without any restrictions for the years considered or language (in general the abstracts are in English). The identification of these topics was based on a preliminary survey of the literature related with these fields and on the findings of, for example, Ruiz-Real et al. [6]. Using the software Zotero [26] 76 duplicated documents were identified. It was considered other topics of search, such as, for example, 'smart farming', 'digital farming', or 'digital agriculture'. A quick search on the WoS (Core Collection), for example, shows that the interlinkages of these topics with the sustainability are more limited (a little more than 50 documents in total), highlighting the 'smart agriculture' as a wider term. It was considered the concept of 'precision agriculture'; however, the CSA is a broader approach that aims the optimization of the whole agricultural system [27]. It was used, also, the term 'sustain*' instead of 'sustainability', however, with this alternative documents were obtained about other issues that not properly about sustainability that is the main focus of this research. In fact, sustainability is not the same that sustainable development, for example. In addition, it could be used the topic "climate-smart agriculture", however this was already addressed by other studies [28]. There is always subjectivity in the choice of the topics of search. The PRISMA statement [23] about the search strategy suggests, namely, a clear explanation of the search terms used and the identification of the databases considered. In any case, these are suggestions that may be explored in future studies with other approaches. Indeed, the identification of directions for future research is an underlying objective of scientific studies.

After removing the duplicated studies 155 researches were considered to carry out a systematic review, following the PRISMA [23] approach schematised in Figure 1.

To better organise the literature review, namely in terms of sub-topics, the PRISMA approach was complement with a preliminary bibliometric analysis, following, for example, Martinho [29] for food marketing, or Nadaraja et al. [30] for sustainable agriculture, or Martinho for agri-food contexts [31]. The bibliometric analysis was performed with bibliographic data (full counting and 1 as the minimum number of occurrences of a keyword), considering co-occurrence as links and keywords as items, following the procedures of the VOSviewer [32,33] software. The bibliometric analysis as support for literature review was considered, for instance, by Martinho [14,15,34]. In addition a factor-cluster analysis was carried out to better identify groups to cluster the several documents with the topics addressed, following Stata [35–37] and Torres-Reyna procedures [38].

Tables 1 and 2 and Figure 2 show that the main keywords found in the documents related with the topics 'smart agriculture' and 'sustainability' may be clustered in the following groups (the name for these groups were identified considering the keywords associated at each cluster highlighted, namely in Table 2 and Figure 2): environmental impacts and climate change; new technologies and approaches; food supply and security; farming systems and crop management; multifunctionality and agricultural/rural devel-

opment. In fact, the information in Table 2 is in agree with the results presented in Table 1 and confirms a group of keywords, in general, related with the new technologies and approaches (cluster 1), other group for the sustainability (cluster 2), for the crop management (cluster), for the food supply (cluster 4) and for the rural development (cluster 5). Figure 2 highlight, also, the relevance of dimensions associated with sustainability, food security, crops management, new technologies, and agricultural/rural development.

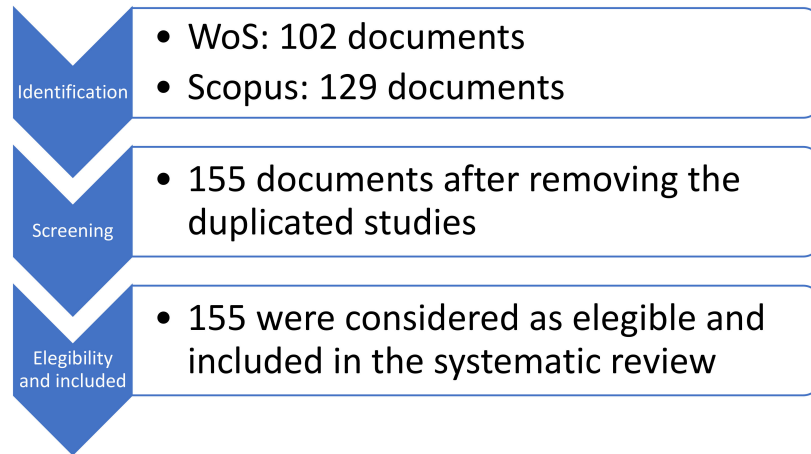


Figure 1. Steps to select the documents for systematic review, considering the PRISMA approach.

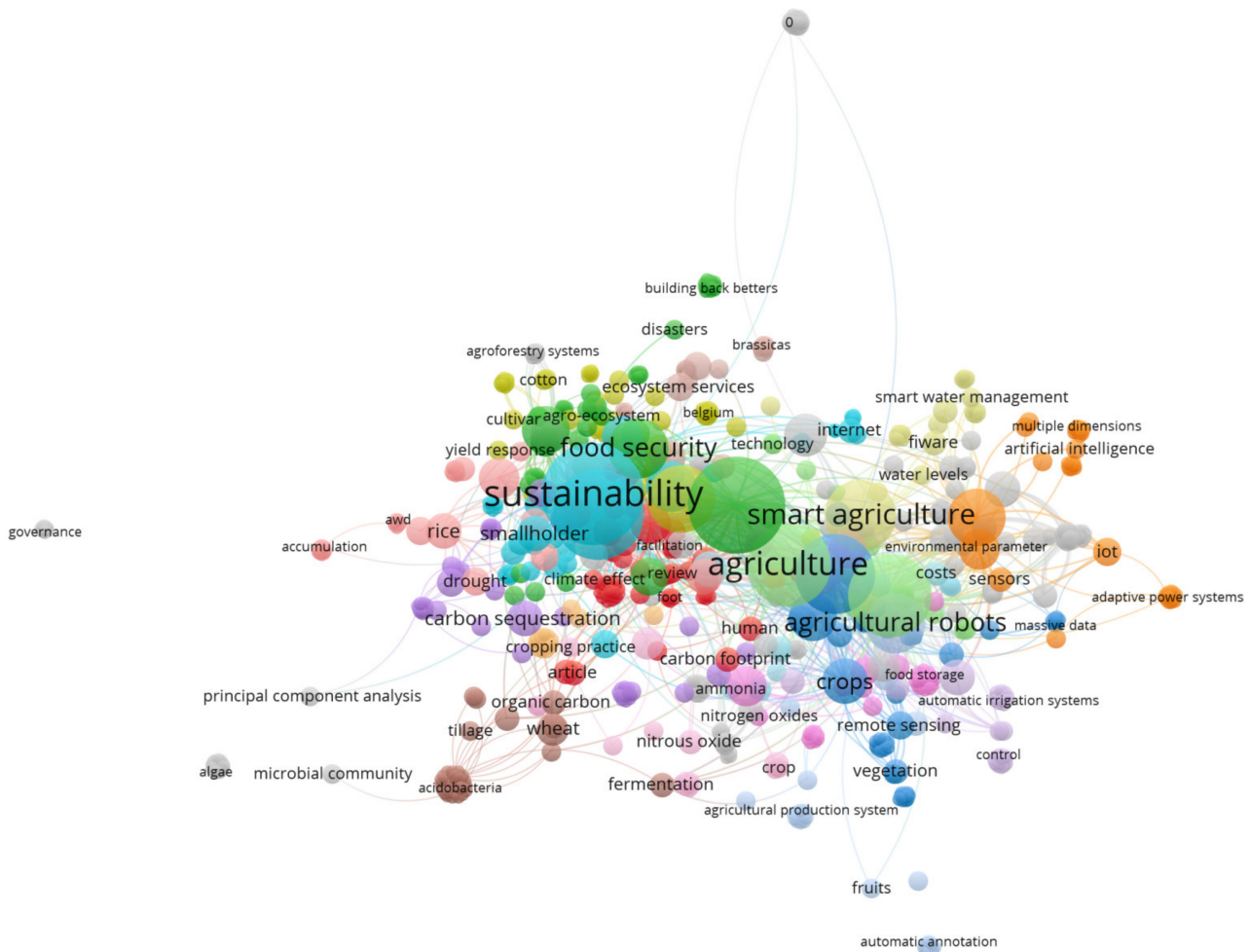


Figure 2. Network visualization map for the topics ‘smart agriculture’ and ‘sustainability’.

Table 1. Top 50 keywords for the topics ‘smart agriculture’ and ‘sustainability’.

| Keyword | Occurrences | Average Publication Year |
|------------------------------|-------------|--------------------------|
| sustainability | 49 | 2019 |
| climate change | 44 | 2019 |
| climate-smart agriculture | 39 | 2019 |
| agriculture | 33 | 2019 |
| sustainable development | 30 | 2019 |
| smart agriculture | 24 | 2020 |
| agricultural robots | 17 | 2020 |
| food security | 17 | 2018 |
| internet of things | 16 | 2020 |
| alternative agriculture | 12 | 2018 |
| adaptation | 11 | 2018 |
| irrigation | 11 | 2019 |
| sustainable agriculture | 11 | 2020 |
| crops | 10 | 2019 |
| environmental sustainability | 9 | 2019 |
| adoption | 8 | 2019 |
| farming system | 8 | 2020 |
| greenhouse gases | 8 | 2019 |
| mitigation | 8 | 2018 |
| agroforestry | 7 | 2018 |
| conservation agriculture | 7 | 2019 |
| food supply | 7 | 2018 |
| adaptive management | 6 | 2017 |
| carbon sequestration | 6 | 2019 |
| cultivation | 6 | 2018 |
| resilience | 6 | 2019 |
| rice | 6 | 2018 |
| smallholder | 6 | 2019 |
| smart farming | 6 | 2020 |
| sustainable intensification | 6 | 2019 |
| wireless sensor networks | 6 | 2019 |
| agricultural development | 5 | 2017 |
| environmental technology | 5 | 2018 |
| greenhouse gas | 5 | 2019 |
| wheat | 5 | 2018 |
| agricultural ecosystem | 4 | 2018 |
| agricultural production | 4 | 2018 |
| agrometeorology | 4 | 2019 |
| agronomy | 4 | 2019 |
| biodiversity | 4 | 2019 |
| coffee | 4 | 2019 |
| crop production | 4 | 2017 |
| crop yield | 4 | 2018 |
| drought | 4 | 2018 |
| ecosystem services | 4 | 2018 |
| efficiency | 4 | 2020 |
| fertilizers | 4 | 2019 |
| impacts | 4 | 2019 |
| india | 4 | 2019 |
| innovation | 4 | 2019 |

Table 2. Results for the factor-cluster analysis with the information from top 50 keywords (occurrences and average publication year).

| Keyword | Cluster |
|------------------------------|---------|
| sustainability | 1 |
| climate change | 1 |
| climate-smart agriculture | 1 |
| agriculture | 1 |
| sustainable development | 1 |
| smart agriculture | 1 |
| agricultural robots | 1 |
| internet of things | 1 |
| sustainable agriculture | 1 |
| farming system | 1 |
| smart farming | 1 |
| food security | 2 |
| alternative agriculture | 2 |
| adaptation | 2 |
| irrigation | 2 |
| environmental sustainability | 2 |
| mitigation | 2 |
| agroforestry | 2 |
| carbon sequestration | 2 |
| resilience | 2 |
| smallholder | 2 |
| agrometeorology | 2 |
| agronomy | 2 |
| biodiversity | 2 |
| coffee | 2 |
| fertilizers | 2 |
| impacts | 2 |
| india | 2 |
| crops | 3 |
| adoption | 3 |
| greenhouse gases | 3 |
| conservation agriculture | 3 |
| sustainable intensification | 3 |
| wireless sensor networks | 3 |
| greenhouse gas | 3 |
| efficiency | 3 |
| innovation | 3 |
| food supply | 4 |
| cultivation | 4 |
| rice | 4 |
| environmental technology | 4 |
| wheat | 4 |
| agricultural production | 4 |
| ecosystem services | 4 |
| adaptive management | 5 |
| agricultural development | 5 |
| agricultural ecosystem | 5 |
| crop production | 5 |
| crop yield | 5 |
| drought | 5 |

3. Systematic Review

In this section will be carried out a systematic review organised considering the PRISMA approach and bibliometric analysis carried out on the previous section. In practice 231 documents were obtained from the WoS and Scopus (102 and 129, respectively) for a search carried out on 15 May 2021 for the topics ‘smart agriculture’ and ‘sustainability’.

After removing the duplicated (76 studies) 155 documents were surveyed. To better show how the research questions and gaps were addressed, for a more sustainable development in the framework of the SDGs [39], the main insights are highlighted in Table 3. Each one of those findings will be presented deeper in the next subsection for literature review. In this perspective, this part will be structured in the following subsections: environmental impacts and climate change; new technologies and approaches; food supply and security; farming systems and crop management; multifunctionality and agricultural/rural development.

Table 3. Main insights from the systematic review.

| References | Main Highlights |
|------------|---|
| [2] | The new technologies and approaches are not exempt of risks and vulnerabilities |
| [40] | CSA approach is a promising solution for the sustainability |
| [41] | Some studies use the terminology of Environment-Smart Agriculture (ESA) |
| [19] | CSA is a concept presented by FAO in 2010, is known as the “triple win” approach |
| [42] | CSA practices improve the soil resilience and quality |
| [43] | The Internet of Things (IoT) and the Internet of Everything (IoE) may bring relevant added value for the farms |
| [44] | The wireless sensor network is an interesting tool to collect data |
| [45] | The biosensors are other techniques to collect information |
| [46] | Mobile applications, big data analytics and information systems, cloud computing, drones, blockchain, artificial intelligence |
| [47] | An efficient use of the agriculture resources, such as water, soil and energy, is crucial for competitiveness and food and security |
| [48] | Agriculture is one of the most vulnerable sectors to the global warming |
| [49] | The agricultural sector contributes with about a third of the anthropogenic GHG emissions worldwide |
| [50] | The eco-efficiency is the buzzword for the sustainability |
| [51] | The rice-wheat cropping systems concern particularly the researchers specifically in South Asia |
| [52] | Africa is another world region where it is important to promote cleaner farming systems |
| [53] | Sometimes the sustainable practices are misunderstood in these countries |
| [54] | In other cases and contexts there is not a convergent view about the CSA practices |
| [20] | CSA concept has a narrow perspective about the current farming contexts and a wider debate is needed |
| [55] | Rural development may benefit from the concept of smart villages |
| [56] | Sometimes is easier to convince the entrepreneurs than the policymakers |
| [57] | For an effective CSA implementation the farmers should be involved in the policy design process |
| [58] | Vocational training and the extension services may contribute for the adoption of the CSA practices |
| [59] | The European Union invested over the last years a significant part of its budget to promote CSA practices |

3.1. Environmental Impacts and Climate Change

In the relationships between the agricultural sector, food security and the environmental impacts, on the framework of the climate change, the climate-smart agriculture (CSA) approach appears as a promising solution [40] for the sustainability [4] with the following three objectives: improve the resilience of the farming sector to the climate change; mitigate the greenhouse gas (GHG) emissions; and guarantee the food security [60]. The resilience will be the main challenge to deal with the climate change [61] and the transition to smart solutions is unstoppable [62]. The objective is to achieve sustainability, resilience, wellbeing, and development [63] with new approaches [64]. In fact, the agricultural sector suffers from several particularities that, often, compromise its competitiveness. The new approaches associated with the different dimensions of the smart agriculture may be an interesting contribution for the farm profitability and financial performance.

Some studies use the terminology of environment-smart agriculture to address the relationships between the agricultural activities and the environment [41]. CSA is a concept presented by FAO in 2010, relaunched by the Conference of Paris in 2015 and is known as the “triple win” approach [19]. The idea is to find solutions for the farms in order to minimise the global warming consequences [65]. The practices associated with CSA are recognized as intensive agricultural techniques compatible with a sustainable development [66]. They are included, also, in silvo-aquaculture [67] and integrated aquaculture [68] systems, in a context called as Agriculture 4.0 [69]. These practices are not understood and implemented in a similar way worldwide [70]. These findings should be considered and addressed properly by the diverse stakeholders, namely the policymakers, for an effective and adjusted implementation of a sustainable smart agriculture.

In these frameworks, the energy management, in an efficient way [71], is critical [72], as well as the soil use [73]. CSA practices improve the soil resilience and quality [42]. Nonetheless, for the policy and planning design, it is important to find metrics that allow to put together the three aims [74] and to bring more insights about this concept [75]. The agricultural practices have impacts on the environment and the climate change, but have, also, implications from the global warming, and this brings several challenges for the farmers and policymakers [76]. To deal with the new contexts faced by the agricultural sector will be needed robust policies [77] and institutions [78], including non-governmental [79], at local, regional, national, and international levels. Indeed, the public institutions and the cooperatives, for example, are crucial for a better organisation of the sector and to increase the compliance with the strategies designed for the agriculture.

3.2. *New Technologies and Approaches*

The Internet of Things (IoT) and the Internet of Everything (IoE) have had great impact on the farms [43] and are forms to improve the productivity in the use of several agricultural resources [80], namely the water, through approaches of smart irrigation [81] and precision agriculture [82]. The smart irrigation systems are important to collect and work environmental data [83]. The IoT allows to implement automated operations with reduced supervision [84] in the whole food chain [85] and agricultural production [86], including in greenhouse agriculture [87] control [88] and in diverse farming systems [89]. The water management is critical, where the IoT may contribute significantly for a more balanced use [90], as well as in the soil health assessment [91] and fertilization management [92], in a perspective of a more competitive agriculture [93]. The potable water will be one of the scarcest resources and here the new technologies will be determinant for a more efficient management.

The new technologies and approaches are, also, important methodologies to support the farmers in other agronomic practices, some of them are available in open source solutions [94]. In some circumstances the government supports are decisive for the new technologies’ promotion, namely at an initial phase [95]. The wireless sensor network, for example, is an interesting tool to collect data about weather, soil, and plant conditions to provide the farmers with information to better manage the pest and disease control and the fertilizers’ use [44]. The biosensors are other techniques to collect information about the condition of the plant and assess its exposure to biotic and abiotic stresses [45]. Namely, in Europe, there are various projects to create new approaches for the farms that include smart technologies. The several findings obtained by the scientific literature may have an important role as a basis of knowledge for these developments.

The continuous assessment of the plant resilience is determinant in a context of climate change and agricultural conditions transformation [96]. The specificities of the conditions faced by the agricultural practices in drylands systems are other contexts where the new technologies may offer relevant added value [97], specifically in Africa [98]. Mobile applications, big data analytics and information systems, cloud computing, drones, blockchain, artificial intelligence [46], remote sensing [99] are other terminologies referred in the scientific literature for a smarter agriculture. However, the new technologies and approaches related with the smart agriculture are not exempt of risks and vulnerabilities [2]. This is an important aspect that must be highlighted by the scientific literature. Indeed, the new technologies and approaches bring new solutions and perspectives, but are not exempt of negative consequences for the sector and for the farmers.

3.3. Food Supply and Security

An efficient use of the agriculture resources, such as water, soil and energy, is crucial to guarantee the competitiveness of the farming sector and consequently the food self-sufficiency and security [47]. Irrigation availability appears as the main driver of the farmers' decisions, jointly with farm labour, seasonality, climate, land, wildfires, and diseases and pest control [100]. An efficient water management is one of the most important practices in the farms [101] and is fundamental for a dynamic and competitive agricultural sector in an era of great challenges [102]. In fact, often, the water availability and management appear as the main concerns for the various stakeholders, specifically the farmers.

Agriculture is one of the most vulnerable sectors to the global warming, which, allied with the population growing, creates serious problems of food security worldwide [48]. Indeed, the demand for agricultural goods increases continuously and the availability of resources decreases [103]. The smart agriculture concept provides adjusted tools to better collect, transmit, select, and analyze data, in a perspective of smarter management [104], with big data [105], for more sustainable farms and, consequently, for a more balanced food supply [106]. The availability of data is crucial for an adjusted assessment of the present and future food supply and security scenarios [107] and here the smart approaches may bring important added value.

The problems related with food security are particularly worrisome in Africa, specifically between the small farmers [108], and these scenarios were worsened with the climate changes contexts [109]. More than 200 million have problems of sub nutrition and the perspective is for this scenario to become worse in the next years and decades [110]. India is another context where the climate change and the food security bring new tasks for the farmers and policymakers [111]. The agricultural strategy instruments and the related organizations play a crucial role to guarantee food security, specifically where the risks are higher [112]. There are some specific contexts that deserve a special attention and this is highlighted by the scientific community.

3.4. Farming Systems and Crop Management

The effective contribution of the smart and sustainable agriculture for a more balanced development depends on the farming systems' management [113], on the agricultural practices implemented in the farms [114], namely those related with irrigation and fertilization [115], on the local conditions [116], specificities [117], and strategies [118]. Other particularities and solutions were highlighted by the researchers, such as the presented in Table 4.

Table 4. Particularities and solutions highlighted by the literature for a more balanced agricultural development.

| References | Particularities and Solutions |
|------------|--|
| [119] | Fodder banks |
| [120] | Fermentation of agricultural waste |
| [121] | Models to identify tomato ripeness |
| [122] | No-tillage, waste management, and agricultural diversification |
| [123] | Conservation agriculture |
| [124] | Based on conservation tillage systems |
| [125] | Nanotechnology |
| [126] | Including for carbon management in soil |
| [127] | Drought-tolerant seeds |
| [128] | Integrated pest control, combined crop-animal agriculture and organic composting |
| [129] | Fertilizer trees and shrubs |
| [130] | Terrace landscapes |
| [131] | Annual crops planted with coconuts |
| [132] | Agroforestry structures |
| [133] | Microalgae |
| [134] | Dambo cultivation |
| [135] | Valorisation of agro-food byproducts |
| [136] | Traditional agriculture |
| [137] | Integrated farming systems |
| [138] | '4R' approach (right source, right rate, right time, right place) |
| [139] | Agronomic rotations and cover cropping |
| [140] | "Positive Deviance" (identifying practices from farms with higher performance) |
| [141] | Genetic strategies |
| [142] | Vertical farming |
| [143] | In the cities |
| [144] | Crop residues management through principles of bioeconomy |
| [145] | Certification strategies |

These solutions as CSA are not universal [146] and depend on the specificities of each context [147].

The agricultural sector contributes with about a third of the anthropogenic GHG emissions worldwide, for what is urgent to find innovative approaches to deal with these impacts [49]. The contexts of the environmental impacts are worse when considered the food industry sector [148]. The eco-efficiency is the buzzword for the sustainability of the farming systems [50] and for a more sustainable crop management [149], where the innovative irrigation adjuvants may have important roles [150].

The new contexts that appeared around the world in the recent years changed the paradigm of the economic sector organization and call for novel ways of farm management [151]. The rice-wheat cropping systems concern particularly the researchers [152], specifically in South Asia [51], because of its importance for the food security [153] and the problems associated with the soil quality, water scarcity, and availability of some production factors, such as labor [154]. Africa is another world region where it is important to promote cleaner farming systems [52], in a framework of CSA practices [155], and where several projects [156], and studies were carried out [157]. This considers the complexity of the African farming systems [158] and its vulnerability to the global warming [159]. The impacts of the climate change in the African countries are, in fact, problematic [160]. Namely because the difficulties in the pest control. However, sometimes the sustainable practices are misunderstood in these countries [53].

In other cases and contexts there is not a convergent view about the CSA practices between the different stakeholders [54]. The perceptions of the diverse actors about the smart agriculture have here their impacts [161]. It is important, namely through the extension services to assess and work the perceptions of the farmers about the smart practices in the farms, because this is decisive to achieve the objectives intended by the

governments, including in terms of sustainability. In addition, some studies argue that the CSA concept has a narrow perspective about the current farming contexts and a wider debate is needed [20], involving interdisciplinary researchers [21] and using recent sustainability indicators, namely those related with the socioeconomic dimensions [22]. These findings support the thesis argued in this study that a broader concept is needed, in a more integrated perspective, to capture the several relationships between the smart agriculture and the sustainability.

In fact, innovative approaches are needed to deal with the multiple and conflicting domains related with the sustainable development [162] in the current realities [163]. The current impacts in the farming systems are implications of the global warming and come from socioeconomic changes, for what are needed integrated approaches [164]. Viticulture and the copper toxicity is another concern [165], as well as the cotton production [166], oil palm plantations [167], cocoa [168], and coffee production [169].

3.5. Multifunctionality and Agricultural/Rural Development

A better organised and planned farming sector may improve productivity and profit. The smart agriculture approaches may be determinant to obtain a more competitive and sustainable agricultural sector with advantages for the rural development in a context of smart villages [55], where the ecosystems are able to adapt to the new realities [170]. The terminology of “smart” came to stay, including for the cities [171]. The concept of climate-smart village and the associated practices are particularly relevant in countries where there are serious problems of food security, such as the India context [172].

The rural and agricultural policies are fundamental instruments to promote and encourage the smart agriculture practices, specifically in the developing countries, where the CSA adoption is low [173]. However, sometimes is easier to convince the entrepreneurs than the policymakers [56], and this may be, in certain circumstances, a real barrier to implement innovation [174]. The adoption of CSA practices is, indeed, a great challenge around the world for farmers and public institutions [175], including in the OECD countries [176]. For an effective CSA implementation the farmers should be involved in the policy design process, namely to be considered the local risks and particularities [57]. The involvement of the stakeholders in the decision processes, in a perspective of citizens/community engagement [177] or multiple engagements [178], improves the compliance with the strategies designed.

The participation of the women in the processes of decision may increase the adoption of CSA approaches, because of the concerns with the family food security. In addition, the vocational training and the extension services are other factors that may contribute for a more effective adoption of the CSA practices [58], as well as, educational programs [179] to prepare the next generations [180]. The extension services are crucial to advice the farmers [181] in the implementation of the CSA practices [182], nonetheless the particularities of these services in some countries may compromise their contributions [183].

In Vietnam, for example, the adoption of CSA practices by the rice farmers is influenced by the following variables: perceptions about the climate change, educational level, credit and capital availability, land tenure, farm size, availability of extension services, and access to markets [184]. In Nigeria the choice of adaptation practices is influenced by the following dimensions: age, land tenure, extension services, gender, farm size, assets, experience, and credit availability [185]. The determinants do adopt sustainable practices seem to be similar in these different parts of the world, where, for example, the land access and use has its relevance [186].

The European Union invested over the last years a significant part of its budget to promote research about the implementation of smart agriculture in the member-states, in the frameworks of the Horizon 2020 and the CAP (Common Agricultural Policy) [59]. The rural and agricultural institutions and their digitalisation is fundamental for a more integrated development [12], namely to avoid the land abandonment and the reduction in the number of small farms in the Europe context [187].

4. Discussion

There are not so many systematic reviews about the ‘smart agriculture’ and ‘sustainability’ topics and less (or none) considering, as complement, the bibliometric analysis, as highlighted by Martinho [31], showing the novelty of this research.

The technological development has been, over the past years, providing tools with applicability in the domain of agriculture and particularly aiming at more sustainable agricultural systems. This technological development is continuously evolving and the knowledge transfer must be, now more than ever, a reality seen as a way to improve agricultural production allied to sustainability goals. Hence new opportunities come from smart agriculture and IoT [43] as ways to improve agricultural efficiency and use of scarce resources such as soil, water, and energy. However, also some possible threats underlie the application of these new technologies, most especially those linked with ethics, since aspect such as confidentiality or integrity might be at risk [2].

Smart agriculture with an integrated view targeting sustainability can help face the challenges [104] derived from the urgent need to feed the growing world population, from inequality of population distribution around the globe or even the asymmetries coming from ultra-high density urban areas as opposed to depopulated rural areas, allied to the scarcity of natural resources, climate change demands, waste management needs, and circular economy promotion. Artificial intelligence and agricultural digitalization certainly contribute to improve productivity while reducing the input/output ratios, thus turning the systems target effective. Optimization of natural resources and of production factors together with cleaner pest control strategies, are on the verge of greener and highly efficient agricultural systems [100].

Climate-smart agriculture improves energy/water/soil management and increments resilience of the agricultural sector, contributing to guarantee food security and attenuating GHG emissions, thus finding a compromise between intensive agricultural production and global warming consequences [47]. Concepts of precision agriculture, smart irrigation and smart fertilization are possible owing to IoT and IoE. They allow to save resources, by for example collecting data from climate, soil, or plants to manage agricultural inputs, while improving productivity and reducing environmental impacts [80], either related with GHG emissions or the biosystem’s ecology. Through controlled and automated farming systems it is possible to improve competitiveness [84], with positive socioeconomic impacts, specifically in rural communities. The challenges are particularly relevant in developing countries where food security is a major risk. Also, the sector of organic farming greatly benefits from these technologies, since in these farming systems better management is crucial for profitability. However, implementation of long term measures and a vast adoption of artificial intelligence and smart agriculture technologies faces some resistance of farmers, especially in some communities [173], much owing to lack of knowledge or lack of appropriate technical support. To this matter, engagement of women into these matters is seen as a major opportunity to better prepare the future generations.

The targets that smart agriculture tries to reach and respond to encompass not only the climate effects, but also other environmental factors as well as social and economic aspects linked with the life of farmers and rural communities all over the world. Hence, the concept of smart agriculture shall be expanded to include all these dimensions and we therefore suggest that an integrated-smart agriculture concept could be used [20].

The main insights discussed in this section show that the topics and the approaches considered, when put together, have novelty [70,74], namely the consideration of the bibliometric analysis for a systematic review in these topics. On the other, the objectives proposed for this study (What are the main relationships between the smart agriculture and the sustainability? Is the concept of ‘climate-smart agriculture’ (CSA) in general considered in the scientific literature sufficiently broader to capture the several interrelationships among the smart agriculture and the sustainability?) allowed to highlight the main contributions from the smart agriculture for the sustainability and the main limitations of this concept

(smart agriculture). In addition, other approaches and topics of search were suggested for future research and highlighted topics already explored directly by the literature.

5. Conclusions

The main conclusions point out to the necessity to face the present and future challenges of the agricultural sector in a more effective way and making use of the technological possibilities that smart agriculture brings. The challenges linked to providing food to the growing world population while at the same time guaranteeing the sustainability of food supply chains must be addressed and looked at as new opportunities to use technology to the service of mankind and the planet. The efficient use of resources, the improvement of the input/output balance of agricultural systems, the mitigation of climate change effect or the socioeconomic impact over rural populations, all are, but not exclusively, part of this global approach. The conceptualization of an integrated approach where all aspects of the problem are included is urgent and therefore we are led to suggest that the somewhat limited concept of climate-smart agriculture could be expanded to a broader concept of 'integrated-smart agriculture'.

In terms of practical implications, the main insights obtained with this research suggest a more effective involvement of the stakeholders in the processes of decision and design of agricultural policy instruments. The participation of the women may be important, considering their concerns with the sustainability and the wellbeing of the family members. In these contexts, the contributions of the different institutions are determinant, specifically through services of extension to involve and support the farmers. Educational programs and vocational training courses are also determinant for an effective implementation of the Integrated-Smart Agriculture practices.

Table 5 presents the main policy recommendations and suggestions for future research from the findings obtain in this research.

Table 5. Policy recommendations, limitations, and future research.

| Policy and Future Studies Suggestions | |
|---------------------------------------|---|
| Policy recommendations | <ul style="list-style-type: none"> - Design new policy instruments that promote the smart agriculture practices in a more integrated way, namely through a greater involvement of the women in the farms. - Create programs to standardize the perceptions about the smart agricultural approaches. - Promote courses to train and raise awareness of the farmers about the advantages and disadvantages of the smart approaches in the farms. - Involve deeper the interrelationships between the actors for a better understanding about the integrated-smart agriculture approaches. |
| Limitations | <ul style="list-style-type: none"> - The selection of the topics to search the documents in the scientific databases has always some subjectivity. The identification of the topics of search in this research is no exception. However, this aspect was discussed and presented suggestions to be addressed in future research with other approaches. |
| Future research suggestions | <ul style="list-style-type: none"> - For future research, it could be interesting to deeper survey the farmers about the main constraints to implement an effective plan for smart agriculture practices adoption. - These results of these studies will give new suggestions to take into account the local specificities and better design adjusted plans and policy instruments. |

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